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The Cost and Effectiveness of Policies to Reduce Vehicle Emissions

SUMMARY AND CONCLUSIONS

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EXECUTIVE SUMMARY

Issues

Transport sector policies already contribute to moderating greenhouse gas emissions from road vehicles and are increasingly designed to contribute to overall societal targets to mitigate climate change. The Round Table investigated the effectiveness and costs of various mitigation options. The question of how to decide on the distribution of abatement efforts across sectors of the economy was also discussed. Within the broad topic of addressing greenhouse gas emissions from transport, the Round Table focused on emissions of CO_2 from road transport and in particular from light-duty passenger vehicles.

Policies that reduce fuel consumption below non-intervention levels are in place in most countries, many adopted for reasons other than reducing CO_2 emissions. In the US, both fuel taxes and fuel economy regulations have been in force for some decades. European governments have adopted high fuel taxes but are now considering introducing fuel economy regulations.

A first core question for the Round Table was whether such a combination of instruments is justified. A second question was whether current policies, and the level of taxes and standards, are in line with societal climate change mitigation goals and, more generally, how such goals ought to be defined.

Combining instruments

There are two general arguments to motivate combining fuel economy regulations and fuel taxes. First, if prevailing levels of fuel taxes fail to stimulate the desired level of reduction in fuel consumption, and if increasing taxes is not politically feasible for the foreseeable future, regulating fuel economy is attractive. Using regulations may be a more costly way of reaching targets, but this approach trades off these costs against political expediency.

Cap-and-trade systems that allocate CO_2-emission permits to drivers free of charge are another potential approach to reducing fuel consumption that might be more politically acceptable than higher fuel taxes. Here too, political feasibility comes at a cost, as free permits imply a loss of valuable public tax revenue, and to a stronger extent than with standards. The comparative administrative cost of permit systems, taxes, and standards is still subject to debate.

The second argument to combine fuel taxes and fuel economy regulations is that there are imperfections in the market for vehicles that are not satisfactorily dealt with by fuel taxes. When analyzing vehicle purchase decisions it is important to keep in mind that a vehicle is a collection of attributes of which fuel economy is just one. When increasing fuel economy implies a reduction in power, for example, the increase in consumer benefits from better fuel economy needs to be weighed against the loss of benefits from lower power. There are indications, however, that consumers underinvest in fuel economy; buying more fuel efficient vehicles that are more expensive but otherwise identical would lead to net benefits through reduced expenditures on fuel over the lifetime of the vehicle. This holds at reasonable levels of private discount rates and a fortiori at social discount rates.

The reasons for these imperfections are not entirely clear empirically, but are related to (a) insufficient information at the point of purchase on the trade-off between more expensive technology and lower fuel costs, (b) frictions in markets for used cars, (c) inappropriate incentives in company car markets, and (d) uncertainty for manufacturers about the reactions of car buyers and competing manufacturers to producing more efficient but more expensive vehicles. These frictions can justify interventions such as providing better information and regulating fuel economy.

When it is judged useful to use a combination of instruments, the issue becomes designing the package to be cost-effective. Exactly what level of fuel tax should be combined with what standard depends on how important the frictions in vehicle markets are. A conceptual understanding of these imperfections is emerging, but their quantitative importance is largely unknown. Estimates of the technology costs associated with better fuel economy are also uncertain. More research on these specific issues would be valuable. At present, it is not clear if prevailing or proposed stringencies for standards are justified by the imperfections observed. Some experts think, for example that the proposed EU standards are too ambitious given prevailing fuel taxes, others think that technology costs are sufficiently low and market imperfections sufficiently strong to justify stringent standards.

Cost-effectiveness is one objective in the design of standards, but regulators often also have to take fairness considerations into account, and specifically the interests of manufacturers that focus on relatively fuel-intensive vehicles. This leads to attribute-based standards, where the allowed level of CO_2 emissions depends on a vehicle attribute like weight or footprint (wheelbase x width). The choice of attribute is not neutral, and there is considerable agreement that footprint is better than weight. This is because weight-based standards may reduce the appeal of reducing weight to improve fuel economy, and with a poorly designed standard an incentive to add weight rather than cut emissions might result. Footprint-based standards avoid such problems to a large extent as footprint is more difficult to change without affecting vehicle characteristics that consumers value highly.

Transport, climate change and other external costs

A comparison of marginal external cost estimates and transport charges suggests that current charges more than cover external costs for passenger cars in many circumstances, with the exception of driving in highly congested conditions. At the same time, CO_2 abatement costs are likely to be lower in some other sectors of the economy. One view is that this calls into question the routine statement that transport should contribute to abatement of greenhouse gas emissions, as road transport is already subject to more than sufficient levels of fiscal incentive to reduce its CO_2 emissions to an optimal level; it is taxed well above the marginal costs of CO_2 emissions. If fuel taxes are seen as an instrument to tackle the main external costs of driving, they are sufficiently high except for driving under heavily congested conditions. Only very ambitious overall CO_2 abatement targets, out of line with damage estimates, could justify further abatement in transport. This view is far from universally accepted, for at least three reasons.

First, deviations from charges set at the level of marginal external costs may be justified in an economy characterized by multiple inefficiencies. While such inefficiencies clearly exist, the evidence on their magnitude does not point in the direction of sharply increasing transport charges.

Second, current marginal external cost estimates relating to greenhouse gas emissions are uncertain and strongly risk-averse policy-makers implicitly may wish to use higher values. Discussions at the round table underlined that such risk-averse behavior comes at a cost.

Third, the case for internalizing external costs is that it improves efficiency and hence net economic surplus. Policy-makers may trade off this objective against others, and therefore choose to deviate from efficiency-oriented policies. Here too, economic analysis points out the costs of such an approach.

1. INTRODUCTION

Transport generates a large and growing share of anthropogenic greenhouse gas emissions. While measures that discourage fossil fuel use in transport are in place, the sector has yet to shift to using low carbon intensity fuels on a large scale. With ambitious greenhouse gas reduction targets, all sectors in the economy will have to decarbonize to some extent. But how can greenhouse gas emission reductions from transport be best put into effect? And what guidance can be given on the distribution of abatement efforts between transport and other sectors?

This paper discusses these issues, with a nearly exclusive focus on road transport and in particular light duty vehicles. The analysis is also mostly limited to policies affecting vehicle technology through regulation of fuel economy and policies affecting vehicle choice and use through regulation, fuel taxes and tradable CO2-emission permits. Other policies, such as fuel quality regulation or explicit attempts to modify mode choice, are ignored although they clearly merit consideration in a broader policy package to reduce carbon emissions from road transport.

We begin by discussing which combinations of policy instruments are likely to mitigate transport greenhouse gas emissions most effectively (Section 2). To many economists it seems strange that this issue even needs to be brought up. Basic microeconomics tells us that greenhouse gases from transport are an externality, and that a carbon tax is the ideal instrument to confront users with the marginal external cost of carbon and reduce emissions to efficient levels. While much is to be said in favor of this principle, it is not clear that it offers *complete* guidance for an effective policy, for at least four reasons.

First, not all parties involved may regard least-cost emission reduction or an efficient level of greenhouse gas emissions as an overriding policy target. Economists tend to focus on efficiency as the preeminent policy objective, but this view is only one input to a policy-making process that also considers other objectives to which it may give more weight. Consequently, marginal external damage estimates or estimates of efficient charges are not necessarily a yardstick for policy evaluation. We emphasize the necessity to separate discussions on policy objectives from those on instruments in section 2.1.

Second, cost-minimizing mechanisms are often taken to be difficult to achieve politically. This implies that the cost-minimizing properties of incentive-based mechanisms need to be weighed against other factors including political feasibility. This is briefly discussed in section 2.2.

Third, if consumers make socially desirable decisions when trading off fuel economy against other vehicle attributes and vehicle prices, carbon taxes (or the equivalent) would be sufficient to align consumer behavior regarding fuel use with societal interests. But there is evidence to doubt whether consumers' decisions on fuel economy are in line with what is socially desirable, suggesting that complementary instruments such as fuel economy standards may be justified. Clearly, such a motivation in no way eliminates the need for improved transport charging structures. The appropriate stringency of existing and proposed standards depends on a further set of considerations, examined in section 2.3.

