Energy policy in transport and transport policy

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ARTICLE INFO

Article history:
Received 15 April 2009
Accepted 15 July 2009
Available online 14 August 2009

Keywords:
Transport
Energy
External costs

Abstract

Explanations for, and indirect evidence of, imperfections in the market for private passenger vehicle fuel economy suggest there is a reasonable case for combining fuel economy standards and fuel or carbon taxes to contribute to an energy policy that aims to reduce greenhouse gas emissions and improve energy security. Estimates of key elasticities, including the rebound effect, indicate that the positive and negative side-effects of fuel economy measures on transport activities and external costs are limited. However, an energy policy for transport does not replace a transport policy that aims to manage the main transport externalities including congestion and local pollution. Conventional marginal cost estimates and standard cost-benefit reasoning suggest that policies that address congestion and local pollution likely bring benefits at least as large as those from fuel economy measures. But the large uncertainty on the possible effects of greenhouse gas emissions constitutes a strong challenge for standard cost-benefit reasoning. Emerging results from methods to cope with this uncertainty suggest that policies to stimulate the widespread adoption of low-carbon technologies in transport are justified.

1. Introduction

Concerns about volatile and rising oil prices and about potentially very costly consequences of greenhouse gas emissions have fueled public debates about the need to manage energy consumption through policy interventions. Oil price changes in recent years highlight developed nations’ reliance on oil imports, so that energy security is again a major policy concern. With respect to climate change, there is a growing political consensus that the expected costs justify action to reduce emissions of greenhouse gases. For both these reasons, the widely held view is that the prevailing pattern of energy consumption needs to change, although just how it needs to change is less clear. Since road passenger transport represents a large and growing share of overall emissions of CO2 and an even larger share of oil consumption, it is routinely assumed that considerable further efforts to reduce transport energy consumption and emissions are required and justified to reach overall societal emission abatement targets, despite the fact that relatively strong policies to moderate transport energy consumption are already in place. This paper discusses some of the argumentation on this issue.

The first goal of this paper is to sketch the scope for cost-effective greenhouse gas abatement efforts in transport. Is requiring large efforts in transport in line with the principle that emissions should be reduced first where doing so is cheapest? Many studies on burden sharing have found that abatement costs are higher in transport than in other sectors, so that cost-effectiveness requires relatively modest efforts from transport (depending on the target, of course). This argument is challenged on the grounds that there are “imperfections” in private vehicle purchase decisions that lead to low investment in fuel economy. Many studies on burden sharing ignore these imperfections, and taking them into account may change results concerning the effort required from transport, in a cost-effectiveness framework. However, whether these imperfections constitute a market failure that leads to underinvestment in fuel economy compared to the efficient level is less obvious.

The problem of low willingness to pay for better fuel economy at least partly stems from consumers’ reluctance to pay up front in return for uncertain reductions in fuel expenditures, and translates into limited incentives to improve fuel economy improvements on producers’ part. Taking a cost-effectiveness view, fuel economy regulations are a reasonable way of handling this problem, as they reduce producers’ uncertainty on what levels of fuel economy to provide on average. A binding standard directs producers towards deploying technological potential towards better fuel economy. Nevertheless, the standard may entail a loss of consumer surplus as alternative deployments of technological potential may generate greater consumer satisfaction.
The justification for a fuel economy standard is that it reduces uncertainty in the market for vehicle fuel economy. A standard then is a complement to fuel taxes and not a replacement. Fuel taxes are well suited to internalize externalities related to fuel consumption, and to a lesser extent those related to miles driven. High fuel taxes will also help manufacturers attain the fuel economy standard, as they narrow the gap between consumers' aspirations and the requirements of the standard. In addition, high fuel taxes provide an incentive for the development of alternative technologies, which will be needed if carbon emissions from transport are to fall drastically. The presence of a binding fuel economy standard itself increases the need for such an incentive, as the improved fuel economy makes conventional technology cheaper to use, which weakens the incentive to develop alternatives.

The second goal of the paper is to put energy policy in transportation in the broader context of transport policies to manage the main transport externalities. Policies to reduce transport energy use may increase or reduce transport activity, depending on the policy approach followed, but evidence suggests these effects are of limited magnitude. We argue that better management of transport externalities merits continuing attention, since the benefits of reducing the external costs of congestion and local air pollution are considerable. Estimates of average external costs suggest that mitigating driving-related externalities yield large benefits, exceeding those of better energy policy in transport. Distance based charges and congestion charges are useful components of a policy package to handle congestion and local air pollution.

We argue there is a reasonable case for fuel economy standards to correct imperfections in the market for vehicle fuel economy, and that there are external costs associated with vehicle use that justify charging policies. What would be the impact of policies that improve the efficiency of these markets as best as they can? Without providing a quantitative estimate, it is safe to say that a policy based on the available evidence concerning the expected damage caused by these market failures would reduce the growth rate of transport emissions of greenhouse gases, but would very likely not reduce them or even stabilize them. With respect to greenhouse gas emissions, this implies that the expected damage from greenhouse gas emissions used in the cost-benefit analysis leads to considerably lower abatement than contained in policy statements that call for drastic reductions of emissions, including those from transport.

