# Climate change, urban air problems and transport policy in the European Union *

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This paper surveys some recent studies on conventional air pollution and climate change in the transport sector in Europe. Fuel efficiency standards, car emission standards and transport pricing instruments are analysed from an economic perspective taking into account environmental and economic efficiency objectives.

**Keywords:** transport, air pollution, greenhouse gasses, externalities, fuel efficiency of cars, cost-effectiveness

## 1. Introduction

The high growth of $CO_2$ emissions that is expected in the transport sector makes it one of the priorities in most climate change policies. The transport sector also contributes to several other air pollution problems as well as to other negative externalities such as congestion and traffic accidents. The EU member countries and the EU Commission have recognised this and have initiated policies to address each of these problems. At the EU level, there is a political agreement on a fuel efficiency standard for cars, more stringent emission limits are being imposed for traditional air pollutants of cars and one has agreed on the principle of pricing transport according to its social marginal costs. Some member countries are considering complementary actions to reduce air pollution ranging from lower prices for public transportation to subsidies for cleaner cars.

The goal of this paper is to survey recent developments in the field of air pollution of cars in the European Union with an emphasis on the policy initiatives at the Union level rather than at the member state level.[1] We take an economic approach. The main question addressed is: what are the policy options that are most effective to reach the different policy goals and how do they rank in terms of costs? Obviously, clear-cut policy conclusions cannot always be reached but one should at least agree on a methodology to rank alternative policy options. We will show that most differences in policy conclusions have more to do with differences in methodology than with differences in assumptions and in data. Defining a correct methodology for cost comparisons, therefore, serves as a secondary objective of this paper.

We start with a brief review of the different problems in the transport sector and the policy initiatives that have been taken at the EU level. Next we survey some of the policy studies that have been undertaken in this domain. The literature on this topic is still limited but growing. We have chosen to regroup the different contributions into four approaches. These range from an environmental effectiveness study, over a cost-effectiveness analysis for one policy instrument, to a cost-effectivenss analysis with different policy instruments in the transport sector and in other sectors up to a transport policy optimisation with environmental side-benefits. We conclude with policy suggestions.

## 2. Problem statement and current policy proposals

We deal with three types of problems: climate change, urban air quality and road congestion. For these problems, local governments, member states and the European Commission share the policy responsibility. The two most commonly used instruments, minimum vehicle emission standards and minimum fuel taxes, are decided upon at the EU level because of market integration constraints. Here the European Commission proposes policies that have to be approved by the member states and by the European Parliament. We will concentrate our review on the discussions at the European level.

### *2.1. Contribution of the transport sector to climate change*

The transport sector represents in the EU some 25% of all $CO_2$ emissions. In this figure the international traffic in and out of the EU is not included. The majority of the emissions (85%) comes from the use of fossil fuels for road transport (cars and trucks). These carbon emissions have been growing at a higher speed than GDP. The European Commission has proposed in its communication

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[1] Those who are interested in a methodological survey of the field of transport and environment can consult [1] and [2] for a general introduction and [3] for a survey of future trends.

on transport and $CO_2$ [4] a wide set of measures to curb the growth of $CO_2$ emissions. Almost all measures proposed are also partly justified by transport considerations. We survey briefly the measures for passengers and freight transport followed by the proposals for the air transport and waterway sector.

For passenger transport, one counts mainly on two measures: one affecting the volume of car use and the other affecting the fuel use (and $CO_2$ emissions) per vehicle-kilometre. According to the EU policy paper, the volume of car use could be reduced by 11% when car use is correctly priced. This will require a modal shift. The second principal measure are more fuel efficient cars. This measure has been accepted by the European federation of car manufacturers (ACEA). The agreement between the Commission and ACEA foresees that the average emission of new cars would decrease from the market average of 186 g/vehicle km in 1995 to 140 g/vehicle km in 2008. The European Commission is considering complementing this measure with fuel efficiency information to consumers and an increase in fuel taxation and another vehicle tax related incentive. Other local measures (promotion of cycling, speed limits, etc.) can each add a few percentages of emission reduction to these measures.