Fourth, greenhouse gas abatement policy does not operate in a vacuum. The transport sector is heavily regulated and heavily taxed (especially in Europe), on grounds ranging from safety to raising public revenue. How do greenhouse gas abatement policy and these other objectives interact, given the current state of policy? And how does it fit in a framework for improved transport policy that addresses all the major externalities? Section 2.4 deals with these questions.

The outcome of the discussion in section 2 is that there reasons to view fuel tax and fuel economy standards as key complementary elements of the policy package to manage greenhouse gas emissions from road transport. Section 3 focuses on the design of standards, taking into account that while the market does not operate perfectly, the alternative of government intervention also struggles to achieve perfection. Hence, how should standards be designed to correct market imperfections? Should standards be uniform across all vehicle types or rather allow emissions per unit distance to increase with vehicle weight or footprint? And should there be a built-in system to increase stringency over time? In order to answer these questions, it is imperative to be clear about (1) what the policy aims to attain and (2) how easy it would be to adapt the measure in the context of changing political aspirations and increased knowledge about demand and supply responses. For the first question, the design of a standard depends on whether the main goal is to influence the composition of the (new) vehicle fleet or to change the technology used in the (new) fleet without affecting fleet composition, although it is clear that aiming to change the vehicle mix increases the potential to reduce emissions. Regarding the question of "future proofing" regulations, it seems important to formulate a policy that provides sufficient certainty for producers facing major investments while retaining enough flexibility to integrate the standard with potential improvements in transport pricing.

Given the insights from sections 2 and 3 on greenhouse gas abatement strategies in transport, section 4 briefly touches on the problem of how the costs of the strategies should be shared across the community (burden sharing). Decisions on how much abatement effort to require from the transport sector depend on the overall abatement target and on the costs of abatement in transport relative to other sectors. Determining abatement costs in an economic sense is difficult, and opinions on relative magnitudes diverge. Overall, the evidence suggesting that abatement costs are relatively high in transport does not seem sufficiently strong to counter the rationale underlying the policy approach outlined in sections 2 and 3, but it raises questions about the tendency to prioritize transport in abatement efforts and highlights the need for careful abatement cost evaluations. Section five sums up and concludes.

2. EFFECTIVE POLICY PACKAGES TO REDUCE GREENHOUSE GAS EMISSIONS FROM ROAD TRANSPORT

While debates on policy instruments to reduce greenhouse gas emissions are often cast in terms of either economic incentives (such as taxes or tradable permits) or command and control instruments (such as emissions standards), there are strong arguments to combine these approaches in the transport sector. In particular, there are analytical grounds for combining carbon or fuel taxes with a fuel economy standard. More practically, an increasing number of regions around the world already have or are likely to adopt fuel economy standards in addition to fuel taxes. Irrespective of whether this approach is taken primarily for reasons of climate change policy or is otherwise justifiable, it is important to understand the interaction between standards and taxes.

The main arguments in favor of fuel economy standards, even when fuel taxes exist and are high, are as follows:

(1) Taking current policy preferences as given, standards are more politically palatable than (even) higher taxes. The trade-off between lower political costs and higher economic costs becomes less of a concern when elasticities of the demand for driving are low because better fuel economy triggers only limited additional driving in that case (section 2.2).
(2) Carbon or fuel taxes are not sufficient to align consumer choices with the socially desirable choices as their influence on some choices is only very indirect. Specifically, standards improve choices of vehicle fuel economy, but they affect only new vehicles so that it takes 15 to 20 years before their full impact on fuel consumption is realised (section 2.3).

In discussing these arguments, it is useful to keep in mind the tension between “standard” economic argumentation favoring a Pigouvian approach to policy assessment and policy design, and policy objectives that imply deviations from this approach (section 2.1). And, while using standards seems reasonable, they are likely to be used jointly with taxes, for reasons explained in section 2.4.

2.1. Marginal external costs and policy design: some clarification

It is a key principle of environmental and transport economics that efficiency is obtained when consumers' and producers' choices are based on prices that reflect marginal social costs. When there are external costs, such as those related to greenhouse gases, local pollution, and congestion, charges reflecting those external costs are the ideal way of aligning prices with marginal social costs. This is the rationale underlying Pigouvian charges.

The partial equilibrium Pigouvian principle has been challenged in the economics literature on the grounds that it applies only in a world where there are no other significant distortions to the efficient allocation of resources in the transport sector. It also implies that policies to mitigate transport externalities should not be influenced by inefficiencies elsewhere in the economy. As neither of these conditions prevail there is a strong case for "second-best" reasoning, and deviations from the simple Pigouvian approach are justified. While conceptually valid, the debate on exactly which deviations are justified is far from resolved. Some economists argue, for example, that transport taxes should be kept fairly low because transport taxes fall particularly on commuting, thus on labor which is already heavily taxed (see section 4). In this paper, we take the practical point of view that even if second-best arguments potentially justify deviations from marginal cost pricing, the existing (not even second-best) transport charges are so poorly related with marginal external costs that a reform of those taxes to bring them closer in line with external costs will improve efficiency.[1]

However, accepting that a comparison of marginal external costs and transport charges informs us about the degree of efficiency in transport markets is not the same as declaring that efficiency is or should be the only policy objective. Even a superficial glance at policy objectives and actual policy shows that policy is not concerned with efficiency alone, but also with equity, industrial policy, trade promotion or protectionism, serving interest groups, etc. Recent policy on biofuels in the EU and the US may serve as an example (OECD/ITF 2008a). The challenge becomes to determine the relevance of efficiency-based reasoning in the policy process. One approach is to participate in the debate and insist on the importance of efficiency as an objective. Another approach is to employ economics to determine the most cost-effective way to attain the political objectives. Both approaches are legitimate and useful, but it needs to be recognized that they differ and that both imply value judgments (insisting on efficiency is not value free, nor is taking policy objectives as given). But confusion arises when both approaches are mixed in the debate, as the following example illustrates.

One common argument against fuel economy regulation, especially in Europe, is that current fuel taxes already exceed marginal external costs, except for severely congested traffic. But this matters only in as far as policy targets are roughly in line with what a Pigouvian approach would prescribe. Such an approach can be defended but will not necessarily be accepted. The point is that this debate is essentially about policy objectives, not about the design of effective policies to attain them. The observation that taxes more than cover external costs in many cases then highlights that policy objectives are in play that

[1] A full alignment of charges with external cost estimates may lead to higher CO_2-emissions, as off-peak driving charges decrease (cf. cost and charge comparisons in Proost et al., 2002). Retaining the overall structure of current charges and adding localized congestion-pricing schemes is more likely to reduce overall driving and CO_2-emissions, but is not optimal for the conventional cost estimates.

do not imply efficient use of scarce resources, an issue that conceivably deserves explicit justification.

A somewhat more subtle version of the same problem arises when considering marginal external costs of greenhouse gas emissions. The comparison of marginal external costs to taxes is often done by referring to some kind of average estimate of the marginal external cost. The use of such an average is reasonable when uncertainty on cost estimates is limited, but harder to defend when there is large uncertainty, as in that case an average is not very meaningful. Given the current controversy among climatologists and economists on the magnitude and the discounting of future damages, it is fair to say uncertainty on the marginal damage costs of CO_2-emissions is large. How to analyze policy when uncertainty is large? One solution is to work with several values of the marginal external cost, including very high ones. But again it is useful to realize that ultimately the discussion is about policy objectives. There is a sense that current policy gives a high weight to avoiding catastrophic consequences of climate change, even if the probability of such a catastrophe is low.[2] One can dispute the desirability of this policy stance, but the issue remains that this policy goal – presumably based on subjective evaluations of probability[3] – implies valuations of greenhouse gas emissions that exceed those used in most comparisons of taxes to marginal external costs. If the policy objective is taken as given, the point that current fuel taxes already cover marginal external costs means nothing more than that other factors than efficiency are considered.