We explore some reasons for this gap between political aspirations and the results from a standard analysis, focusing on the question whether the use of expected values of damage from externalities in cost-benefit analysis is appropriate. For externalities that are relatively well understood, such as congestion and local air pollution, the answer is yes. But for greenhouse gas emissions and climate change, the presence of large uncertainties may require a different approach. Within such an alternative approach, large uncertainty may lead to ambitious targets for greenhouse gas emission reductions. What would such targets imply for transport? Given that stabilization of global passenger transport emissions at 2010 levels requires a fuel economy of 3.5 l/100 km on average by 2050 under expected global growth of the vehicle stock and vehicle use (JTRC, 2008b), ambitious targets likely can only be met at reasonable cost through widespread adoption of low-carbon-intensity technologies. From this we conclude that the presence of strong uncertainty justifies efforts to develop further alternative technologies and bring them to the market. High fuel prices, through taxes or through high pre-tax prices, are an important incentive in this regard. Credible commitment to climate change targets, also in times of high oil prices, is another prerequisite. In addition, public support for research and development is useful when the social returns to innovation are larger than the private ones.

The structure of this paper is as follows. Section 2 discusses the cost of greenhouse gas emissions abatement in private road passenger transport, paying particular attention to decisions on fuel economy in the vehicle purchase market. In Section 3, we provide an overview of the interactions between energy policy in transport and policies to handle other transport externalities, and discuss externalities related to greenhouse gas emissions and to energy security in some detail. Section 4 concludes.

2. Cost-effective ways of reducing CO2 emissions from road passenger transport

In deciding how to achieve an abatement target for greenhouse gas emissions, however determined, it makes sense to start with the cheapest abatement opportunities and select increasingly expensive options until the target is reached. Section 2.1 briefly reviews some attempts to provide empirical content for this least-cost principle from a general equilibrium perspective. Section 2.2 presents technology cost estimates suggesting that no regret fuel economy improvements are available in transport, discusses possible explanations for why such no regret options are not realized in the market, and how fuel economy standards can be expected to improve the market outcome at low cost. Fuel economy standards reduce the cost of driving so increase the demand for it (the rebound effect), and this affects the policy's economic cost. Section 2.3 reviews evidence on the rebound effect, concluding that is small enough that fuel economy standards are effective tools to reduce fuel consumption with limited impacts on other external costs of transport.

2.1. Comparing abatement costs across sectors

Applied general equilibrium models of various degree of detail have been used to obtain an economy-wide view of greenhouse gas abatement opportunities, their costs and their effects on emissions. These studies usually adopt the standard assumptions of the applied general equilibrium tradition, including perfect competition and constant returns to scale across the economy. For example, Proost (2008) discusses a study of burden sharing between sectors for Belgium, based on relative resource costs of the adoption of less emission-intensive technology and on losses in surplus resulting from cost increases. There is no permit trading among countries and nuclear power generation is assumed to be phased out by 2030 (a policy that may be reversed), leading to higher abatement costs in power generation. The study finds that the effort in the transport sector is very small for abatement targets of less than 10%, and stays well below the country-wide effort as targets become more stringent over time; see Table 1. Nearly all abatements in transport are realized through the adoption of alternative technologies (specifically, alternative fuels used in conventional engines), not through a reduction of transport activity of passenger car transport (which entails a loss of consumer surplus).2

According to this study, sectors should not be expected to contribute in proportion to their share in economy-wide emissions, as abatement costs may strongly differ between them. In
particular, abatement costs in transport are relatively high. Similar results are found in a general equilibrium analysis for the EU 15 (Abrell, 2007), where inclusion of surface transport in the European Trading System produces welfare gains while strongly reducing the sector’s percentage reduction of emissions, compared to the current situation where transport is not included in the trading system but prevailing transport taxes are retained. Including surface transport in the ETS increases greenhouse gas reductions in mainly power generation and energy-intensive manufacturing.

The literature suggests several reasons why abatement technology is relatively expensive in transport. First, there are few cheap low-carbon substitutes for conventional engine technology. Second, transport fuels have been relatively expensive (compared to other sectors) in many parts of the world, mainly because of relatively high taxes. These high prices arguably have induced the market to take up cheap abatement options already, making further reductions expensive. Third, transport fuels are less carbon-intensive than some other fuels, so that carbon taxes would have smaller effects on energy prices in transport than in other sectors. For example, introducing a tax of $50 per ton of carbon in the US would increase the price of coal by about 140%, while the price of gasoline would rise by 6% (Parry, 2007), implying more limited incentives for abatement in transport.

While the arguments explaining relatively high abatement costs in transport are sound, they are challenged on various grounds. One objection is that the assumptions on costs of alternative technology embedded in the general equilibrium models are too high, as no account is taken of declining costs when production levels rise. Experience suggests that costs indeed do generally decline, but whether this will also hold for alternative technologies such as batteries, etc., is uncertain. Another objection is that the arguments explaining higher costs in transport are partly empirical, but also are partly based on economic inference: further abatement in transport must be relatively costly because energy was relatively expensive in the past and alternatives have not yet been adopted. This inference relies on the assumption that transport markets work very well, in the sense that all surplus-improving technological potential is realized. Abandoning this assumption modifies results, as is discussed next for the market for vehicle fuel economy.

2.2. Inefficiencies in the market for vehicle fuel economy

In this section we briefly review two studies on the technology cost of, and the savings from improving vehicle fuel economy for passenger vehicles. Both studies conclude that the discounted savings on fuel expenditures outweigh the costs when using standard private discount rates. This would imply that improving fuel economy is a no regret abatement option. It does not imply that using the technology to improve fuel economy is the type of deployment that generates the largest benefits to consumers, as alternative uses may be valued higher. Nevertheless, the findings indicate that vehicle markets do not realize all surplus-improving technological potential. We explore potential explanations for why this may be the case, and ask whether there is a reasonable case for viewing fuel economy standards as a low cost abatement option.

