Regulatory Measures to Reduce the Impact of Old Cars on Air Quality

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Abstract

From the perspective of economic efficiency there are obvious advantages of regional differentiation of regulatory measures instead of relying on nationally uniform regulation, which is due to the fact that adverse health impacts, as well as other negative externalities, such as environmental damage and congestion, vary between locations. One conclusion of the analysis is that ranking of economic instruments depends on whether regulation is imposed nationally or regionally. Another implication is that if road pricing is not possible to implement locally, then command and control need to be considered.

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Introduction

Road traffic is a significant source of emissions of hazardous substances. Air pollutants including particulates, nitrogen oxides and volatile organic compounds give rise to an increase in mortality, cancer and respiratory diseases. An extensive medical health study showed a clear connection between emissions from road traffic and lung cancer (Länsstyrelsen 2003a). Those who had lived in areas where the concentrations of nitrogen dioxide from road traffic exceeded annual averages of 30 micrograms per m\textsuperscript{3} in ambient air in Stockholm in 1955-1970, contracted lung cancer 50 percent more frequently than a control group, regardless of whether they smoked or not. At many locations with heavy traffic, measurements of ambient air show even higher levels. The levels that were found causing negative health impacts are not extreme. In Tallinn, for example, an annual average of nitrogen dioxide of 36 micrograms per m\textsuperscript{3} air was measured at Viru monitoring site in 2002.\textsuperscript{3}

A specific problem with air pollution originating from road traffic is that high concentrations of pollutants occur in city streets where human exposure is significant. To reduce the risks for human health, Sweden has introduced air quality standards in towns and cities (Ordinance 2001:527). However, the standard on nitrogen oxides, which will come into force in 2006 and that on particulates in 2005, will be difficult to achieve in Sweden’s two largest metropolitan areas: Stockholm and Gothenburg. Analyses have shown that road traffic is the major cause for not reaching the air quality standards (SLB- Analys 2002 and SLB- Analys 2003). A particular problem is that old cars, lacking a catalyst converter, still dominate emissions although their contribution to traffic performance is minor.

The Swedish air quality standards for particulates and nitrogen dioxide are based on European Union air quality directives, 1996/62/EC and 1999/30/EC. However, Sweden aims at reaching the standards earlier than stipulated by the EU limit values that are to be met by 2010. The new Swedish legislation has given municipalities far-reaching powers to curb pollution if the air quality standards are not met. Stockholm and Gothenburg have suggested various regional regulatory instruments to reduce the impact on air quality from traffic. Special attention has been given to the fact that emissions increase with the age of the car. One suggestion is to regionally increase the scrapping subsidy for cars lacking catalyst converters (Länsstyrelsen 2003b and Länsstyrelsen 2003c).

Different regulatory instruments can be used to reduce the impact on ambient air quality from road traffic. Command and control methods include bans on old cars, environmental zones and stricter requirements for car inspections. Among economic instruments, raising taxes and fees on old cars represent two options. Increasing scrapping subsidies offers an alternative to taxes. In both cases the owner is given economic incentives to get rid of the car. The question, however, is how to choose between different alternatives.

One of the aims of the current project is to study the efficiency of different regulatory measures, nationally and regionally. The method chosen for assessing efficiency has been to rank different regulatory measures by benchmarking their practical implementation against the expected adjustments of a first-best measure, “perfect” road pricing. Another aim has been to estimate the level of taxes that correspond to economic efficiency. In order to calculate the level of efficient taxes, the cost of emissions were estimated in two steps. First a computer-based model, the EMV-model\(^4\), was used to calculate the levels of exhaust emissions of road traffic. Then, to assess the external costs, emissions were valued according to the national cost benefit valuations, recommended by the Swedish Working Group for Cost-Benefit Calculations in the transport sector ASEK (see SIKA 2002).

The analysis of this paper was motivated by the recent changes in Swedish legislation, but since many cities in Europe and elsewhere struggle with air quality problems originating from road traffic, often times worse than those of Swedish cities, the issue is highly relevant for other cities as well. It is possible to generalise from the benchmarking analysis to other cities and countries. Although the estimated costs of externalities are country and city specific, the method we have used is applicable also to other cases.

2. Efficient Reduction of Air Pollution from Private Cars

In order to assess how well different regulatory instruments work, it is important to establish the goal, which they are to achieve. The study has stipulated that economic efficiency is the goal of regulating the negative health effects from private cars. Regulatory measures, which increase the outflow of old vehicles from the car fleet should, therefore, be analysed from this general aim. It is possible to also derive sub-goals of the general aim. Cost-effectiveness, for instance, is a necessary condition to achieve economic efficiency. One implication of cost-effectiveness is that the negative health impacts from road traffic should be reduced at lowest possible cost to society.

The negative health impacts from road traffic may be reduced in different ways, either by reducing total traffic performance, reallocating traffic in time and space or reducing the emissions from those vehicles that are in use. Introduction of regulatory measures, which reduce the age of the car fleet, is a way to reduce emissions from vehicles in use. In order to assess the cost-effectiveness we need to compare different regulatory instruments.