2.2 Economic costs, political expediency, and instrument choice

A strong argument in favor of incentive-based approaches, like taxes or cap-and-trade programs, is that they generally minimize the costs of attaining a policy target. Standards can also be designed minimize costs, but this possibility relies on all the necessary information being available to policy makers.[4] The informational requirement for incentive based instruments is much less demanding as the implementation of the cost-minimizing solution is decentralized to parties that presumably have the required information, or can collect it a lower cost than a regulator. One more attractive feature of incentive-based approaches like fuel taxes or carbon-trading schemes is that they affect all transport users, not just those who contemplate buying new cars. But these attractive traits of incentive-based approaches need to be weighed against others. We consider four examples: political feasibility, administration costs, asymmetric information, and uncertainty on cost and damage functions.

First, cost-minimizing policies may not be politically feasible at present. It is routinely argued that this applies to higher fuel taxes, and not only in the US (e.g. Raux, 2008). Even

[2] For example, the high marginal damage costs in the Stern report (Stern, 2006) relate to the discounting method used, and this method is interpretable as translating strong aversion to extreme events into a regular discounting framework.

[3] It is also possible that the policy objectives are defined on the basis of electoral attractiveness. This is more problematic, as it leads one to expect climate change will soon be replaced by a different issue, and this makes it hard to come up with credible long run policies. Arguments on economic costs then may be used to defend abandoning the cause (all this irrespective of whether one thinks climate change policy in transport or in general is justified).

[4] This is a necessary but not a sufficient condition. An additional requirement is that policy aims to minimize costs, rather than seeking rents.

when the economic costs of a standard are as high or higher than those of a tax, a standard is more politically palatable than higher fuel taxes and therefore is a practical though costly way forward, particularly in the short-run. At the Round Table, this point of view raised concerns that regulation reflects a need to show willingness to act but boils down to little more than political window-dressing. Nevertheless many experts are of the opinion that regulation is useful, even if it is not the ultimate or only solution. In particular, support for fuel economy regulation does not imply lack of support for improved pricing structures.

It is clear that difficulties with increasing fuel taxes have different implications depending on prevailing tax levels. Fuel taxes in the US are relatively low and when increasing them is deemed impractical in the near future, alternative policy approaches become attractive. Making the same argument for Europe and Japan, with higher fuel taxes, is less straightforward; convincing evidence to justify regulation on other grounds, some of which are discussed below, then become of key interest.

In this context, it is worth mentioning that the downsides of a standard compared to a tax are more limited when the elasticities of demand for driving are low, while these same low elasticities increase the political difficulties of appropriate fuel taxes because the appropriate taxes are higher when elasticities are lower (Small and Van Dender, 2007b). The empirical evidence on the elasticities of demand for fuel and for travel also indicates that both are substantially below one, and that drivers respond to higher fuel prices by investing in better fuel economy to a larger extent than by reducing driving (Johanson and Schipper, 1997), and increasingly so (at least according to US evidence, Small and Van Dender, 2007a). By the same logic, a fuel economy standard may mimic the response that consumers would have had to higher fuel prices (in terms of fuel economy) quite well, and the amount of extra driving generated by lower fuel costs per mile (because of better fuel economy) is limited. The latter effect, known as the rebound effect, is a source of concern to the extent that increased driving leads to higher costs associated with non-internalized externalities related to congestion, accidents, and air pollution.[5] But the evidence suggests these concerns are not major ones because the rebound effect is rather small, and partly offset in congested conditions (where external costs from extra driving are largest). And mitigating extra costs related to the rebound effect is best done by tackling those externalities directly, instead of giving up the goal of reducing fuel consumption.

Second, the cost-minimization argument for incentive-based instruments in general ignores the administrative costs of implementation and operation. But administration costs are relevant when considering cap-and-trade greenhouse gas policies in transport. Raux (2008) proposes a cap-and-trade instrument in transport through a system that allocates greenhouse gas permits freely on a per capita basis. The reason for giving permits to drivers is that this makes the program politically acceptable, on the argument that drivers will accept a cap if they receive rights but not if taxes are increased or permits are auctioned. While Raux argues that the operation costs of such a system are limited because it is added on to existing financial and distribution networks, others fear costs would be higher than anticipated. In addition, many argue that the combination of increased fuel taxes with explicit and transparent revenue redistribution schemes may attain the same goal of political and social acceptance, at a much lower cost. Of course, the efficiency properties of such

5 The rebound effect is good news in the sense that increased driving resulting from lower fuel costs leads to more consumer surplus (keeping other quality attributes of the vehicle constant).

revenue redistribution schemes are not necessarily ideal[6], although they may compare favorably to the loss of revenue implied by tradable permits. Administrative costs of cap-and-trade at upstream levels (e.g. refineries) are likely lower, but then the social acceptance advantage is lost[7], and the case for cap-and-trade becomes weaker in that sense.

Third, in a world where all information is common knowledge, a standard and a tax are equivalent in the sense that a tax rate can be set that produces the same amount of abatement as a standard would.[8] The true case for a tax is that it requires less information on the policy-maker's behalf than a regulation because decisions on how to reduce emissions are made by consumers and firms, not by the regulator. Collecting and processing information on abatement costs is costly for businesses emitting CO_2 or producing vehicles emitting CO_2, but more costly for a regulator. This is because information provision is prone to incentive problems when collected by the regulator (businesses and other interest groups may misrepresent costs and levels of emissions). This suggests that a standard is likely to turn out more costly than a tax.

Fourth, the comparison of price-based instruments (such as taxes) and quantity-based instruments (such as cap-and-trade systems and, in a setting of common information, standards) is complicated by uncertainty. The seminal article by Weitzman (1974) tells us that the relative performance of price and quantity based instruments depends strongly on the slope of the marginal damage function. If marginal damages are more or less constant, i.e. each extra unit of emissions causes damage similar to the previous unit, then small deviations from the desired total level of emissions will not cause major extra costs, and taxes work well. But if, in contrast, damages increase sharply with emission levels, then it is important to get the quantity target right, because exceeding it entails large and possibly catastrophic consequences. In this case, instruments that give direct control over the level of emissions, like cap-and-trade systems, are attractive. A standard works well too, at least if the regulator knows enough about individual sources' abatement costs. Stavins (1996) considers more general patterns of uncertainty than Weitzman, and finds stronger support for quantity-oriented instruments[9].

So which type of marginal damage function is relevant for greenhouse gas emissions? This brings us back to the last issue of the section 2.1. The view in many economic analyses is that the damage function is fairly flat, suggesting tax-based approaches are more suited. But some climate change and economic work and much of the political rhetoric is more consistent with a sharply rising damage function (threshold effects implying there is a benefit to acting quickly). A quantity-based approach is more in line with this "sense of urgency"

6 Existing or proposed systems routinely imply some form of earmarking of revenues to the transport sector, a constraint that may lead to suboptimal revenue use.

7 Experience with electricity companies in the European Trading System suggests refiners can be expected to pass on the costs of tradable permits in fuel prices even if permits are initially distributed free of charge. As soon as permits are tradable they become an asset, and the companies holding them maximise the returns they can obtain from these new assets. Because of this ability to pass through opportunity costs to final consumers, the European Commission proposes to amend the EU Directive on emission trading to impose auctioning of permits on the power sector earlier than in industrial sectors that consume energy (COM(2008)16 Final).

8 In finding this tax rate, the behavioural responses to both instruments need to be accounted for (e.g. a tax makes driving more expensive, but a fuel economy standard reduces the fuel cost of driving a unit distance.)

9 In applying Weitzman's arguments and their generalizations, we implicitly assume it is justifiable to apply it directly to transportation. The discussion of burden sharing in section 4 points out this assumption is controversial.

because it gives the regulator more control over total emissions. While this argument holds true in general, there are some issues with its validity for a fuel economy standard. First, controlling fuel economy is not the same as controlling fuel consumption of new cars. Second, the standard initially only affects fuel economy of new cars and takes up to 20 years to affect the whole fleet. Both arguments call for complementary measures, i.e. a standard may be justified but is not the only part of the policy package.