A study on abatement costs by McKinsey (see Enkvist et al., 2007, for an overview) compares changes in the cost of technology to changes in operating costs, ignoring potential demand responses. Similar to the work discussed in Proost (2008), it finds that improvements in conventional engines and the adoption of some types of biofuels are the most attractive costly measures in transport. Also in line with Proost (2008), cost-efficient abatement may imply a sectoral distribution of the burden that deviates strongly from sectors’ current shares of emissions. For example, taking a global perspective, the transport sector’s share in total abatement up to a cost level of 40 €/ton is 6%. At the country level, however, burden shares may be more in line with emission shares, Germany being a case in point (McKinsey & Company, 2007). However, in contrast to Proost (2008) and Abrell (2007), the McKinsey study finds considerable potential for improvements in vehicle fuel economy at a negative cost, meaning that better fuel economy should be promoted even in the absence of emission abatement targets.

In calculating net abatement costs, the McKinsey country studies assume that fuel savings are discounted over a period of 4.5 years at a 4% discount rate, and using consumer prices rather than resource costs. Demand is taken to be fixed, and all other vehicle attributes are unchanged. This result suggests that, since using more efficient technology generates net benefits to vehicle users but this technology is not in fact adopted, there are imperfections in vehicle markets that cause underinvestment in fuel economy. However, the 4% discount rate is below usual values for a private discount rate, which are around 7%.

The Impact Assessment of the EC’s proposed regulation (EU, 2007b) comes to similar conclusions regarding underinvestment in fuel economy, finding an average retail price increase of €1300 per vehicle to attain the proposed average emission rate of 130 g/km in the EU by 2012. This cost increase is accompanied by average lifetime fuel cost savings to the consumer of €2200–2700 at fuel prices of €11.1 and €12.01, respectively, using a discount rate of 4%, a vehicle lifetime of 13 years, and an annual distance driven of 16,000 km. Here too, vehicle attributes other than fuel economy are kept constant.

The calculation implies net savings, or an increase of consumer surplus, of around €1000, at a constant vehicle quality and a discount rate of 4%. Again, the 4% discount rate is low. However, in order to equalize costs and benefits, a discount rate of around 20% would need to be used, much higher than standard values for private discount rates. Consequently, the assessment suggests that on average the proposed EU-regulation produces consumer surplus gains instead of losses, unless consumers use very high discount rates for good reason. To repeat, this does not imply that using the (cost-increasing) technology to boost fuel economy is optimal from the consumer’s point of view, as alternative

### Table 1

Reductions of CO₂-emissions at the country level compared to baseline levels, Belgium.

<table>
<thead>
<tr>
<th>Year</th>
<th>Target (% reduction compared to 1990)</th>
<th>Country Effort (% reduction compared to baseline)</th>
<th>Transport sector effort (% reduction compared to baseline)</th>
<th>Activity reduction cars (%)</th>
<th>Activity reduction trucks (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2010</td>
<td>−7.5</td>
<td>−18</td>
<td>−1</td>
<td>0</td>
<td>−2</td>
</tr>
<tr>
<td>2020</td>
<td>−30</td>
<td>−59</td>
<td>−17</td>
<td>0</td>
<td>−5</td>
</tr>
<tr>
<td>2050</td>
<td>−52.5</td>
<td>−76</td>
<td>−48</td>
<td>0</td>
<td>−5</td>
</tr>
</tbody>
</table>

Source: Proost (2008), Tables 4 and 5.
deployments, e.g. boosting performance and/or comfort, may yield larger surplus gains. But the figures do question the efficiency of the new and/or used vehicle markets, as in a fully efficient market any available net surplus gains would be realized. So, while these numbers are not definitive evidence, they suggest there are market imperfections that justify a policy intervention. If policy steers the use of technology towards fuel economy, the cost needs to be calculated as the difference in surplus produced by the use of technology best liked by consumers, and the surplus from using technology to improve fuel economy.

The technology cost studies suggest that improved fuel economy entails net benefits for consumers. What might explain the existence of such “money on the table”? Fuel economy is mostly determined when a vehicle is purchased, although driving behavior, maintenance and aging matter as well. Is a fuel tax or a carbon tax in itself sufficient to address both vehicle purchase and vehicle use decisions? If the tax is set at the level that is consistent with the carbon reduction target in road transport, and if car buyers efficiently trade off investments in fuel economy against higher fuel expenditures and other vehicle attributes like comfort, safety, and power, it should be. However, several arguments favoring an extra instrument to guide purchase decisions have been put forward. We briefly consider some of them.

A broad statement is that car buyers implicitly use high discount rates when deciding on fuel economy, i.e. that they are “myopic”. This can be taken to mean that car buyers' private discount rates are higher than social discount rates, or that implicit discount rates in vehicle purchase decisions are higher than “normal” private rates.