However, if considering economic efficiency, other aspects than health impacts need to be assessed. Measures that reduce the age of the car fleet may have other consequences, such as reducing environmental damage and improving traffic safety. Since all these impacts affect economic efficiency, all of them are of importance when assessing the economic efficiency of different regulatory measures.

2.1. Conditions for Economic Efficiency

An economically efficient transport system has to fulfil the following conditions:

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\(^4\) The EMV model is a regional and national calculation tool for energy consumption and regulated emissions from road traffic, developed by the Swedish National Road and Transport Research Institute, VTI.
1. Investments in new infrastructure, new technology and new vehicles are economically profitable (total benefits exceed total costs);
2. If there are several alternative investments to choose from, the most profitable alternative is chosen, implying that profitability is not a sufficient condition when there is more than one profitable alternative;
3. Traffic on existing infrastructure is priced correctly – the price of a trip should correspond to the social cost (i.e. private plus external cost) of the trip.

The first two conditions secure an efficient development of vehicles and infrastructure and the last one secures an efficient use of existing vehicles and infrastructure. The current study uses the last condition to assess different regulatory instruments.

2.2. Adjustments Following from Efficient Pricing

Road traffic brings about external costs of different kinds. By definition, the external costs are costs that are not fully considered by those who cause them. External costs arise from negative health impacts and the environmental damage of emissions, congestion costs, noise costs and increased risks of accidents. A person who considers driving by car to work pays attention to travel time and the risk of accidents that he exposes himself to, but most probably not to the congestion, emissions, noise and risks of accidents that his decision imposes on others. The fact that a car trip causes external costs implies that the price, i.e. the out-of-pocket cost paid by the driver, typically is below the social cost of the trip.

The higher the external costs, the higher is the deviation between the private and the social cost. Efficient pricing means that the price paid by the motorist corresponds to the social cost of the trip. This motivates charging higher prices for trips that impose larger external costs. Environmentally friendly vehicles should by this reasoning be priced lower than conventional vehicles. Pricing should by the same motivation reflect that external costs are higher in agglomerations than in the countryside.

It is technically possible to achieve efficient charging by imposing road pricing. The aim is to give the road users incentives to avoid choices that give rise to high external costs and to stimulate alternatives with low or no external costs. However, while road pricing is theoretically a very suitable instrument for dealing with the external costs of road traffic, the practical implementation can be a difficult challenge. The external costs of road traffic depend on many factors and vary with each specific situation. External costs vary both according to the characteristics of the vehicle and with the use of the vehicle (in space and time). Also, the human exposure to emissions varies between trips. Perfect pricing consequently implies that there is a unique price for each trip. In practice it is probably impossible to achieve perfect road pricing. The practical problems concerning the information requirements and other associated costs need to be considered when assessing whether to use one specific regulatory instrument or rather choose an alternative. In the case of perfect road pricing, transaction costs appear to be very high, implying that the costs of perfect road pricing may exceed benefits.

The method we apply for assessing different regulatory measures takes its starting point in two steps: (i) identifying what kind of consequences (e.g. road user behavioural adjustment) we expect from a perfect road pricing system, and (ii) analyse whether alternative regulatory instruments give rise to similar adjustments.
The method assumes benchmarking of economic measures against the expected adjustments of a first-best measure, “perfect” road pricing. In a ”first-best” world, information costs and other transaction costs are absent. In such a world, a perfect road pricing system is possible and costless to implement. Without transaction costs, however, alternative measures such as command and control instruments are equally efficient; the same behavioural effects can be achieved at no cost. From an efficiency point of view it is therefore not possible to compare alternative measures solely on the basis of first-best assumptions; instead we need to introduce real world assumptions of positive transaction costs. It implies that we in the analysis must take explicit account of the fact that all regulatory measures are flawed – in their practical application. Alternative measures can thus only be meaningfully compared by investigating their respective ability to economise on transaction costs relative to the first-best ideal, i.e. their ability to approximate the first-best solution while minimising the cost of implementation. It follows that simple command and control systems sometimes can be more efficient than sophisticated road pricing systems.

Perfect road pricing will create incentives that will lead to the following adjustments:

- Transfers from car use to alternative modes of transport;
- Reducing the number of kilometres of all remaining cars;
- Re-allocating the remaining car traffic in time and space;
- Substituting less environmentally friendly vehicles with more environmentally friendly vehicles;
- Increasing the scrapping of old vehicles;
- Encouraging more rapid technological development.

Transfers from car use to alternative modes of transport

Road pricing raises the cost of car trips, which makes driving less attractive in comparison to other modes of transport. A certain share of people will give up driving and choose other modes of transport for making trips.

Reducing the number of kilometres of all remaining cars

Perfect road pricing implies that charges depend on distance. Car drivers will, therefore, to a greater extent make shorter trips than otherwise.

Re-allocating the existing car traffic in time and space

Perfect prices will also be differentiated according to time and space. The purpose is to give road users incentives not to drive in places and at times when many people are exposed to exhaust emissions, e.g. during rush hours in densely populated areas.