2.3. Addressing vehicle purchase decisions

At present, the main goal of climate change policy in transport is to reduce CO_2 emissions from carbon based fuel use.[10] Fuel use is determined by how much people drive and by the fuel economy and fuel type of their vehicles. Fuel economy is heavily determined when a vehicle is purchased, although driving behavior, maintenance and aging matter as well. Is a fuel tax, or ideally a carbon tax, in itself sufficient to address both vehicle purchase and vehicle use decisions? If the carbon tax is set at the level that is consistent with the cost of CO_2 emissions, or the carbon reduction target for road transport, and if car buyers trade off investments in fuel economy against higher fuel expenditures and other vehicle attributes like comfort, safety, and power, it should be. However, there are several arguments favoring an extra instrument to guide purchase decisions. We briefly consider some of these arguments, focusing first on private car buyers, and next on the company car segment.

For private car buyers, one argument is that private discount rates are higher than social discount rates. In that 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.[11] 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. It is worth noting that this argument for a policy intervention is controversial: regulators do not generally[12] 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 reasoning is especially unclear if fuel taxes cover marginal external costs, because in that case the policy rationale must be that consumers should be induced to discount at the social rate. The higher discount rates can be due to the option value of more flexibility for consumers (waiting for an even better technology, uncertain car needs etc.) and it is not clear why the problem is more acute in vehicle purchase decisions than in other energy saving decisions (e.g. domestic heating and cooling). Nevertheless, the argument receives considerable support.

A further argument is that consumers pay little attention to fuel economy, because they care more about other attributes and the share of fuel costs (and therefore *a fortiori* the size

[10] A broader approach may be called for as other emissions also have climate effects. For example, emissions of particulates (particularly generated by diesel engines) modify the albedo-effect, darkening the surface of polar ice and reducing the reflection of solar radiation. Jacobson (2002) argues that controlling this form of black carbon is a very effective way of quickly reducing transport's climate impacts.

[11] See Verboven, 1998, for econometric evidence that car buyers' discount rates are in line with "rational" private discount rates, given available vehicle models. The author remarks that this finding differs from results for other durables, implying that policy rationales differ as well.

[12] Although some such interventions exist, e.g. through subsidies for home insulation.

of savings from better fuel economy) in total purchase and use costs is small.l[13] There are also of imperfections in the used car market (see Greene and German, 2007 for argumentation, and Turrentine and Kurani, 2007, for survey evidence; section 3.3 picks up on these issues in the discussion of the EU proposal for regulating CO2-emissions). With little effort from the buyers' side, it is possible that fuel economy investments are not optimal, although it is less clear why there should be a systematic error in the direction of underinvestment. It was noted that, contrary to expectations, fuel economy decisions for company car fleets and for freight trucks are prone to similar imperfections to those for privately owned light-duty vehicles.[14] From the manufacturers' perspective, little attention to fuel economy from consumers may translate into strategies that steer vehicle design towards more highly valued attributes, like power and comfort. With such a supply response, available fuel economy probably is lower than in a world where consumers do make highly sophisticated and accurate decisions on fuel economy. A manufacturer will not be inclined to use technology to provide better fuel economy if there is large uncertainty as to whether consumers will want to buy it and also as to how competitors will deal with the same problem. A standard can correct this problem as it provides clarity on what performance level needs to be reached by the manufacturer and its competitors.

In many European countries, a substantial share of new cars is purchased by companies rather than private car buyers. For example, according to Nieuwenhuis and Wells (2006) the share of company cars in the UK is between 50% and 70%. High market shares are also observed in The Netherlands and Sweden. Company cars are on average larger and more powerful than private cars. This size effect spills over into other market segments, as private buyers' aspirations are affected by company car characteristics and company car characteristics affect the supply in used car markets some years down the line. It was also noted that the value of fuel intensive cars depreciates more quickly than that of smaller cars, indicating that there may be a mismatch between large car characteristics and private buyers' willingness to pay (partly driven by income).

The UK government has responded to these issues by changing the "benefit-in-kind" tax advantages for company car users to make them strongly dependent on the CO_2 emissions of company cars. This measure has had a marked effect on the characteristics of the vehicle stock and company cars are now on average more efficient than new cars purchased privately. OECD/ECMT (2007, 70-72) shows that in 2001 the average CO_2 emissions of new private cars equaled around 176g/km while those of the average company car were around 181g/km; in 2005, the average for private cars was 173g/km against 167g/km for company cars.

Given the evidence on prevailing imperfections in vehicle markets, the question remains whether the stringency of existing and proposed regulations is in line with what is justified on the basis of the previous arguments. It may be the case that existing and proposed standards require bigger improvements in fuel economy than can be explained by failures in markets for vehicles such as those explained above. Indeed, the stringency of standards

[13] Provision of more information, clearly and strikingly presented (e.g. through window stickers) for consumers at the point of purchase may help.

[14] This is partly an information problem. Since fuel economy evaluations for trucks relate to stand-alone engines, they don't provide very good guidance for making decisions on which level of fuel economy to buy. It was pointed out that manufacturers simulate fuel consumption of various truck configurations, but don't voluntarily share it. Furthermore, since externalities per unit distance are high for trucks and fuel tax rebates are common, the divergence between privately and socially optimal decisions may be larger for trucks than for cars.

seems consistent with a policy approach that either starts from the assumption that technology to improve fuel economy is very cheap, or that explicitly aims to go beyond correcting market imperfections and steers vehicle buyers away from their preferred choices. This highlights, as mentioned earlier, that there is a political choice to be made whether higher vehicle costs and/or foregone consumer surplus are a price worth paying for the desired CO_2 reductions. There is a more discussion of these issues in section three.

2.4. Standards and taxes

The gist of the previous subsections is that there are arguments to suggest incentive-based approaches and fuel economy standards should work in tandem to govern fuel use in road transportation. Among incentive-based instruments, it was argued that taxes are likely to outperform trading schemes because they can attain social acceptance similar to that of trading schemes at a lower cost, at least if taxes are accompanied by explicit and transparent revenue use schemes. There also is reason to favor taxes or auctioned permits, over grandfathered permits: the former generate valuable public revenue, the latter do not. Of course, underlying this statement is the assumption of efficient or at least not wasteful revenue use. This assumption is not straightforward as there is a potential conflict between acceptability as achieved through revenue redistribution and efficiency of revenue use. Finally, if revenue is important, one must consider that a standard, through its effect on fuel economy, will reduce revenues as well, which is one more reason to think carefully about which standard to combine with which tax. We discuss these points next.

High transport taxes were in place, at least in Europe, well before energy security and climate change concerns moved up the political agenda. Transport is a source of considerable public revenue, and economic analysis suggests it also is a “good” source of revenue because low elasticities result in relatively low economic costs of raising tax revenue from transport. This means that policies that reduce transport tax revenues are likely to meet political resistance and/or may cause additional economic costs. If transport tax revenues are not replaced by other sources, this poses a budgetary problem. If they are replaced, it is likely that the economic costs of raising the same amount of revenue increase. These public revenue concerns are relevant for any policy that reduces tax rates or the tax base. In particular, this tradeoff reduces the appeal of tradable permits, at least if they are given away instead of auctioned, because of their large impact on fuel tax revenues (standards also affect the tax base but presumably less drastically so).[15]

The revenue argument not only applies to surface transport, but also to maritime transport and aviation, sectors for which inclusion in the European Trading System is anticipated. Even if permits for those sectors do not replace existing taxes but add new constraints, the public value of foregone revenue needs to be considered, and this suggests permits should be auctioned, not grandfathered or otherwise distributed for free. The choice between distributing permits for free or auctioning them is neutral when the market for permits works well (not straightforward) and when the social value of permit revenues does not depend on who gets them (whereas it is argued above that they are more valuable as public revenue). If it does not matter how permits are allocated, it does not matter who

[15] The revenue impact of permits can be mitigated to some extent by, for example, providing them for free to households but auctioning them for commercial transport. More generally, hybrid permit systems, for example those that add permits on top of existing taxes, may have a role to play in a policy package that trades off revenue concerns, acceptability, and effectiveness in reducing CO_2 emissions.

acquires the property rights, from an efficiency perspective. One argument for grandfathering then is that the agents who initially used a resource (like the atmosphere) for free and are now faced with constraints on that usage, merit the property right. A different view is that the atmosphere is common property, so public ownership (leading to public revenue through auctions or taxes) is preferred. The latter position is more in line with the Pigouvian approach, which rests on the view that users of a scarce resource should incur the full social costs of using it.