In the first case, private discounted values of future fuel savings are below the social discounted values, leading to private underinvestment in fuel economy from the social point of view even in the presence of appropriate fuel taxes. The issue here is not that consumers make “wrong” decisions in the sense of miscalculating savings from better fuel economy from their private point of view, but that private and social valuations of future benefits and costs differ, so that a policy is justified. It is worth noting that regulators do not generally interfere with private investment projects because private discount rates are thought to be higher than the ones used in public project appraisal, and it is not obvious why a different approach should apply to vehicle purchase decisions. The argument is particularly tenuous if fuel taxes cover marginal external costs, because in that case the future fuel expenditures are discounted at marginal social cost. When considering investment in fuel economy as a risky project (which, as clarified below, it is), the costs of uncertainty are borne by individuals, so that the policy treatment of risk is the relevant one (Arrow and Lind, 1994). Despite these arguments, it is clear that in a cost-effectiveness approach (which allows justifications of targets other than market failures), the existence of high implicit discount rates creates a wide gap between social and private discount rates.

In the second case, consumers underinvest in fuel economy in the sense of using a discount rate that exceeds the normal private discount rate. The 20% implicit discount rate implied in the EU Impact Assessment (see Section 2.1) is one example. The evidence in Turrentine and Kurani (2007) that consumers implicitly require payback periods of 3 years or so is another. Verboven (1998) and Espey and Nair (2005) provide counterexamples, with econometric evidence that car buyers' discount rates and willingness to pay for fuel economy are in line with “normal” private discount rates, given available vehicle models. In face of this mixed evidence, why would high discount rates be used when deciding on fuel economy? One argument is that consumers pay little attention to fuel economy, because they care more about other attributes and the share of fuel costs (and a fortiori the size of savings from better fuel economy) in total purchase and usage costs is small. Given that processing information on how fuel economy translates into probable savings on fuel expenditures takes costly effort, consumers may decide a detailed calculation is not worthwhile. From a policy perspective, this problem may be overcome by providing better information on potential savings from purchasing better fuel economy. From an analytical perspective, the argument says that consumers make inaccurate decisions on fuel economy, but not that they systematically invest too little.

Recently, Greene et al. (2009) suggested a framework that does imply systematic undervaluation of fuel economy, when compared to the textbook model of an expected utility maximizing consumer. They show that when consumers are loss averse and uncertain on factors that determine optimal fuel economy, they will invest less in fuel economy than consumers that maximize expected utility. The uncertain factors that affect fuel economy choices are effective vs. labeled fuel economy, the lifetime of the car, the amount of driving, and fuel prices, among others. Among those factors, uncertainty on realized fuel economy is the main driver of low investment, according to a calibrated numerical exercise. The numerical example also suggests the impact of loss aversion is large, as the expected saving from a fuel economy improvement of $405 for an expected utility maximizer is equivalent to a loss of $32 in the case of loss aversion.

Still according to Greene et al. (2009), low willingness to pay for fuel economy by consumers translates into strategies on manufacturers' part that steer vehicle design towards more marketable attributes, like power and comfort. With such a supply response, available fuel economy turns out lower than in a world where consumers are not prone to loss aversion. A manufacturer will be disinclined to use technology to provide better fuel economy if there is large uncertainty on whether consumers will want to buy it and on how competitors will respond to the same problem. A fuel economy standard helps correct this problem, as it provides clarity on what performance level needs to be reached, by a manufacturer and by its competitors.

The loss-aversion argument is compelling in the sense that it provides a theoretical argument for consumers' low willingness to pay for fuel economy improvements, argues convincingly that this demand curve is what producers take into account when deciding on what fuel economy levels to provide, and that a standard is a good way of making sure manufacturers deviate from this demand curve and provide better fuel economy. The case for a standard is particularly strong when fuel taxes are low and incomes high, as both factors widen the gap between consumers' aspirations, which drive supply decisions, and policy targets for fuel economy. This gap is wide in the US, but it also prevails in

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4 Although some such interventions exist, e.g. through subsidies for home insulation.

5 Loss aversion means that consumers evaluate outcomes in terms of changes from a reference state of wealth, and that losses are valued more than equivalent gains (to a larger extent than can be explained by declining marginal utility).

6 It was noted in JTREC (2008a) that, contrary to expectations, fuel economy decisions for company car fleets and for freight trucks are prone to similar imperfections as those for privately owned light-duty vehicles. Loss aversion may help explain this phenomenon as well.

7 For this reason, econometric evidence on “appropriate discount rates” does not in itself imply that the market produces levels of fuel economy that would result from an expected utility framework, as manufacturers may supply fuel economy in line with preferences guided by loss aversion.

8 Note that an attribute-based standard provides no absolute certainty on which level of fuel economy to produce, in the sense that uncertainty over consumer preferences on and competitors’ responses to the attributes remains.
Europe. For example, it is reasonable to think that the failure of the voluntary agreement in the EU to reduce CO₂-emissions was partly caused by the lack of policy initiative to support the agreement during a period of strong economic growth and declining real fuel prices, at least in the early years of the agreement.

However, some questions remain. First, is loss aversion a market failure, or is it a description of preferences that generates a demand curve which is to be taken as given when thinking about policy? There is evidence that loss aversion is pervasive, and indeed that the model is simply a better description of actual behavior than is the expected utility framework. It then is not clear that it provides a basis for policy intervention, unless one explicitly takes the hypothetical market outcome that would be obtained in the absence of loss aversion as the norm, instead of letting consumers optimize according to their loss averse preferences.  

Second, the loss-aversion argument may apply to other vehicle attributes than fuel economy. For example, decisions on how much to invest in comfort and performance are plagued by uncertainty over the vehicle’s lifetime and on the intensity with which it will be used as well. The uncertainty on real performance and on future attribute prices (e.g. future taxes on performance) matters less, however, so that loss aversion is more of an issue with fuel economy than with these other attributes.