Substitution between less and more environmentally friendly vehicles

Perfect road pricing takes into account the fact that old and new vehicles have different emissions. The charges imposed on old more polluting vehicles will therefore be higher than those imposed on new vehicles. On average, the total price of owning and driving a car will most likely increase.

The net impact on new car sales is ambiguous since there are two forces pulling in opposite direction. First, since the average cost of owning/driving a car increases, car sales in general will decrease. We refer to this as the “income effect”. Second, since the charges will be differentiated, some of those who own older cars will either buy a newer car or shift to alternative modes. We refer to this as the “substitution effect”. The total impact on new car sales cannot be specified in advance since the two effects are opposite. However, what is known for sure is that there will be a substitution from old polluting cars to new and more environmentally friendly cars (and to
alternative modes of transport). It is also possible to distinguish the effect on sales of old cars. For old cars, the income and substitution effects work in the same direction; as the demand for old cars decreases and the market prices go down, more people will find it worthwhile to scrap the car rather than selling it in the market.

**More rapid technological development**

Higher charges for cars with inferior environmental characteristics (related either to the vehicle or the fuel) will increase the demand for cars with better environmental characteristics. Both the car industry and the fuel industry will thus be given incentives to develop and produce more environmentally friendly alternatives.

### 3. Assessment of Economic Instruments

In the previous section we discussed the expected behavioural adjustments resulting from perfect road pricing. In this section we will use these adjustments to benchmark how well different regulatory measures, road pricing included, perform from an efficiency perspective in their practical implementation. The purpose is to benchmark the performance from an environmental perspective. Table 1 shows a summary of the performance of four different economic instruments. The economic instruments are:

- Environmentally differentiated road pricing
- Environmentally differentiated fuel taxes;
- Environmentally differentiated vehicle taxes;
- Environmentally differentiated scrapping subsidies.

**Table 1. Comparison between Different Environmentally Differentiated Economic Instruments**

<table>
<thead>
<tr>
<th>Regulatory instrument</th>
<th>Environmentally differentiated road pricing</th>
<th>Environmentally differentiated fuel taxes</th>
<th>Environmentally differentiated vehicle taxes</th>
<th>Environmentally differentiated scrapping subsidies</th>
</tr>
</thead>
<tbody>
<tr>
<td>Transfer to alternative modes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Partly</td>
</tr>
<tr>
<td>Fewer kilometres</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Trip re-allocation in time and space</td>
<td>Yes</td>
<td>Partly</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Vehicle substitution</td>
<td>Yes</td>
<td>Partly</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Increased scrapping</td>
<td>Yes</td>
<td>Partly</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Technological development</td>
<td>Partly</td>
<td>Partly</td>
<td>Partly</td>
<td>No</td>
</tr>
</tbody>
</table>

The table gives a simplified picture of the pros and cons of different regulatory instruments. A “Yes” implies that it is possible to design the instrument to optimally achieve the desired adjustment. Achieving the exact adjustments as those of a “first-best” solution is very difficult, perhaps impossible, no matter the instrument considered. It is, however, possible to approximate these adjustments. Above we present a very simplified picture, where “optimal” can be translated to “best possible approximation taking into account the problems of imperfect information and positive transactions costs”. “Partly” indicates it is possible to reach some of the desired adjustment or reach
the adjustment in a suboptimal way. “No” means no attainment of the desired adjustment.

Besides benchmarking the different regulatory measures, the table illustrates how it is possible to combine different measures in order to approximate the effects of perfect pricing. Environmentally differentiated fuel taxes combined with differentiated vehicle taxes will, for instance, be a potential alternative to road pricing. However, only road pricing has the ability to give rise to efficient trip re-allocation in time and space.

3.1. Environmentally Differentiated Fuel Taxes

General increases in fuel taxes give car owners incentives to shift to alternative modes of transport. Implementation of environmentally differentiated taxes implies that the owners of the oldest cars, i.e. cars that use the least environmental friendly fuels, will be given the highest incentives to adapt their behaviour, by shifting either to newer cars or to alternative modes (note, however, that cars of different ages often use the same type of fuel). Increased fuel taxes will also give remaining car owners incentives to reduce distance driven. With the right design of the system, the effects could be similar to those of road pricing.

By imposing higher and differentiated fuel taxes certain re-allocation in time and space may also be possible since fuel consumption is higher when there is congestion. But, the trip re-allocation will be non-optimal, since congestion is not regulated directly, as is the case with (perfect) road pricing. It is also possible to reach a certain degree of substitution of vehicles when taxes are differentiated according to the environmental impact of the fuel. The problem is that the taxes can be differentiated only according to the characteristics of the fuels, not those of the vehicles. The desired effects regarding vehicle substitution and scrapping (which relate to the characteristics of both fuels and vehicles) can thus only partially be achieved.

One advantage of differentiating the fuel taxes according to the environmental characteristics of the fuels is the incentives it gives to development of new and improved fuels. The impact, however, will not be as extensive as in the case of environmentally differentiated road pricing, since the latter gives incentives to the development of both better fuels and better vehicles.