One position is that the foregone permit revenue is the price to pay for politically feasible abatement options. Another view is that revenues might be used so inefficiently that reducing them is not very costly to society (although it still may be politically challenging.) A less extreme view is that more modest abatement targets need to be set if it turns out that politically feasible instruments turn out to be very expensive. It can also be argued that improved transport charging systems, in the sense of better aligning charges with key external costs including congestion, are more likely increase revenues than reducing them if the right instruments are chosen (OECD/ECMT 2003), and it does seems feasible to gather a political coalition in favor of such a reform.

At first sight, it does not seem opportune to combine a cap-and-trade policy with a fuel economy standard, simply because both instruments aim to directly control fuel use, unless the arguments regarding the steering of vehicle purchase decisions (section 2.3) are also thought to hold under a tradable permits scheme. But a standard can be seen as an accompanying measure to influence the supply of vehicles and ensure consumers have the option of switching to more fuel-efficient cars in response to higher costs of CO_2 emissions. Standards may also be designed to stimulate technological development, in the anticipation of future (more stringent) caps. If taxes and standards are combined, and the standard is binding in the senses that it pushes fuel economy beyond what it otherwise would have been, fuel tax revenues decline and the revenue issue reappears in a less extreme form. One approach is to compensate the erosion of the tax base by higher unit taxes. A different take is that the vehicle market imperfections discussed in section 2.3 actually lead consumers to pay too much fuel tax at present, so that the social value of fuel tax revenues is lower than it would be in a perfectly functioning market. In the latter case, compensating fuel tax increases should be at most partial.

It was noted in the previous subsection that standards are in one sense attractive to manufacturers in that they reduce uncertainty on exactly what level of fuel economy needs to be attained. But with a standard alone, there may be considerable tension between what the standard requires and what consumers desire. Arguably, the US approach of combining low fuel taxes with a standard has provided manufacturers with an incentive to evade the standard, for example by focusing on the light truck segment of the market. As is well known, the original motivation for less stringent requirements for light trucks was to protect farming and business interests, as the light trucks segment of the market mainly concerned pick-up trucks. But manufacturers developed minivans and SUV's, considered light trucks under the regulation but predominantly used for passenger transport. The market share of these new types of light trucks rose quickly, a tendency reinforced by low real fuel prices.[16]

[16] The strong rise in fuel prices in the US in recent years has reduced the market share of light trucks in new vehicle sales. CBO (2008), p.15, shows a decline in the market share of light trucks in new vehicle sales from 2004 to 2006 from 55.2% to 52.8%. More recent figures show a continuation of this trend, likely reinforced by a slowing economy, as sales of large SUV's declined by 40% between January 2007 and January 2008, while much more small cars were sold (FT, 2008, p.5).

These observations illustrate that provisions to protect particular groups in a regulation may have unintended and undesirable consequences, an issue to be kept in mind when designing a regulation (section 3). In addition, it is clear that the tension between regulatory targets and consumer preferences can be weakened by (higher) fuel taxes, and this is one more reason to view both instruments as complements.

A last point, before discussing the design of standards in some more detail, is that the main approach up to now has been to compare the effects of combining taxes and standards with using either instrument in isolation. A somewhat different approach is to view standards as a reasonable and feasible interim approach in anticipation of a more comprehensive overhaul of transport policy in the future. From this perspective, standards are sometimes seen as a reasonable "quick fix" as long as they do not constrain future policy developments too much. If such future policy goes in the direction of fiscally discouraging CO_2 emissions, then current regulations should stimulate options to abate CO_2. But since any regulation will be gamed in ways that cannot be anticipated, there is a risk that unproductive compliance strategies are implemented, leading to pure waste and little steering towards low-carbon options.[17]

As pointed out before, the value of standards as an interim solution needs qualification because long lead times and slow fleet turnover rates imply that standards take a long time to reach their full intended effect. In contrast, charging for fuel or carbon has an immediate effect (although impacts in terms of increasing investments in fuel economy also take time). The value of standards as a "quick fix" is related to their appeal in terms of political action rather than to immediate impacts on fuel consumption.

3. THE DESIGN OF FUEL ECONOMY STANDARDS

This section discusses issues to be taken into account when designing a fuel economy standard. Section 3.1 elaborates on the seemingly obvious point that the structure of a standard should reflect its objectives. In many cases, an attribute-based standard is chosen and section 3.2 discusses the choice of attributes. In section 3.3, we deal with the costs of attaining a standard, and section 3.4 handles the issue of discrepancies between test cycles, used to measure manufacturers' performance, and on-road performance. It is worth noting that the absence of a similar section in this paper on the design of price structures reflects the focus of the debates in the Round Table on which this paper is based, and in no way implies the design of price structures is unimportant.

[17] An additional future policy lever deserving close attention is spatial planning, as land-use patterns can limit excessively the potential to reduce travel demand.

3.1. Goals and characteristics of a standard

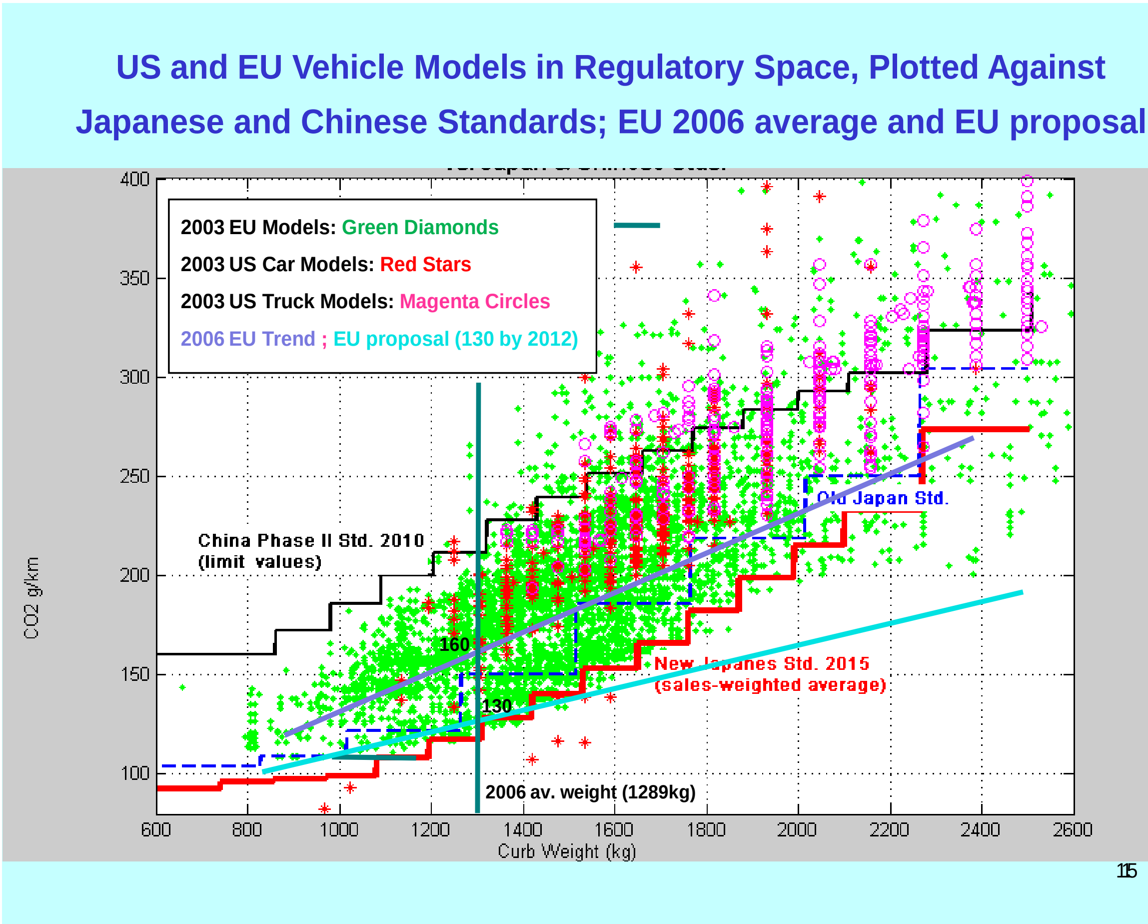
The broad goal of a car or truck fuel economy standard is to reduce fuel consumption from road transport by pushing vehicle or fleet economy beyond market levels.[18] But this overall objective can be pursued in two ways. First, the standard can aim to modify the mix of new vehicles sold, for example it can try to discourage the production and purchase of larger, more powerful, and less fuel-efficient vehicles. Second, the standard can focus on improving the fuel economy of the types of vehicles that are being sold. Such fuel economy improvements likely require the use of costly new technologies or the redeployment of available technology to improve efficiency rather than performance or comfort. While many regions or countries are using or plan to use fuel economy standards for light duty vehicles, they differ in the emphasis put on these two goals. The revised CAFE standards in the US apparently focus on improving the economy of vehicles currently marketed, less on modifying the vehicle mix. This approach fits well in a culture that refrains from regulatory intrusion in private choices whenever possible. The revised standards also help shield domestic producers from international competition. Given the increased share of light trucks in the light duty fleet (a rise partially triggered by CAFE itself), this approach does limit the potential to save fuel, even when gasoline prices are high. The Japanese top-runner approach, where standards are determined by good performers within a vehicle class, is similar in spirit to CAFE: the idea is to improve fuel economy within a class, not so much to affect the market mix of different classes of vehicle.