According to the Commission document, improved road freight logistics could reduce the empty truck kilometres. Other important factors are improved land use planning and the development of efficient railfreight, inland waterways and coastal shipping to reduce the energy intensive road freight volume.

For air transport and $CO_2$ a communication has been announced. This mode of transport has the highest growth rate. Measures could include a tax on kerosene and fuel efficiency standards.

### *2.2. Urban air problems*

The transport sector has up to now been the most important source of emission for conventional pollutants (CO, VOC, $NO_2$, PM) in urban areas. It is not only the most important source of emissions in quantity terms but also the most damaging source per unit of emission because of the high concentrations of emissions at low height and the high population density at the places of emissions. It is accepted that 1 ton of emissions emitted at ground level could be 5 to 10 times more damaging than 1 ton emitted at higher height by central heating, industry or power stations. Therefore, transport emissions have much more local health effects than the emissions of other sectors.

The first directives of the Commission implementing the catalytic converter standards in 1991 and 1994 (91/441/EEC and 94/12/EC) were heavily criticised by industry. The complaint was that neither the benefits nor the costs of the standards had been assessed. The Auto-Oil Programme (abbreviated as AOP), an assessment exercise of the Commission in collaboration with the automobile industry and oil industry, has innovated in terms of assessment methodology. In the AOP-I programme (1992–1996), an explicit cost-effectiveness approach has been followed. The basic premise was that emission standards on new cars as well as new motorfuel qualifications are only justified if they are the cheapest way to reach urban air quality targets in EU cities. The complexity of the relation between emission reductions and urban air quality was taken into account via atmospheric air pollution models and there was an effort to make car emission standards compete against other policy instruments such as fuel qualifications, gasoline taxes, etc. The European Parliament did not follow the recommendations of the AOP-I but opted for more stringent car emission and fuel standards. One of the reasons might have been the unbalanced composition of the AOP-I group where the regulated industry was overrepresented.

The second AOP-II study that started in 1997 takes into account a wider range of policy measures and relies on improved models and data. $CO_2$ emissions are in principle not an issue in the Auto-Oil Program.

### *2.3. Transport problems as such*

The 1995 Green Paper of the Commission on “Fair and Efficient Pricing in Transport” [5] recommended the use of social marginal cost pricing for all modes. This principle was seen as the best way to use the existing transport infrastructure efficiently. The social marginal cost includes the resource costs plus the external congestion costs,[2] the external accident costs, the external noise and air pollution costs and the maintenance costs directly related to the use of the infrastructure. Each of these different cost elements should be internalised making use of pricing instruments that are as close as possible to each type of cost. The longer term implication of this pricing principle is that the present system of fuel excises and registration taxes is to be replaced by a combination of lower fuel taxes and higher electronic road tolls as well as vehicle taxes that depend on the emission characteristics and improved insurance premium structures. In the follow-up white paper on infrastructure pricing [6], it is stated that the social marginal cost pricing principle is to be applied to infrastructure pricing of rail and road.

## 3. Organisation of the survey

Many policy measures have been announced for the transport sector and the European Commission is a forerunner in its attempts to integrate the different policy dimensions. This integration is not easy and different routes have been proposed in the literature leading to conflicting conclusions. The different approaches can be classified into four

[2] We consider congestion as an externality in the sense that every road user does not take into account the time losses he causes to other road users. Some sources consider congestion as a different type of externality than noise and air pollution because congestion only affects the other road users. This distinction is not really meaningful: what matters is the inefficiency in the pricing of road use.