3.2. Environmentally Differentiated Vehicle Taxes

Higher vehicle taxes give car owners incentives to shift to alternative modes of transport. By differentiating the taxes according to vehicle characteristics, which is possible to solve technically by tying the differentiation of the tax to the age or to the environmental classification, incentives to efficient substitution between different types of vehicles are also created as are incentives to efficient increases in scrapping rates of old cars. The disadvantage is that the differentiation of vehicle taxes will neither reduce the number of kilo metres of remaining vehicles, nor will it re-allocate trips in time and space.

3.3. Environmentally Differentiated Scrapping Subsidies

An important difference between vehicle taxes and scrapping subsidies, from the perspective of efficient pricing, is that scrapping subsidies do not reduce the demand for cars. Both fuel taxes and scrapping subsidies will increase scrapping of old cars.
However, only fuel taxes can accomplish an efficient reduction in the demand for vehicles. Another difference is that it is more difficult to use scrapping subsidies with the purpose of creating incentives for substitution between old and new cars. Scrapping subsidies have their main effect on old cars, which are close to their technical lifetime.

4. Vehicle Taxation according to Environmental Externalities

In this section we analyse the possibilities to and consequences of creating a system of vehicle taxation that is differentiated according to the principles of economic efficiency. The aim is to create a system of vehicle taxation that leads to the adjustments shown in Table 1. In order to achieve these adjustments, the taxes should, according to economic theory, correspond to the social costs of environmental damage. In order to determine these tax levels, it is necessary to estimate the external costs and to assess to what extent road users already pay for the externalities by existing taxes or charges. A plausible assumption is that existing fuel taxes are set to coincide with the external costs of greenhouse gases, i.e. carbon dioxides.

One of the agencies of the Swedish Government, the Swedish Institute for Transport and Communications Analysis (SIKA), is responsible for publishing recommendations and reviews of national parameter values to be used in cost-benefit calculations in the transport sector. Table 2 below shows the current valuations of hydrocarbons, nitrogen oxides, particulates and carbon dioxides, each of them valued in SEK per emitted kilogram\(^5\). The valuations are specified by their local impact with respect to population and ventilation. The regional parameter values refer to global and regional impact of pollutants.

The local costs of hydrocarbons (HC) and nitrogen oxides (NO\(_x\)) reflect the estimated value of health impacts. Besides health impacts, the estimate of particulates also includes the dirt effect of particulate emissions. The health impacts have been derived using epidemiological dose-response functions, which estimate the risk of catching respiratory diseases (SIKA, 2002). The regional valuations have been derived indirectly according to costs of complying with political goals (ibid).

The social costs of emissions from road traffic vary to a great extent depending on human exposure at the location of emissions. The local costs of hydrocarbons, nitrogen oxides and particulates are therefore approximately 10 times higher in Stockholm than in Laholm, which reflects the variation in population and density in these cities. The total valuations, which are given by the local plus the regional estimates do not vary as much as the local ones, but the variation is still significant.

<table>
<thead>
<tr>
<th>Table 2. Local and Regional Costs of Pollutants</th>
</tr>
</thead>
<tbody>
<tr>
<td>Population*</td>
</tr>
<tr>
<td>Local values:</td>
</tr>
<tr>
<td>Sthlm inner city</td>
</tr>
<tr>
<td>Uppsala</td>
</tr>
<tr>
<td>Falun</td>
</tr>
<tr>
<td>Södertälje</td>
</tr>
<tr>
<td>Laholm</td>
</tr>
</tbody>
</table>

\(^5\) 1 EUR=9.1 SEK, annual average of 2004, Bank of Sweden.
The costs shown in Table 2 will be used for determining the efficient level of vehicle taxes. A crucial difference between vehicle taxes and road pricing is that vehicle taxes are charged annually and that they do not depend on the distance. In theory, it is possible to charge every vehicle according to mileage of the previous year. However, in the following we will assume that vehicle taxes are differentiated between vehicles, not according to the driving habits of the owners.

The EMV-model was applied in order to find the total annual mileage and emissions of private cars by different environmental classes. The emissions were then valued according to the national parameter values for cost benefit calculations. The results are presented in Table 3 below. The table shows both per kilometre cost and the total annual cost of different environmental classes of petrol vehicles.