The Chinese standards (see Figure 1) are explicitly designed to discourage the production and purchase of heavier vehicles, as the weight-dependent standard is relatively more stringent for heavy vehicles and less so for light ones; many current heavy EU and US cars and US light trucks do not meet the Chinese standards, while all lighter cars do. On condition that the standards are actually enforced, they can be expected to generate a vehicle mix that differs markedly from what an unregulated market would have produced, with lower emissions of CO_2 as a likely consequence. It is equally likely that enforcement of the standards carries a cost in terms of foregone consumer surplus. According to some observers (FT, 2008, p.4), Chinese consumers are particularly status-sensitive when purchasing cars, leading them to buy large cars when they can. To the extent that status is related to the absolute size, power and comfort of the vehicle, this means that the foregone surplus is large. But when status mainly depends on how one vehicle differs from others, the standard helps avoid a race to the top, and the foregone surplus is limited. Such considerations apply to all markets, not just China.

In December 2007, the European Commission launched a proposal to introduce a weight-based fuel economy standard aiming to attain an average fuel economy corresponding to 130g CO2/km as of 2012 (EU, 2007a). The proposal is shown in Figure 1, along with the 2006 weight-CO_2 relation for newly sold cars. The European Parliament since communicated it prefers a standard of 125g CO2/km as of 2015, but the basic structure of the policy remained unchallenged (EP, 2008). The way the standard is structured provides considerable flexibility on whether it is attained by changing the mix of vehicles sold or through improved fuel economy of types currently sold. In particular, the standard allows higher emissions for heavier vehicles, but the improvements to be made for heavier vehicles

[18] While recognizing there are important differences, we do not distinguish here between standards that aim to reduce fuel consumption and those that aim to reduce CO2-emissions.

Figure 1. **Vehicle models and fuel economy regulation**



The figure compares the relation between weight (kg) and CO_2-emissions (g/km) for existing vehicle models and for existing and proposed fuel economy regulations. For vehicles, it shows:

- The 2003 EU models (green diamonds),
- The 2003 US car models (red stars) and the 2003 US truck models (magenta circles),
- The 2006 EU average relation between weight and emissions for vehicles sold (blue line);
- also shown is the average weight of 2006 EU cars sold (vertical line at 1,289kg).

For regulations, the figure shows:

- The China Phase II Std. for 2010 (black stepped line),
- The old Japanese standard (dashed blue stepped line),
- The new Japanese standard (red stepped line),
- The proposed EU standard of 130g/km on average as of 2012 (turquoise line).

Source: Feng An, Presentation at IEA/ITF Workshop 28-29 January 2008, with JTRC additions.

are larger than for lighter ones, if one compares with the weight–emissions relation for 2006 vehicles and also if compared with the technical relation between weight and emissions. This feature suggests there are incentives to reduce weight (or at least discourage upsizing) and affect the vehicle mix.[19] But a pooling provision, which can be seen as a system that essentially allows manufacturers to trade or bargain between each other in groups (although the price of a unit of CO_2 emissions is not necessarily made explicit), may change this apparent incentive to reduce weight.[20] Overall, it appears the EU's main aim is to reach the target for the average fleet, and it accepts higher costs of reaching this target in return for a "fair" treatment of producers that currently focus on larger cars (see section 3.2). The proposal also reflects a judgment that an extra vehicle cost of € 1 300 on average in case the vehicle mix is unaffected, is acceptable.

3.2. The choice of attributes and the timing of the standard

All standards, except in China, apply to the sales weighted average for each manufacturer's vehicles (sometimes differentiated by category of vehicle); the Chinese standards apply at the level of each individual vehicle. A sales weighted average standard provides manufacturers with more flexibility than vehicle-specific standards would. The US CAFE regulation for cars is uniform, as the same target is set for each manufacturer's fleet. Alternatively, standards can be varied on the basis of attributes, such as weight or footprint (area delineated by the four wheels of the vehicle). The Chinese and the proposed EU standards are weight-based, and the revised CAFE standard for light trucks uses footprint. The effect of adopting attribute-based standards is that targets differ from one manufacturer to another to the extent that their sales mix differs. Most existing or proposed standards are static, where by static we mean that a policy decision is required to change requirements. A dynamic standard would include a mechanism to modify stringency over time. Only the policy proposed for the EU contains a dynamic element, as the weight-CO_2 relation used in the regulation will be adjusted if substantial increases in vehicle mass are detected before the year of implementation (that is, if vehicles become noticeably heavier by 2012, the standard will become stricter).[21]

Regulators can use attribute-based standards to strike a balance between objectives to manage the vehicle mix and "fairness"-related objectives. For example, if the regulator wishes to reduce the share of fuel-intensive cars (or avoid their widespread adoption), a uniform standard would provide a strong signal in that direction. But a uniform standard may simply be unattainable for manufacturers of the fuel-intensive cars (which could be deemed unfair), unless it is set at a level that is too lax to have an impact on manufacturers of less fuel-intensive cars. A standard that is based on a vehicle attribute that correlates to fuel-intensity provides an intermediate solution, as it allows trading off cost-minimization and fairness concerns.

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[19] Reducing the slope of the curve as weight increases is a way of further discouraging heavy vehicles. For example, the line could be made horizontal starting from a weight of 2000kg or so.

[20] The inclusion of the pooling mechanism is based on fairness considerations, but it may affect incentives to change weight. Trading does reduce compliance costs, as can be seen from the EC Impact Assessment report (EU, 2007b), and from a study on CAFE suggesting costs of the same target are about 15% lower when trading is allowed (Austin and Dinan, 2005).

[21] This dynamic feature potentially harbors perverse incentives. A manufacturer producing vehicles well below the weight-CO_2 curve would in theory have an incentive to increase the weight of its models in order to provoke tougher standards that would have a relatively more severe impact on its competitors.