Third, the numerical illustration in Greene and German (2007) suggests that uncertainty on realized fuel economy is the main reason why willingness to pay for fuel economy is lower than in a standard utility-maximization framework. One might argue that better information could reduce this problem. A standard of course determines the aggregate average level of fuel economy directly, so in that sense is superior to information provision. However, it could be the case that with an attribute-dependent standard, consumers may still underinvest by choosing for better attributes than they would have in the absence of the standard, as long as they remain unclear on how fuel-efficient their vehicle will actually be.

Summarizing, the loss aversion framework provides a plausible hypothesis of why levels of fuel economy resulting from the market are below those one would expect on the basis of an expected utility framework. However, additional empirical support is required to increase the model’s credibility, and even then it is not straightforward that the existence of loss aversion justifies a standard or a different policy intervention. Justifying policy on the basis of loss aversion involves a judgment that fuel economy levels resulting from loss averse preferences are too low, because loss aversion itself constitutes a market failure or because preferences are context-dependent. Within this view, the case for fuel economy standards seems fairly strong. But the argument is open to discussion, and the issue remains contentious.

The criticisms above focus on the justification through loss aversion of a correction in the market for fuel economy as such. A different approach is to focus on cost-effectiveness and ask whether loss aversion and uncertainty could affect the choice between quantity-based regulation and prices to attain an abatement target, however defined. Loss aversion and uncertainty on the part of consumers lead to uncertainty for producers on how much to invest in fuel economy, and this results in fuel economy levels that reflect high implicit discount rates. A price-based approach increases what consumers want to pay for fuel economy but does not necessarily affect their treatment of uncertainty, so does not alleviate producer uncertainty either. Producers may remain reluctant to invest in better fuel economy under these circumstances. Consequently, the government is not sure how effective its tax-based approach will be in triggering investments. If government cares about such investments, for example because it believes this makes policy less prone to reversibility by future policy-makers, then it may favor a quantity-based approach over a price-based one, precisely because the quantity-approach reduces flexibility (see Glazer and Lave, 1996, for a similar argument). In this approach, where the government has a preference on how fuel consumption in transport is reduced, the choice for a standard for fuel economy may be justified.  

Given these arguments for fuel economy standards, it appears that existing and proposed standards require bigger improvements in fuel economy than can be justified by market imperfections. Indeed, the stringency of standards seems consistent with a policy approach that either starts from the assumption that technology to improve fuel economy is cheap, or that implicitly attaches a very high value to reducing greenhouse gas emissions and improving energy security, but which lacks a clear view on what costs are imposed on consumers. We suggest possible motivations for ambitious abatement targets in Section 3, but note here that with the current evidence the basic message from the general equilibrium analyses of the type reviewed in Section 2.1 remains valid: abatement costs in transport appear to be relatively high.

In Section 2.3, we discuss a potential problem with fuel economy standards: more fuel-efficient vehicles are cheaper to drive so will be driven more, and this reduces the effectiveness of standards. As will be seen, the empirical evidence indicates that this problem is of limited practical relevance.

2.3. Standards and the rebound effect

Section 2.2 discussed possible justifications for fuel economy standards from a normative point of view. This section takes a positive approach, looking into the ultimate effects of standards on energy consumption and transport demand. Specifically, we consider a common argument against fuel economy standards: they increase the amount of driving and the external costs associated with that. It is clear that the cost of driving a mile declines as vehicles become more fuel-efficient, and that this tends to increase the demand for driving and for fuel. This feedback effect is known as the rebound effect. Note that the demand for driving increases because this generates net benefits to the driver, so there are benefits and not just external costs. However, the effectiveness of a fuel economy standard in reducing aggregate fuel consumption would be undermined if the rebound effect was large. Conversely, fuel taxes would become more effective. This section discusses evidence for the USA that the rebound effect is small and likely will become smaller.

Table 2 shows selected results from Hymel et al., 2008.  

This study jointly estimates the rebound effect (the elasticity of driving with respect to the fuel cost per mile), induced demand (the elasticity of driving with respect to capacity), and the congestion effect (the elasticity of travel delay with respect to the fuel cost  

10 The government may also prefer using a standard because it cares strongly about reaching the abatement target, perhaps out of a sense of urgency, and less about how much it will cost to get there. This argument has no direct relation with the issue of loss aversion.

11 This study updates and extends Small and Van Dender (2007a). It confirms the results of the earlier paper and in addition investigates interactions between the rebound effect, induced demand, and congestion as well as extending the time span of the data from 36 to 39 years.
per mile). The sample contains annual data on US states and Washington, DC from 1966 through 2004. The econometric specification allows the elasticity to vary with income, the fuel cost of driving, and the level of congestion. Since these variables change over time, the elasticities change over time as well. The table shows long-run averages for some elasticities at the sample average and for 2004, the last year in the sample. Specifically, it shows the rebound effect (\( e_{MP} \)), the rebound effect for constant congestion (\( e_{MP|cong.} \)), the fuel price elasticity of fuel demand (\( e_{FPP} \)), and the congestion effect (\( e_{delay,Eff.} \)).