Table 1
Different studies surveyed.

| | Approach | Cost concept | Policy instruments considered |
|---|---|---|---|
| Hacq, Bailey | Environmental effectiveness in transport sector | None | Standards on transport emissions<br>Volume of transport |
| Albrecht | Environmental effectiveness of ecobonus in transport sector | Impact on government revenues | Ecobonus for cars |
| Proost | Cost-effectiveness of fuel efficiency standard of cars | Welfare = consumer and producer surplus + government revenue | Fuel efficiency standard |
| Koopman<br>EUCARS | Cost-effectiveness of a $CO_2$ reduction in transport sector | Welfare (cf. supra) | Gasoline taxes<br>Car standards<br>Vehicle taxes |
| AUTO-OIL | Multi-sectoral cost-effectiveness of conventional air pollutant reduction | Welfare (cf. supra) | Gasoline taxes<br>Car standards<br>Vehicle taxes<br>Reductions in non-transport sectors |
| Proost, Van Regemorter | Multi-sectoral cost-effectiveness of $CO_2$ reduction | Welfare (cf. supra) | Measures in different sectors (including taxes and standards in transport sector) |
| Proost, Van Dender | Transport policy optimisation | Welfare (cf. supra) | Transport pricing<br>Car standards |

types. The first type are environmental effectiveness studies. The second type are environmental cost-effectiveness analyses of one policy measure. The third type are environmental cost-effectiveness studies comparing alternative policy instruments to achieve one goal. The final type of analysis are studies that optimise transport policy while attributing benefits to environmental improvement. We will show that the way the different types of policy objectives are integrated is the main source of differences between the different studies.

Table 1 presents the different studies that we will discuss. This is a selection that is not complete and biased in the sense that the work of the author of this paper is overrepresented. The main purpose of the selection was to represent the differences in the type of approach.

## 4. Environmental effectiveness studies

Hacq and Bailey [7] study how, in Europe, the environmental objectives of the transport sector can be reached by a combination of emission standards on cars and reductions in transport volumes. They compare different scenarios of which the business-as-usual and the $CO_2$ reduction scenario are the most interesting for us. The horizon of the study is 2010–2030. In the business-as-usual scenario, the assumptions of a fuel efficiency standard of 5 l/100 km (120 g/vehicle kilometre) together with the implementation of the new EU-vehicle emission standards lead to important reductions of traditional air pollutants ($NO_x$ and VOC – 70%) but the $CO_2$ emissions might increase by some 11% despite the stringent fuel efficiency standard. In the $CO_2$ reduction scenario, one assumes that the Kyoto target has to be met by a proportional reduction in all sectors, including transport. An important conclusion of this policy study is that, under these assumptions, meeting the Kyoto target requires for the transport sector a decrease in volume of transportation of the order of 25–40%. The projected strong gain in fuel efficiency for cars and to a smaller extent for trucks is in itself insufficient to achieve the Kyoto targets for the transport sector.

This study is a typical example of the goal oriented (or backcasting) thinking of environmental pressure groups and policy makers: the European $CO_2$ emission reduction has to be reached whatever the costs and it has to be reached in a proportional way in all sectors, including the transport sector. This study only tells us whether environmental objectives are met are not. As there is no computation of the cost of using fuel efficiency standards or transport volume reductions, no conclusion can be drawn on the appropriateness of the two policies.

Albrecht [8] examines the environmental effectiveness of an ecobonus for cars. The ecobonus is an environmental subsidy (also known as feebate in the US) for car-buyers that buy the 10% most fuel efficient car models. For Belgium this would cost the Government 40 million ECU and this could be financed by an increase of registration taxes on old cars. He expects that this instrument is very effective as it is able to reduce $CO_2$ emissions of cars by some 15% compared to 1998. This study computes the budgetary cost for the government but does not compute the total welfare costs of the ecobonus. The budgetary cost to the government is at most a political implementation constraint but not a good indicator of the welfare cost. The total amount of the subsidy gives only an idea of the welfare cost (excl. climate change benefits) if there are no other price distortions in the economy. In that case the subsidy gives an upper limit of the increase in resource cost of more fuel efficient vehicles that has to be compensated in order to make consumers buy the efficient cars. As this study only looks into one instrument it does not allow to compare the ecobonus with other policies on a cost-effectiveness basis.