Given this motivation for attribute-based standards, the question remains which attribute is best, with the debate focusing on the choice of weight or vehicle footprint. There are reasons to think a footprint-based standard is more appropriate than a weight-based one. Reducing weight increases fuel economy, so it would be perverse to produce a standard that is *so much* stricter for light vehicles that the weight-reduction strategy becomes unattractive.[22] More generally, weight-based standards reduce the appeal of reducing weight as a compliance strategy, compared to a uniform standard. This is problematic, as large increases in fuel economy will require weight reductions unless performance is reduced and/or very strong increases in the market share of alternative powertrains are realized (see Cheah et al., 2007 for an analysis of the trade-offs between these efficiency-improvement strategies). Footprint-based standards avoid this problem to a large extent. Reducing the weight of a vehicle with the same footprint does not change the goal set by the standard for that vehicle, but it does improve its fuel economy. Footprint is also less prone to strategic manipulation than weight, because changing the footprint of existing models is difficult, and increasing it on new models tends to increase weight, which leads to lower fuel economy and/or reduced performance. In addition, consumers' willingness to pay for vehicles is arguably more closely correlated with its footprint than with its weight, meaning that manufacturers will be less inclined to manipulate footprint for compliance reasons alone. The fact that footprint is less closely related with fuel economy than is weight, is in this sense a good thing rather than a flaw.

Weight reduction has been criticized as a compliance strategy, particularly in the United States, because of its presumed negative impacts on traffic safety. But this view is no longer considered to be the barrier to policies that promote lighter vehicles that it once was. According to, for example, Ahmad and Greene (2005) and Dynamic Research (2004), safety correlates more with vehicle size than with weight, as size allow for crush space. In that sense, standards that encourage lighter but not smaller cars are acceptable. And safety also strongly correlates with the degree of heterogeneity of the vehicle fleet on the road. A crash between two midsize cars poses less fatality and injury risks, other things being equal, than a crash between an SUV and a small car.[23] So standards should probably not stimulate heterogeneity of the fleet (which the CAFE regulation unfortunately and unintentionally has done; by contrast, the weight-based approaches discussed above seem well designed in this regard).[24]

Finally, it is noted that the stringency of standards is often discussed in terms of the average target and the way it is implemented. However, given long lead times in vehicle manufacturing, the timing of the standard is crucial as well. A case in point is requiring an average fuel economy improvement in the EU from 160g CO2/km in 2006 to 130g CO2/km as of 2012, which will be challenging, especially since no final decision has been taken yet (in early 2008). Even if technological solutions to this end are available, an implementing

[22] Not *every* weight based standard entirely eliminates the rationale for weight reduction as a means to improve fuel economy, hence the italics on "so much". The EC proposal seems carefully crafted to avoid falling into this trap. Nevertheless, manufacturers may switch to diesel engines (which are heavier than gasoline engines) to arrive at a laxer standard and improve fuel economy in the process. Such intensified dieselization is not necessarily ideal from a broader public health perspective (OECD/ITF, 2008b).

[23] See Anderson (2007) for an econometric analysis of the relation between light truck market shares and traffic fatalities.

[24] With a sufficiently homogenous fleet, cars can probably be lighter ánd smaller without increasing safety costs (Evans, 2004 and SMP, 2004).

period of 4 years or so is difficult and costly.[25] Delaying implementation in return for a tougher target (125g cO2/km by 2015) as proposed by the European Parliament seems a reasonable option in that sense although it has been argued that policy in the European Union towards achieving a fuel economy target of 130 g/km, or indeed 120 g/km, in 2012 has been clear for several years already.

3.3. The costs of improving fuel economy through standards

If improving fuel economy were costless would it not be achieved by the market unaided? Section 2 listed some reasons why vehicle markets don't necessarily spur optimal decisions on fuel economy, even if externalities are priced in accordance with policy objectives. A different issue is that of technology cost estimates. Debates on, and announcements of, regulation often generate a range of cost estimates, with those by regulated entities higher, those of beneficiaries' interest groups lower, and the regulator's in the middle. Ex post estimates tend to be below the ex ante estimates. For the case of the EC's proposed regulation, many think that cost estimates in the Commission's Impact Assessment (EU, 2007b) are on the high side, since they don't account for economies of scale, learning by doing, or consumers' response in terms of moving away from heavier cars.[26] The force of economies of scale in driving down costs tends be important in practice. In addition, strict standards are thought to contribute to technological leadership, which may favorably impact regional industry's comparative advantage in the anticipation of increased fuel economy requirements elsewhere. In this view, the costs to meet fuel economy requirements are seen as productive investments. But, even if the basic argument is accepted, there is little indication that they are the best possible investments.[27]

The Impact Assessment of the EC's proposed regulation (EU, 2007b) produces an average retail price increase of € 1 300 per vehicle. According to the same source, this cost increase is accompanied by average lifetime fuel cost savings to the consumer of € 2 200 to € 2 700 at fuel prices of € 1/l and € 1.20/l respectively, using a discount rate of 4%, a vehicle lifetime of 13 years, and an annual distance driven of 16 000 km. Vehicle attributes other than fuel economy are kept constant.

The calculation implies net savings, or an increase of consumer surplus, of around € 1 000, at a constant vehicle quality and a discount rate of 4%. In order to equalize costs and benefits, a discount rate of around 20% would need to be used[28], much higher than values for private discount rates. Consequently, the assessment suggests that on average the regulation produces consumer surplus gains instead of losses if consumers unless consumers use very high discount rates. 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

[25] If redesigned vehicles can use technologies that are ready for mass production, the lead time is 2 to 3 years. If not, 5 to 6 years preparation time is needed. Incorporating the technologies in the entire fleet takes even longer.

[26] Of course, this consumer response may entail a welfare loss.

[27] In addition, it is not clear in general why policy would be required for producers to take up profitable business opportunities (e.g. Palmer et al., 1995). But in this specific case the business case depends heavily on policy itself, so the argument for leadership is reasonable from a regional perspective, given sufficient confidence that other regions will ultimately adopt similar policies.

[28] Number taken from a March 12, 2008 email exchange with Richard Smokers, with permission.

deployments, e.g. boosting performance and/or comfort, may yield larger surplus gains.[29] 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 do point to the existence of 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.

Allowing for consumer responses in terms of vehicle choices and the amount of driving implies a downward adjustment of technology cost increases, as indicated by the TREMOVE simulations included in the EU Impact Assessment. Economies of scale and of learning may very well also lead to lower costs, as is suggested by theory and by experience with earlier regulations, but there is no reliable or widely available evidence to substantiate the possible size of these effects. One reason for this lack of hard evidence is strategic, as industry has obvious incentives not to divulge information they may have before the standard is introduced. Another reason lies in the limited understanding of the exact processes that drive economies of scale or learning effects.

3.4. Test cycles and on-road fuel economy

The goal of a standard is to control on-road fuel economy, to ultimately reduce fuel consumption. Standards are enforced at the level of new car sales, on the basis of fuel economy as measured on a standardised test driving cycle. Unfortunately, large discrepancies between current test results and on-road performance have been measured, usually in the direction of on-road performance being worse than the test cycle suggests. Test cycles can never match on-road behavior perfectly and a single test can not reflect the prevailing road and traffic environment for every single driver but some improvements to standard test cycles can be suggested. The US EPA applies a uniform reduction factor to the test results on fuel economy for light duty vehicles to provide consumers with figures for new vehicles that are much closer to fuel consumption typically achieved on the road.

There is the issue that manufacturers can tune vehicles to perform optimally in a test cycle, in the knowledge that on-road performance will be worse. To avoid this, one possibility is to work with a range of test cycles, e.g. highly congested urban, off-peak urban, interurban, rural etc., so reducing the possibility of optimizing on one or two cycles. For vehicle efficiency labeling in particular it is useful to provide figures for both urban and extra urban driving cycles, allowing consumers to choose the cycle that corresponds more to their normal usage.