The first row of the table shows that in percentage terms the rebound effect is 21.1% at the sample average, but only 7.9% in 2004. This means that a fuel economy increase of 10% translates into a reduction of overall fuel consumption by 9.21% if the determining variables remain at 2004 values. At these values, fuel economy standards seem quite effective in reducing fuel consumption. The main reasons for the decline in the elasticities over time are that in 2004 incomes are higher and fuel prices are lower than at the sample average (see below for more discussion).

The second row of the table shows what the rebound effect would be if there were no congestion. This estimate is higher than that in the first row, indicating that the presence of congestion dampens the rebound effect: better fuel economy does lead to more driving, but less so when there is congestion, because congestion itself is a deterrent to driving.

Row three shows the elasticity of fuel demand with respect to the price of fuel. This elasticity depends on the rebound effect (which equals the elasticity of driving with respect to the fuel cost of driving, where the latter is the ratio of the fuel price and fuel economy) and on the elasticity of fuel economy with respect to the price of fuel (not shown). Like the rebound effect, the fuel price elasticity of fuel demand is lower in 2004 than at the sample average. In fact, the fuel price elasticity declines mostly because of the decline in the rebound effect, as responses in terms of fuel economy are constant throughout the sample (see Small and Van Dender, 2007a, for more discussion). Drivers respond to higher fuel prices mostly by improving fuel economy, and less so by reducing driving. Note that this implies that using fuel prices to reduce driving-related (as opposed to fuel-consumption related) external costs will not work very well, a point discussed further in Section 3. The long-run price elasticity of gasoline in our estimates is \(-0.337\) over the entire sample, declining to \(-0.254\) in 2004. With the travel component declining sharply and the fuel-intensity component approximately constant, travel is becoming a notably smaller component of the response to fuel prices. This finding is confirmed by a study for twelve OECD countries by Johansson and Schipper (1997), and more recently in a meta-analysis by Brons et al. (2007).

The fourth row of Table 2 gives the elasticity of travel delay due to congestion with respect to improvements in fuel economy. Better fuel economy leads to cheaper and therefore more driving, and more driving increases congestion, as the discouraging effect of congestion at the margin is not strong enough to compensate the price decline following improved fuel economy. The long-run elasticity is 0.11 at the sample average, declining to 0.04 in 2004. According to these results, better fuel economy causes a small amount of additional delay, likely not large enough to wipe out the benefits of lower fuel consumption and of additional driving.

We find that the rebound effect declines with income and rises with fuel prices. Why should rising income diminish the rebound effect and higher fuel prices increase it? Our model provides no direct answer, but there are some plausible explanations. First, higher incomes cause the share of fuel expenditures in total expenditures to decline, which may lead to lower elasticities. Second, higher incomes lead to higher values of time, so that time costs of travel become relatively more important than fuel costs. Higher fuel costs then translate into proportionally smaller increases in the generalized price of travel (the sum of time and money costs), and assuming that drivers respond mainly to this generalized price, this reduces the elasticity with respect to the money costs. However, there are reasons why higher incomes could lead instead to larger elasticities: the share of discretionary driving is likely higher for higher income households, and it is easier to cut back on such driving than on “mandatory” travel. Hughes et al. (2006) find larger price elasticities of gasoline demand for higher incomes than for lower income households, while at the same time finding that this elasticity declines over time.

What about the future? In a nutshell, our results suggest that fuel consumption by passenger vehicles has become less price-elastic over time, and that it is increasingly dominated by changes in fuel efficiency rather than in the amount of driving. Furthermore, our results identify two main reasons for this: rising incomes and falling real fuel prices. One of these – rising incomes – can be presumed to characterize the future as well, whereas the other – falling real fuel prices – probably cannot. As illustrated in Small and Van Dender (2007b), the effect of rising incomes is likely to dominate that of increasing fuel prices, so that a further decline of the rebound effect is more likely than an increase. This reinforces the view that a fuel economy standard is a relatively effective instrument to reduce fuel consumption, and its impact on travel demand, with the associated benefits and external costs, is limited. Against this background, the next section discusses relations between policies to reduce energy consumption in transport and policies to mitigate transport externalities in more detail.

### 3. Energy policy for transport and broader transport policy

#### 3.1. How large are the main external costs of transport?

In Section 2, we focussed on the role of private passenger transport in an economy-wide effort to reduce energy consumption. We tentatively concluded that fuel economy standards are

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12 This does not say that the amount of driving does not respond to fuel prices.

13 The meta-analysis does not directly check for the impact of income but, like our study, it finds no evidence of a trend in the price elasticity of fuel consumption. This indicates that a simple time trend is inadequate to capture the effects of the complex changes in income and fuel cost over the time periods covered by the various studies.

14 Yet another factor is that richer households own more vehicles, allowing them to respond to fuel price increases by using the more fuel-efficient vehicles more intensively. This seems mainly a short-run reaction, and would tend to make them respond less through changes in travel but more through changes in average realized fuel efficiency.
justifiable components of an energy policy in transport. However, while energy issues in transport are important, they are not the only transport policy issues. The transport sector raises policy concerns because of the presence of large and irreversible investments and because of its wider economic impacts. In addition, transport activities cause external costs related to congestion, safety, and air pollution, noise, barrier effects, water quality, etc. In this section, we discuss the relative importance of, and the interaction between, some of the main external costs of transport. Will attention to energy make management of other external costs more difficult? Does attention for other externalities change the optimal response to energy problems? We study the relative importance of the main external costs of transport by comparing estimates of their current order of magnitude, where we look at averages over a large class of users as well as sources of variation. When considering energy and transport policies, this comparison provides some indication on how policy priorities could be defined. One problem with this approach is that the presence of market failures and policy concerns outside the transport sector implies that optimal transport prices likely deviate from marginal social costs. However, it is very likely that second-best transport pricing would align charges more closely with external costs than is the case for the current price structure, so that the comparing current charges to marginal external costs is a useful starting point.