### Table 3. Annual Environmental Costs of Petrol Cars of Various Environmental Classes (Jan 1st 2002)

<table>
<thead>
<tr>
<th>Environmental class</th>
<th>Number of vehicles</th>
<th>Km/car per year</th>
<th>Tot SEK/km</th>
<th>CO₂ SEK/km</th>
<th>Tot SEK/car/year</th>
<th>CO₂ SEK/car/year</th>
<th>SEK/car excl CO₂/year</th>
</tr>
</thead>
<tbody>
<tr>
<td>2005</td>
<td>149 024</td>
<td>21 070</td>
<td>0.27</td>
<td>0.25</td>
<td>5 683</td>
<td>5 315</td>
<td>368</td>
</tr>
<tr>
<td>2000</td>
<td>84 543</td>
<td>21 882</td>
<td>0.28</td>
<td>0.25</td>
<td>6 048</td>
<td>5 553</td>
<td>495</td>
</tr>
<tr>
<td>MK1</td>
<td>84 339</td>
<td>15 770</td>
<td>0.30</td>
<td>0.27</td>
<td>4 785</td>
<td>4 197</td>
<td>587</td>
</tr>
<tr>
<td>MK2</td>
<td>1 173</td>
<td>16 919</td>
<td>0.31</td>
<td>0.27</td>
<td>5 281</td>
<td>4 519</td>
<td>762</td>
</tr>
<tr>
<td>MK3</td>
<td>356 953</td>
<td>14 652</td>
<td>0.36</td>
<td>0.29</td>
<td>5 322</td>
<td>4 177</td>
<td>1 145</td>
</tr>
<tr>
<td>A12</td>
<td>741 746</td>
<td>12 012</td>
<td>0.38</td>
<td>0.28</td>
<td>4 570</td>
<td>3 416</td>
<td>1 154</td>
</tr>
<tr>
<td>A11</td>
<td>359 946</td>
<td>10 807</td>
<td>0.56</td>
<td>0.28</td>
<td>6 052</td>
<td>3 026</td>
<td>3 026</td>
</tr>
<tr>
<td>A10</td>
<td>577 448</td>
<td>9 819</td>
<td>0.74</td>
<td>0.29</td>
<td>7 230</td>
<td>2 870</td>
<td>4 359</td>
</tr>
<tr>
<td>Older</td>
<td>306 961</td>
<td>9 219</td>
<td>0.75</td>
<td>0.30</td>
<td>6 954</td>
<td>2 795</td>
<td>4 159</td>
</tr>
</tbody>
</table>

*Note: New cars were sold in Sweden in 2004 must at least be of environmental class 2000. Better cars, which fulfil the requirements, and which will become obligatory in the EU in January 2006, are classified as 2005.*

The number of vehicles refers to January 1st 2002 and shows only the number of petrol cars. The costs of carbon dioxide emissions (CO₂) make up an important share of the total emission costs, especially for new cars. One reason is the larger average mileage of new cars. Another reason is that other emissions than CO₂ have been successfully reduced due to technological development. The total annual environmental cost of a car varies between SEK 7,000 and 4,500. Excluding the costs of CO₂ emissions, which we assume already are “internalised” by current fuel taxes, an average car contributes to external costs by SEK 400-4,400 annually. The estimated external costs...
cost of a car that lacks a catalyst converter (A10 or older) is about SEK 4,000. Because emission costs mainly differ according to other pollutants than CO₂, which has no direct health effect, the difference between new and old cars is considerable from a health perspective. The health cost of an old car is thus about 10 times higher than that of a new car.

The estimates in Table 3 relate to national averages supposing that the median valuation of Falun can be attributed to the emissions in average agglomerations. According to the EMV-model, the average transport performance in agglomerations is 36 percent of total annual mileage. If the valuations of Stockholm inner city are applied to these average driving habits, the emission cost (excluding CO₂) approximately doubles. However, for cars lacking catalytic converters the difference is somewhat less dramatic. The annual cost for a non-catalyst car with 36 percent of mileage in Stockholm inner city will be approximately SEK 6,500. By applying the valuations of Laholm, the annual cost is reduced to SEK 3,400.

By relating the environmental classes to the age of the car it is possible to use the information in Table 3 to derive the environmental cost by age (see Appendix 1 for information about the correlation between model years and environmental classes). Figure 1 shows the total environmental costs and the costs excluding CO₂ by the average age of the car. If a vehicle tax is used for internalising the environmental externalities, then the tax reduction an individual receives when shifting cars should at least be equivalent to the environmental benefit from the change. An individual who changes from a twenty year old A10-class to a new 2005-class car should thus receive a tax reduction corresponding to the environmental benefit from this change. If we disregard emissions of carbon dioxides, the value of the average annual environmental benefit for society is almost SEK 4,000.

The expected adjustment that is possible to achieve by the tax or another economic instrument is, in principle, achievable with command and control measures. However, only economic instruments assure cost-effectiveness. The following example illustrates how economic instruments assure cost-effectiveness: Suppose the annual vehicle tax on old cars lacking a catalyst converter is increased by SEK 4,000. Such a tax increase will create incentives for the owners of these cars to consider other alternatives such as buying a new car or shifting to a different mode of transport. Choosing either of these alternatives implies that the SEK 4,000 tax is avoided. Those individuals who value the sacrifice of choosing one of these alternatives at less than SEK 4,000 will get rid of their old car, whereas those who value the sacrifice at more than 4,000 SEK will pay the tax and keep the car. The reason why it is not cost-effective to persuade someone whose cost of sacrifice exceeds SEK 4,000 to get rid of the car, is that the benefits to society of reducing pollution from one car lacking a catalyst converter amounts to approximately SEK 4,000, as was shown in Table 3. In case the costs of regulation exceed the benefits, there will be a waste of resources.
5. Regional Differentiation of Regulatory Measures

By charging prices or taxes that correspond to the cost of externalities, road users are given incentives to consider the total costs of their trip. The higher the external costs, the higher should the charges be in order to make the external cost internal. This is the reason why the oldest vehicles, lacking catalytic converters, should pay the highest taxes. By the same logic there are efficiency reasons to differentiate taxes between different areas implying that road users who drive in agglomerations pay more than those who drive in sparsely populated areas. The aim is to give road users incentives to avoid choices that lead to high social costs and promoting choices, which have low or no external costs.