Technologies have recently become available for measuring exhaust emissions in real time, with the potential to record violations of emissions limits under any driving conditions or modify the electronic engine management system when violations are recorded. This is being deployed to control NOx emissions but the technique could conceivably be used also

[29] The point here is that there seem to be imperfections in car purchase markets (and if Verboven's 1998 results are general, these imperfections are not related to discounting), not that the numbers justify the proposed stringency of the regulation. Evaluating the stringency also requires valuing the loss of public revenue due to the erosion of fuel consumption as a tax base, an issue of social relevance but ignored in consumers' decisions on fuel economy.

for CO_2 emissions (which are relatively easy to measure as they are directly determined by fuel consumption), allowing non-excedence limits to be set to all driving conditions. But how such limits would be enforced is another matter; the practicality of the approach is questionable.

A related concern is the difference in test cycles among regions and countries. Not only does this make comparison of fuel economy requirements difficult, it also may make the exploitation of economies of scale by global producers harder, although the high degree of differentiation by region of non-regulated specifications for models sold on several continents suggests such economies of scale may be exaggerated. At the same time such costs may be outweighed by benefits of regional standards that are tailored to regional conditions. For example, driving in congested cities in Europe may be sufficiently different from driving in congested cities in Japan or the US, that a uniform cycle implies a loss of precision for all three.

Modifying test cycles and achieving international harmonization takes time, and the current negations for a world-wide standard test cycle for light duty vehicles at the UNECE is expected to take over a decade. A harmonized test cycle therefore faces the difficult task of being fit to regulate technologies entering the market far into the future and needs to be suited to hybrid and electric vehicles if it is to be universal. This ultimately requires moving to a well-to-wheel measurement of CO_2 emissions.

Test cycles not only employ standardised driving patterns but also standardised vehicle configurations. The tests are run with all peripheral equipment, such as heating and cooling systems and electric motors for opening windows or driving windscreen wipers, turned off.[30] Some potential fuel economy enhancements are thus not reflected in test results and cannot be influenced by CO_2 emissions or fuel economy standards as currently formulated (e.g. improved air conditioners and high efficiency electrical systems). The use of low friction lubricating oils or low rolling resistance tyres does affect test results, but there is no guarantee they will be used in vehicles on the road. The potential savings from better lubricants, tyres, air conditioners, and electrical systems are not trivial and can amount to 5 or 10% of current average fuel consumption (OECD/ECMT /IEA 2005). Moreover, they tend to have low costs and in some cases are amenable to retrofitting. To incentivise uptake of these technologies specific incentives may be required because they are immune from conventional vehicle standards and because they are even more weakly affected by fuel or carbon taxes than vehicle purchase decisions (see section 2.3).

30 Beginning with model year 2008, the US Environmental Protection Agency uses five cycles to determine fuel economy for the Fuel Economy Guide. One of these tests has air-conditioning running. But the fuel economy used for CAFE compliance uses only two tests (city and highway), with air-conditioning off (http://www.epa.gov/fueleconomy/420f07066.htm).

4. BURDEN SHARING

Many multi-sectoral models, including the ones underlying Proost (2008), find that abatement costs in the transport sector are higher than those in other sectors such as power generation, some industries, and domestic heating and cooling. Consequently, *if* least-cost attainment of targets is desired, they suggest relatively modest efforts in transport, at least when abatement levels are in line with marginal damage estimates (see section 2.1 for a discussion of why this may not be the case). This argument can be challenged on at least two grounds.

First, as mentioned in section 3.3, the estimates of costs of technological improvements towards better energy efficiency in transport may be too high, as they are typically derived in a static framework that ignores economies of scale and learning. The question remains whether over-estimates are more frequent for transport than for other sectors. The argument that the costs of further improvements in transport are high appears reasonable in areas with a long history of high fuel tax levels in transport and not in other sectors. That such high taxes matter seems clear from a comparison of fuel economy levels in the EU and the US, although taxes are not the only explanation.

Second, even if technology costs are high in transport, this does not in itself imply that the economic costs are particularly high. This is because economic costs are not driven by resource costs alone in an economy characterized by multiple sources of inefficiency. One reason to think economic costs in transport are relatively low is that demand for it is relatively inelastic. Transport activities are tied to local production and consumption, so are not a mobile tax base. This is in contrast to some industries that may relocate in response to strict targets or higher taxes and the consequent increase in local costs (such relocation options are taken into account in the models used in Proost, 2008). It was noted that the profitability of some industries involved may be low or negative, implying limited or no losses of surplus from relocation. If one views the local loss of industrial activity as a cost (a view not universally accepted), then requiring larger efforts from transport may be justified.

A further question is how environmental and revenue raising concerns should affect the level of transport taxes. If transport really is a relatively non-distortionary tax base, then taxes exceeding marginal environmental damage are justified, because the economic costs of imposing an extra burden on it for environmental reasons are limited, at least if measures are chosen that generate public revenue. One specific reason why the costs of high transport taxes might be low in terms of efficiency would be that they fall mainly on non-labour activities, an attractive feature because labour tax distortions are already high. The empirical evidence on this issue is scant, but suggests that road transport taxes are more or less neutral with respect to labour supply, so do not exacerbate labour market distortions too much (West and Williams, 2007, find that transport and labour supply are slightly substitutable in some cases and independent in others). Aiming for taxes that reflect marginal external costs is a reasonable way forward from an efficiency point of view. Clearly, this is very different from requiring carbon taxes over and above current fuel taxes, a view that is difficult to defend on efficiency grounds. According to the bulk of the empirical evidence, improving transport charges does not necessarily mean focusing on CO_2 but instead on congestion, external accident costs, and local pollution. Such a policy likely entails sizeable CO_2 benefits, but it prioritises transport policy instead of energy policy (OECD/ITF, 2008b).

5. CONCLUSION

There is considerable consensus, but no unanimity, that pursuing climate change goals will require greenhouse gas abatement efforts in the transport sector, and that a combination of incentive-based instruments and regulation of fuel economy is appropriate. Agreement on just how much effort should be asked from transport, and consequently on the stringency of transport policy packages, is less wide. The case for substantial effort from transport relies to a considerable extent on assertions that technology costs for improving fuel economy are quite low and that market inefficiencies exist, particularly regarding consumer and producer decisions on fuel economy. These same arguments favor a policy package where regulation and incentive mechanisms complement each other. The case against particularly strong efforts in transport relies on assertions that cheaper abatement options exist in other sectors and also on the policy position that current measures already cover marginal external costs, making further efforts undesirable.

Against this background, one conclusion is that if there is a political decision to reduce greenhouse gas emissions from transport, this should be done by combining carbon or fuel taxes with standards. Taxes are preferred over grandfathered permits because they generate public revenue, although hybrid systems can mitigate the revenue loss from permits; if permits are auctioned rather than distributed for free, they also generate revenue, but their social and political appeal (compared to taxes combined with revenue redistribution schemes) is then weakened.

A second conclusion is that there is a need for more research. As such, this is a foregone conclusion, but some priorities can be defined. First, careful analysis of greenhouse gas abatement costs in transport and in other sectors is needed. While conceptually sound, the empirical underpinning of many of the arguments as to why costs are high or low is rather weak. Second, this paper argues that regulation of fuel economy is justified when there are imperfections in vehicle markets. Here too, the conceptual framework is convincing and there is evidence that there really are imperfections, but a clear quantitative understanding of the size of the inefficiencies (and consequently of the stringency of a regulation designed to correct them) is lacking.

It needs also to be recognized that policy is developed under uncertainty and with incomplete evidence. Policy needs to be underpinned by research into the likelihood and the costs of making errors. A policy imperative to achieve climate change mitigation implies giving a high weight to possible but unlikely catastrophic events. This in turn implies reducing the weight given to other transport and environment policy goals that have more certain, more immediate and potentially larger benefits, as in the case of reducing particulate emissions or congestion. Research in this area may help achieve balance in policy priorities.

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