Table 3, taken from Small and Van Dender (2007b), collects estimates of the main marginal external costs of road passenger transport, and classifies them according to whether they depend mainly on fuel consumption (climate change and oil dependency) or on vehicle-miles travelled. For comparison, the fuel-related external costs are converted to a marginal cost per vehicle-mile, using the fleet average fuel efficiency for passenger vehicles (e.g. 22.9 mile/gal for the US in 2005).

The fuel-related costs portrayed in Table 3 are potentially very large in aggregate, but it appears that other external costs are even larger. The three studies listed in Table 3 (excluding the last column) find that congestion involves larger external costs than fuel-related externalities, and except for the “low” Harrington–McConnell values, the same is true of air pollution and accidents. In nearly all cases, congestion alone is found to outweigh the fuel-related externalities by a large margin. If we use the higher fuel-related figures in the last column of the table, the picture changes somewhat, although even then fuel-related externalities do not dominate other externalities. However, the validity of the averages in the table as guides for policy can be questioned. In the case of climate change, the main problem is the enormous uncertainty; this is discussed further in Section 3.2. With respect to energy security, the argumentation underlying the numbers is not entirely convincing (see Small and Van Dender, 2007b, for a discussion).

What about variation of marginal external costs? The figures in Table 3 are national averages, but some of these costs vary strongly over time and place. For example, a French study (Grange, 2007) finds that the marginal external congestion costs of driving in urban traffic are about ten times as high as those of driving in interurban traffic. This conclusion is corroborated by other studies, which in addition point out that the congestion costs depend strongly on time of day (e.g. Proost et al., 2002). Similarly, pollution costs from motor vehicle use vary widely depending on location, fuel type, age of vehicle, and vehicle maintenance practices. For example, pollution costs are higher for diesel than gasoline cars, because of the high health costs associated with emissions of small particulates. When particulate filters are relatively cheap, this disadvantage of diesel cars can be handled.

It is worth emphasizing that the best policy responses to fuel-related and mileage-related externalities are quite different. Raising the price of fuel induces a mileage reduction but also, to an increasing extent, an increase in fuel efficiency (see Section 2.3). This means that a fuel tax is not a very effective instrument to address mileage-related externalities. A numerical illustration by Parry and Small (2005) confirms that the endogeneity of fuel economy greatly reduces the effectiveness of a fuel tax to curb mileage-related external costs. This means that the optimal fuel tax will not reflect the full mileage-related external costs. Instead, the tax rate would be set at only roughly 40 percent of the value that is obtained by multiplying cost-per mile figures by fuel efficiency. An optimal distance-related tax would be much more effective, given the relatively bigger importance of these external costs. However, using a distance-related tax to address a fuel-related externality such as global warming would fail to elicit one of the most important responses needed, which is an increase in fuel efficiency of vehicles. In addition, although better than a fuel tax, a mileage tax is not ideal for handling congestion, which varies strongly over time and place. There is evidence that the response to imposing targeted congestion charges (i.e., ones that vary by time and place) would

Table 3
Marginal external costs from automobiles, US cents/mile, 2005 prices.

<table>
<thead>
<tr>
<th></th>
<th>Low</th>
<th>High</th>
<th>Low</th>
<th>High</th>
<th>Low</th>
<th>High</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Fuel-related:</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Climate change</td>
<td>0.3</td>
<td>1.2</td>
<td>0.5</td>
<td>2.0</td>
<td>0.3</td>
<td>3.7</td>
</tr>
<tr>
<td>Oil dependency</td>
<td>1.6</td>
<td>2.7</td>
<td>n.a.</td>
<td>n.a.</td>
<td>0.6</td>
<td>2.4</td>
</tr>
<tr>
<td><strong>Driving-related:</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Congestion</td>
<td>4.2</td>
<td>15.8</td>
<td>31.0</td>
<td>35.7</td>
<td>5.0</td>
<td>5.0</td>
</tr>
<tr>
<td>Air pollution</td>
<td>1.1</td>
<td>14.8</td>
<td>1.1</td>
<td>5.4</td>
<td>2.0</td>
<td>2.0</td>
</tr>
<tr>
<td>Noise, water</td>
<td>0.2</td>
<td>9.5</td>
<td>0.1</td>
<td>2.5</td>
<td>n.a.</td>
<td>n.a.</td>
</tr>
<tr>
<td>Accidents</td>
<td>1.1</td>
<td>10.5</td>
<td>2.6</td>
<td>4.5</td>
<td>3.0</td>
<td>3.0</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>6.6</td>
<td>50.6</td>
<td>35.3</td>
<td>50.1</td>
<td>10.9</td>
<td>16.1</td>
</tr>
<tr>
<td>Percent fuel-related</td>
<td>22</td>
<td>7</td>
<td>1</td>
<td>4</td>
<td>8</td>
<td>38</td>
</tr>
</tbody>
</table>

**Sources:** Harrington and McConnell (2003), Table 3, Sansom et al. (2001), Parry et al. (2007a), Table 2.

**Notes:** All numbers converted to 2005 US price levels. n.a. means not estimated, in some cases due to an explicit argument that the quantity is small. Fuel-related costs are converted from per gallon to per mile using prevailing average fuel efficiency. Some external costs, including congestion and pollution, vary by time and place (see text).