Four different economic measures were assessed in Table 1: road pricing, fuel taxes, vehicle taxes and scrapping subsidies. The adjustments of a perfect road pricing system were used for benchmarking each one of these measures. The conclusion was that it is possible to attain all adjustments of efficiency, except efficient trip re-allocations in time and space, when implementing a system that combines fuel taxes, vehicle taxes and scrapping subsidies, differentiated according to the environmental characteristics of fuels and vehicles. The possibility of a regionally differentiated system was, however, not considered. Below we discuss the theoretical as well as practical requirements for regional differentiation. The first step is to specify the desired impacts of an efficient regional differentiation.

5.1. Desired Regional Impacts

The health impacts and other external costs of road traffic are significantly higher in agglomerations than in the countryside. A perfect pricing system thus implies that the cost of driving should be higher in densely populated areas than in sparsely populated areas. The purpose is to create incentives for road users to make adjustments that lead to a reduction in the total health impacts and other external costs, by taking into account these regional differences. Since health impacts vary depending on the number of
people exposed, the reduction in these impacts could be achieved through a geographic re-allocation of traffic and distribution of old and new cars rather than through a reduction in traffic. There are several alternative ways to achieve the desired regional adjustments. However, before discussing them, we will define more precisely what the desired adjustments of an optimal regionally differentiated road pricing system are:

- the transfer from cars to alternative modes is larger in agglomerations than in the countryside;
- the replacement of old cars for new cars is larger in agglomerations than in the countryside;
- earlier scrapping of old cars take place in agglomerations than in the countryside;
- traffic is re-allocated from agglomerations to the countryside, which may imply that car drivers choose to make trips in areas where human exposure is low;
- regional re-location of the car fleet, denoting an outflow of less environmentally friendly vehicles from agglomerations and an inflow of environmentally friendly vehicles to agglomerations.

For discussing regional differentiation we use the expressions 'agglomeration' and 'countryside'. A large city and a small town or some other examples for denoting areas differing with respect to the size of population and population density can equally well replace the terminology in use here.

**Regionally differentiated road pricing**

Road pricing that is differentiated according to the external costs of pollutants is by definition differentiated by geography. The plan to introduce congestion pricing for a trial period in Stockholm aims at charging higher prices at times and places when congestion and emission costs are the highest – on roads to and within Stockholm inner city during rush-hours. The major advantage, from the perspective of efficient pricing, is the opportunity to differentiate charges locally. Earlier we referred to the difficulties to introduce road pricing nationally, which among other things depends on the need to collect extensive information about the external costs of various places for various times. The information requirement is much lower when considering road pricing for a city. However, although the need for information is much smaller at the city level, it is still unusual that cities have put road pricing into practice. There may be several reasons for this. The low acceptance of road pricing has been put forward by Jones (1995) as one major reason for the difficulties of implementation. Different aspects of road pricing acceptance have been further elaborated, for instance, by Forslund and Johansson (1999) and Hårsman et al. (2000).

**Fuel taxes**

Regional differentiation of fuel taxes implies two things: a higher average fuel tax in the agglomeration than in the countryside and a larger price difference between fuel qualities in agglomerations than in the countryside. In principle this implies that the greater the population density, the higher is the price and the larger is the differentiation. Assuming there are no practical problems related to regional differentiation of fuel taxes implies higher and more differentiated fuel prices for people who refuel their cars in agglomerations. Since people who refuel their cars in agglomerations typically drive
there, a system like this could work, at least in theory, by resulting in the regional impacts described above.

However, practical problems can arise when implementing regional differentiation of fuel taxes. One major problem is the unwanted side-effects that may occur if the system is put into practice. It would be difficult to prevent people who normally drive in agglomerations to refuel their cars in the countryside. For those who live in agglomerations there are extra costs associated with refuelling their cars in the countryside, but if the price difference is large enough, it will be profitable to drive extra miles to refuel the car in the countryside.

One would expect that a certain degree of differentiation is practically possible and theoretically defensible, but if the price difference is too large the side-effects may become counter-productive. If the costs outweigh the benefits, the adjustment will result in almost unchanged traffic in the agglomeration and an increasing total trip length because of the long trips to filling stations in the countryside.

**Vehicle taxes**

Regional differentiation of vehicle taxes should be designed with respect to human exposure and the characteristics (i.e. age) of the car, since these two factors affect the health impacts. A regionally differentiated vehicle tax system implies higher taxes and a greater degree of differentiation in agglomerations than in the countryside. The taxes would be particularly high for people living in large agglomerations and driving old cars with low environmental performance.