There is a much greater interest in the analysis of anticipated scrappage schemes in the US than in Europe. One nice example is Alberini et al. [12] who estimate an emission abatement function for accelerated vehicle retirement on the basis of individual data. They find that scrapping programs tend to draw in vehicles in the poorest condition with the lowest remaining life. This implies that these general scrap programs may not be very effective in terms of emission reduction because one scraps cars that will not be used intensively anyway. Programs that target the highest polluters will be more effective. Other studies of scrap programs in the US have pointed to the possible adverse consequences of these programs on income distribution as scrap programs put a floor on the prices for the lowest end of the car market [13].

## 5. What is the cost of using one environmental policy instrument: the case of fuel efficiency standards for cars

At present, the fuel efficiency standard for new cars is the principal policy decision targetting explicitly the $CO_2$ emissions from cars. In the EU, there already exist high fuel taxes but this is considered more an element of the public finance policy. In environmental policy circles one takes for granted that a fuel efficiency standard is a good instrument. It is presented as an instrument that is cost-effective in terms of emission reduction and is advanced as a no-regret measure for consumers.

Proost [11] makes a simplified computation of the welfare cost of a 5 l per 100 km standard for 2005. Two assumptions are needed for the computation. First one needs an assumption about the development of the fuel efficiency in the absence of the policy measure. He makes a computation for a representative gasoline car of medium size that consumes 6.5 l in 2005 without a standard (an average autonomous progress of 1% per year). The second assumption concerns the additional resource cost of manufacturing a more fuel efficient car. Here direct or indirect estimates can be used. In the direct method, one looks for engineering estimates of making a 5 l car with equivalent properties. As far as we know, no such estimates exist for Europe. For the US the cost of these standards is monitored continuously by the Department of Commerce. But this computation is by no means uncontested as EPA uses an estimate of only one third of that of the Department of Commerce [12]. We use here an indirect estimate of the additional manufacturing cost of a fuel efficiency standard that is based on the rationality assumption for consumers and producers on the car market. The idea is that consumers choose vehicles on the basis of the lowest user cost for given performance characteristics. In a competitive market, producers aim to offer cars that have, for given car characteristics, a mix of fuel efficiency and manufacturing costs that minimise the user cost of the consumers. Therefore, any car that, because of a fuel efficiency standard, is offered with a bet-

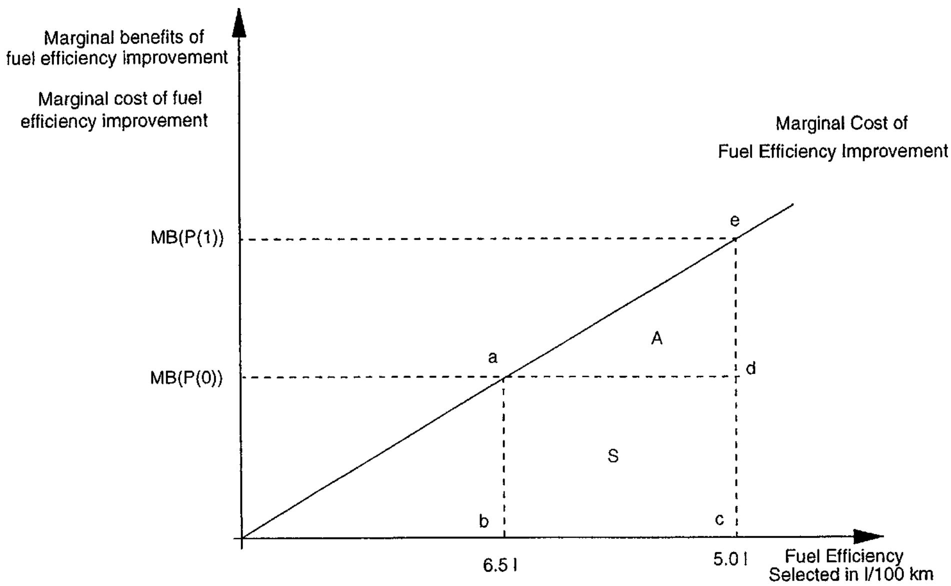


Figure 1. Relation between fuel price, fuel efficiency and marginal cost of fuel efficiency improvements. P(0) = present fuel price; P(1) = new fuel price that allows to reach the standard or price level that induces the car manufacturers to build more efficient cars; area A = additional cost of using a more efficient car (increased capital cost related to km driven that is not covered by fuel expenditure savings; area S = consumer fuel savings due to a more fuel-efficient car; MB(P(1)) = marginal benefits of fuel efficiency improvement if fuel price = P(1).