* Same as Parry et al. except for climate change ($0.76/gal, from Stern, 2006) and oil dependency ($0.55/gal, from the high end of range in Leiby (2007), Table 1.

**15** It is just a starting point, as the actual formulation about policies requires much more information, including cost and demand functions.
involve a lot of shifting of trips across time periods, modes, and routes, and less overall reduction of trips; thus the most efficient policies would aim at shifting trips in this manner rather than simply reducing all trips.

3.2. Marginal external costs of motor-fuel consumption due to climate change

The climate-change cost calculated by Parry et al. (2007a), shown in the next to last column of Table 3, is based on a damage estimate of US$25 per tonne carbon, i.e. $25/TC, at 2005 prices, a figure found in several reviews (e.g. Tol, 2005) but lower than those in Stern (2006). The marginal cost of damage from carbon emissions is, however, highly uncertain. This is because the effect of emissions on climate outcomes is highly uncertain, because it is not known how societies respond or adapt to problems that emerge slowly over time, and because opinions on how to quantify future impacts differ. We briefly discuss some of the controversies below.

Human adaptation to climate changes may occur in many ways, although adaptation cannot mitigate all damage. Some adaptive measures will be extremely costly, but these costs will be spread over many decades. On the basis of Table 3, there is no indication that such costs dominate the costs of congestion and air pollution. To the extent the cost estimates are valid, the appropriate conclusion is not to ignore the problems with smaller costs; it is rather to maintain perspective relative to other problems when setting priorities.

The second major source of differences among analysts is the matter of discounting future costs and benefits. Discounting is appropriate because observed savings behavior appears to be roughly consistent with a long-term growth model in which people discount their own or their descendants’ future utility at very modest interest rates (the so-called “pure rate of time preference”), and simultaneously seek to smooth their consumption in a world where long-term growth is making them richer. Consumption smoothing can be seen as an ethical position against income inequality across generations: since future generations are roughly consistent with a long-term growth model in which development will only be realized if there is a strong policy commitment to climate change, finding much stronger support for policies to mitigate quickly than in the traditional model.

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The implications of Stern’s assumptions is an actual discount rate of only 1.4% per year (Weitzman, 2007). Nordhaus (2007) provides some numerical examples of using such low rates. Suppose a “wrinkle in the climatic system” threatens to reduce world consumption by 0.1% forever, starting in year 2200; this}

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10 One $C$ means one metric ton or tonne (1000 kg) of carbon. Given that carbon comprises a fraction 12/44 = 0.2727 of the weight of a carbon dioxide molecule, $\$1$ per $C$ is equivalent to $\$3.667$ per metric ton of $CO_2$. According to US National Research Council (2002, p. 85), one $C$ is the carbon content of 413 gallons of gasoline.
instead will accomplish most of its results through technological changes specifically targeted to energy savings, mostly through the use of more fuel-efficient vehicles and perhaps also through alternative fuels. By choosing technological solutions when permitted, consumers will avoid more thoroughgoing behavioral changes such as changes in travel mode, trip patterns, and home and work location, which evidently are more costly for them. Measures to address congestion may induce changes in patterns of travel demand that imply reductions of greenhouse gas emission, but not enough to meet ambitious abatement targets.

4. Conclusion

We have reviewed and interpreted some recent work on inefficiencies in private road passenger transport and possible policies to alleviate them. We conclude that fuel economy standards in combination with fuel taxes are a good way of improving fuel economy. Drivers’ loss aversion and uncertainty lead to reluctance on producers’ part to provide costlier and more fuel-efficient vehicles. A fuel economy standard remedies this uncertainty directly, although imperfectly when the standard is attribute-dependent. Fuel economy standards and fuel taxes are complements rather than substitutes. The level at which to set fuel taxes depends on which functions the tax is supposed to perform. Estimates of marginal external costs and of elasticities provide guidance on appropriate fuel tax levies.

There are, however, reasons to be skeptical about using average marginal external cost estimates of greenhouse gas emissions. The main problem is the large uncertainty over these costs, which implies that averages are not necessarily very informative. Appropriate accounting for low probability catastrophic outcomes is difficult and standard cost-benefit analysis may be ill-suited to the task. Alternative methods are not readily available, but emerging literature suggests higher implicit damage estimates and drastic abatement targets than are obtained from the standard approach. To be met, such targets require the wide-spread adoption of low-carbon technologies, also in transport. In order to create the conditions for such technologies to mature, a strong policy commitment to abatement and the creation of a stable environment for investments and research and development is at least as important as maintaining a relatively high level of fuel taxes.

Energy policies in transport are not likely to lead to drastic changes in the nature of transport activity, because drivers prefer to respond to higher energy prices by investing in fuel economy more than by adapting driver behavior. This also means that pursuing energy savings by trying to change strongly transport activity is a very costly approach. Improving transport policy to manage congestion and local pollution externalities yields large benefits, and merits continued policy emphasis even if they were to contribute little to energy and climate policy.

References


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Wiberg, Karin, 2007. Does the Swedish fuel tax imply reductions of greenhouse gas emissions and work location, which evidently are more costly for them. Measures to address congestion may induce changes in patterns of travel demand that imply reductions of greenhouse gas emission, but not enough to meet ambitious abatement targets.