As with fuel taxes there are practical problems with the regional differential of vehicle taxes due to unwanted side-effects. Since the burden of an extra high vehicle tax is due to the fact that the owner lives in a large agglomeration, it will create incentives to avoid the costs. The main challenge with regionally differentiated vehicle taxes is to prevent car owners living in agglomerations to register their car on a relative’s or friend’s address in the countryside. However, there are also measures to restrict such unwanted activities. One simple way to prevent people in the countryside from registering several cars in their name on their residential address is to charge a higher vehicle tax on a household’s second car than on the first, and a higher tax on the third car than on the second. The negative side-effects from a regionally differentiated vehicle tax appear to be easier to prevent than those of a regionally differentiated fuel tax.

One advantage of regionally differentiated fuel taxes and vehicle taxes is that the differentiation creates incentives for a regional re-allocation of the car fleet, implying that the least environmentally friendly vehicles, which run on the lowest fuel qualities, will be re-located to regions where emissions are less harmful. A regionally differentiated scrapping subsidy will not have the same impacts.

**Scraping subsidy**

Differentiating scraping subsidies by considering regional variations in the social costs of the vehicles implies that subsidies for retiring old cars will vary regionally. Since new cars are not scrapped, unless they are demolished by road accidents or because of robbery, there is no reason to differentiate scraping subsidies for new cars. The regional differentiation will, therefore, imply higher scraping subsidies for those who live in agglomerations and own cars with low environmental performance, compared with those owning a similar car but live in the countryside.
If assuming away the negative side-effects, the regionally differentiated scrapping subsidies will result in some of the desired impacts that were described initially. The rate of vehicle retirement would be faster in agglomerations than in the countryside. In addition, substitution of old cars for new cars would be larger in agglomerations than in the countryside. However, one drawback is that there will not be any regional re-location of the remaining vehicles, i.e. no outflow of cars with a low environmental performance from agglomerations and no inflow of environmentally friendly vehicles to agglomerations.

In addition, there are negative side-effects from regionally differentiated scrapping subsidies. There is a risk that old cars will be transferred from the countryside to new owners in the agglomerations in order to receive a higher subsidy. One way of avoiding this, however, is to require a qualifying period of ownership before being entitled to a higher scrapping subsidy.

6. Regional Differentiation vs. National Measures

The health impacts from road traffic depend primarily on human exposure, which calls for regional and local policy measures. Theoretically, there are obvious advantages of regional differentiation rather than designing national measures, because of adverse health impacts, as well as other negative externalities. Comparing regional differentiation to national measures makes it important to highlight two issues: The first issue is that negative side-effects may occur as a result of regional differentiation. The second issue is that the optimal mix of regulatory instruments may differ when considering the regional instead of the national level.

In the above analysis, we identified negative side-effects as a result of all regionally differentiated economic instruments, except road pricing. At a general level, these side-effects imply a lower degree of differentiation. Less differentiation will also reduce the negative impacts on income distribution – this could be an important issue since individuals living in agglomerations would be more affected than those who live in the countryside. However, the drawback of adjusting the regional differentiation is that it reduces the impact of pollution management.

The recommendation, when regional differentiation is considered, is to implement road pricing because of the efficiency advantages. This is in contrast to the recommendation at the national level, where the costs of collecting information about local variations in negative externalities appear to be too high to motivate the benefits of a system of environmentally differentiated road pricing in the entire nation. At the national level, the analysis supports a combination of environmentally differentiated fuel taxes and vehicle taxes, as the first choice. The second best choice is to implement either fuel taxes or vehicle taxes. The second best choice for regional differentiation is a combination of regionally differentiated fuel and vehicle taxes. The third best choice is scrapping subsidies.

The above analysis benchmarked only economic instruments. However, if road pricing is not a feasible option at the local and regional level, the drawbacks because of the negative side-effects motivate further investigation. A comparison of economic instruments to command and control measures such as bans on old cars and environmental zones should be carried out in order to evaluate the performance of other regional alternatives. At the national level, however, economic instruments are recommended because of reasons of cost-effectiveness.
The extra cost of command and control is smaller when imposing it in a restricted area, because it reduces the number of people who are affected. Also, if a ban to drive in the city centre is introduced on cars lacking catalyst converters, those owning such cars may still use their cars for other trips, thus limiting the cost of sacrifice. Since health costs vary to a large extent, the benefit of reducing pollution at the most negatively affected locations, e.g. in downtown areas of high-density cities, may exceed the cost of sacrifice even for the individual with the highest cost of sacrifice. If this is the case, it is efficient to eliminate all traffic from this area. It implies that self-selecting mechanism of economic instruments is irrelevant and that economic instruments have no more advantages over command and control measures. In this case a ban is the appropriate choice – it leads to the right effects and is easier and less costly to implement.

Conclusions

In this paper we have analysed the efficiency of practical implementation of different regulatory instruments, which reduce the impact of old cars on air quality. From the perspective of economic efficiency there are obvious advantages of regional differentiation of regulatory instruments instead of relying on nationally uniform regulation, because adverse health impacts, as well as other negative externalities, to a large extent vary between regions.