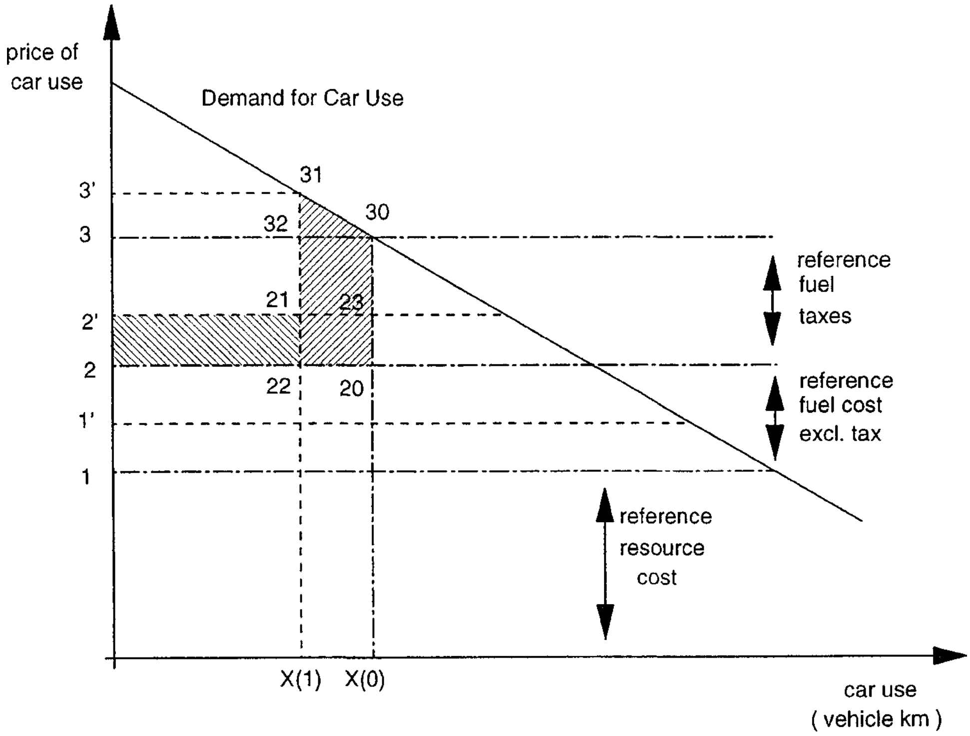


Figure 2. Net social costs of a fuel efficiency standard in the absence of external costs (other than $CO_2$).

ter fuel efficiency will have a higher manufacturing cost. This idea is used in figure 1 where the marginal cost to the manufacturer of producing a more fuel-efficient car (the upward sloping curve) is compared with the marginal benefits to the consumers of increasing the fuel efficiency (every fuel price defines a horizontal marginal benefit line). Assume an initial fuel price of P(0) in 2005, a transparant and competitive car market will then produce cars with a fuel consumption of 6.5 l per 100 km because the corresponding horizontal marginal benefit line crosses the marginal cost of making cars more fuel efficient in point a. Take now a fuel standard of 5 l keeping the consumer price constant. The total extra manufacturing of making such a car is given by the area under the marginal cost curve: area S + A. For the consumers, the net discounted cost of buying and using a more fuel-efficient car is lower as area S represents the fuel savings (discounted over the lifetime of the car) they make at fuel prices P(0). In our example, area A equals 500 EURO, while area S equals 850 EURO. This would imply that the average car price with the standard increases by some 13%, and the first estimate of the welfare cost of the standard equals 500 EURO. This first welfare estimate is probably an underestimate of the true welfare cost (excluding $CO_2$ benefits) because motorfuel is very heavily taxed. This is illustrated in figure 2 for the transport by car market for a given year.