Another aim of the paper was to estimate the level of vehicle taxes that correspond to economic efficiency. According to the estimates we have made, based on the case of Sweden, there are large differences in emission costs between vehicles of different environmental classes. Because emission costs mainly differ according to other pollutants than CO\textsubscript{2}, which has no direct health impact, the difference between new and old cars is considerable from a health perspective. If disregarding emissions of CO\textsubscript{2}, the annual environmental cost of an average car varies between SEK 400 and 4,400. The health cost of an old car is thus about 10 times higher than that of a new car. The estimated external cost of an average car lacking a catalyst converter is about SEK 4,000 annually. However, depending on the size of the agglomeration, the cost of an average car lacking a catalyst converter may vary between SEK 3,400 and 6,500.

One important conclusion from the benchmarking analysis is that the ranks of economic instruments differ if regulation is designed as nationally uniform instead of regionally differentiated. The recommendation, when regional differentiation is considered, is to implement road pricing because of the efficiency advantages. This is in contrast with the recommendation for choosing efficient regulation at the national level as the costs of information about the local variations in negative externalities appear to be too high to motivate the benefits of a system of national road pricing. At the national level, the analysis supports a combination of environmentally differentiated fuel and vehicle taxes, as the first choice. The second best choice is to implement either fuel taxes or vehicle taxes which are differentiated according to their environmental impact.

The second best choice for regional differentiation is a combination of regionally differentiated fuel and vehicle taxes. Among those regulatory instruments that were ranked at the regional level, scrapping subsidies is the last choice.

However, there are some important drawbacks of regional differentiation of taxes and subsidies that cannot be neglected. Regional differentiation of taxes and subsidies produce negative side-effects, which reduce the steering impact of pollution management. If the negative side-effects outweigh the benefits and if road pricing is not
possible to implement, command and control measures should be considered. The difference from an efficiency perspective between economic instruments and command and control measures are smaller when regulation is implemented in a limited area. On the one hand, the extra cost of command and control is smaller when imposed in a restricted area, because it reduces the number of people who are affected. Neither is the consequence as drastic as that of national command and control. If a ban to drive in the city centre is introduced on cars lacking catalyst converters, the motorists may still use their cars for other trips, thus limiting the cost of sacrifice. In addition, since health costs vary to a large extent, the benefit of reducing pollution at the most negatively affected locations may exceed the cost of sacrifice even for the individuals who have high costs of sacrifice. Also, the lower cost of implementation supports the use of command and control measures in limited areas that are affected by heavy pollution from traffic.

References


Hårsman, Björn Sirje Pädam and Bo Wijkmark 2000. Ways and Means to Increase the Acceptance of Urban Road Pricing, Final report of the PRIMA project. Research Project for the Commission of the European Communities, DG TREN.


SLB-Analys 2002. Beskrivning av problembildens för halterna av käveoxid i Stockholms län i förhållande till miljökvalitetsnormerna. (Description of the problems of high levels of nitrogen oxides in Stockholm County in relation to air quality standards).
Environmental classes regulate the level of emissions of CO, NO\textsubscript{X} and HC (also particulates for diesel cars) by denoting standards of g/km of exhaust emissions. Cars of environmental Class 2005 comply with European Union standards obligatory from 2006 (Euro IV) and environmental Class 2000 denotes the minimum requirements for cars from model year 2000, see table A2.

In 1993 environmental classes (MK1, MK2 and MK3) were introduced in Sweden. MK3 denoted the minimum requirements and the environmental classes MK2 and MK1 referred to more stringent standards that had been introduced in the US and California, respectively. When Sweden became a member of the European Union in 1995 the levels of MK3 and MK2 were adjusted to match EU standards. Catalyst converters became obligatory from model year 1989, but it was possible to buy cars with catalyst converters already from model year 1987. The first generation of cars with catalyst converters are denoted by environmental class A11 and the second generation by A12. All cars of classes A10 or earlier lack catalyst converters.

### Table A1  Environmental Class, Model Year and Age, January 1\textsuperscript{st} in 2003

<table>
<thead>
<tr>
<th>Environmental class</th>
<th>Model year</th>
<th>Age on Jan 1st 2003</th>
</tr>
</thead>
<tbody>
<tr>
<td>A11</td>
<td>1987, 1988</td>
<td>15-16</td>
</tr>
<tr>
<td>Older classes</td>
<td>-1983</td>
<td>20+</td>
</tr>
</tbody>
</table>

Environmental classes regulate the level of emissions of CO, NO\textsubscript{X} and HC (also particulates for diesel cars) by denoting standards of g/km of exhaust emissions. Cars of environmental Class 2005 comply with European Union standards obligatory from 2006 (Euro IV) and environmental Class 2000 denotes the minimum requirements for cars from model year 2000, see table A2.

### Table A2  Emission Standards of Environmental Classes of Petrol Cars (g/km)

<table>
<thead>
<tr>
<th>Environmental class 2000</th>
<th>Environmental class 2005</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carbon oxides (CO)</td>
<td>2.3</td>
</tr>
<tr>
<td>Hydro carbons (HC)</td>
<td>0.20</td>
</tr>
<tr>
<td>Nitrogen oxides (NO\textsubscript{X})</td>
<td>0.15</td>
</tr>
</tbody>
</table>

Source: The Swedish Environmental Protection Agency