The reference manufacturing resource cost of a car (without standard) is given by horizontal line 1, the sum of the car costs and the fuel cost excluding taxes is given by line 2, the full consumer cost including fuel taxes and including the manufacturing cost of cars is given by line 3. The equilibrium volume of car use before the standard equals X(0). The effect of a fuel efficiency standard is simulated by the lines $1'$, $2'$ and $3'$. When we assume as in figure 1 that the car producers have already optimised the fuel efficiency level of their cars as a function of the reference fuel price, the new full consumer cost of car use with fuel efficiency standard, given by line $3'$, must lie above line 3. The height of line $3'$ is the result of increased manufacturing costs and lower fuel costs. The total welfare loss of the car fuel efficiency standard (excl. environmental benefits) can now be estimated more correctly by the sum of the loss in total consumer surplus and government revenue due to the reduced car use (area 22 31 30 20) and the loss of surplus on the remaining car km (area $2'$21 22 2). The first area is a welfare loss because the willingness to pay for these car kilometres (demand function) was higher than the real resource cost of these kilometres (line 2). The second area is a welfare loss because it corresponds to the net increase of resource cost of producing the remaining car kilometres.

In table 2 we present an estimate of the welfare costs for a standard medium sized car using the methodology of figures 1 and 2. This table adds one more element to figure 2: it considers possible side benefits associated to the reduction of other air pollutants ($NO_x$, VOC, CO, PM10) and the reduction in congestion and accidents. The net cost without any secondary benefits is 389 ECU per year per car. This is the sum of the loss in surplus for the remaining car kilometres plus the loss in welfare due to the change in volume.

Table 2
Welfare costs of fuel efficiency standard for a gasoline car in ECU '90.

| | Annual basis | Per kg of $CO_2$[a] |
|---|---|---|
| *For new volume of car use (14908 km/year)* | | |
| (1) net increase resource and fuel costs (excl. fuel tax) | 248.4 | |
| (2) loss in fuel tax revenue | 121.2 | |
| (3) decrease in other external air pollution costs | 25.2 | |
| *Due to change in volume (−464 km/year)* | | |
| (4) loss in consumer surplus | 3.6 | |
| (5) loss in fuel tax revenue | 16.4 | |
| (6) reduction all external costs (including congestion, accidents, other air pollution) | 289.4 | |
| (7) net cost without secondary benefits = (1) + (2) + (4) + (5) | 389.2 | 0.67 |
| net cost with secondary air pollution benefits = (7) − (3) | 364 | 0.63 |
| net cost with secondary air pollution, congestion and accident benefits = (7) − (3) − (6) | 74.6 | 0.13 |

[a] Total $CO_2$ abatement per year per car equals 577.7 kg, source: [11].

This estimate of the net welfare cost is much higher than the net cost for the consumer of buying a more fuel-efficient car (in figure 1 this is area A that equals on a yearly basis only 120 EURO). The major difference lies in the high tax revenue losses that were not counted in the estimate based on consumer prices in figure 1. This comes down to a welfare cost of saving $CO_2$ of 0.67 EURO per kg of $CO_2$ and this is very high compared to other reduction options. Of course saving fuel will also reduce the emission of other air pollutants and this can reduce the net annual welfare loss per car. The major side benefit that can be achieved is, however, the reduction in external congestion and accident benefits. After deducting these benefits we obtain a much lower abatement cost per kg of $CO_2$ of 0.13 EURO in table 2. These benefits are real but are very much dependent on the area considered (urban area or not) and on the inefficient mix of instruments used at present. The side-benefits shown in table 2 are an estimate for the peak period in the Brussels urban area and should therefore be considered as an upper bound. The second danger in using congestion and accident benefits is that they only exist in as far as the transport policy remains as inefficient as it is now. So there is a risk in taking long term environmental measures on the basis of other policy inefficiencies that may and should disappear when congestion and other air pollutants are tackled by a combination of more efficient instruments as there are road pricing and environmental taxes.

This is a strongly simplified discussion of the cost of saving $CO_2$ via a fuel efficiency standard. We could include other features that have shown up in the US literature on standards. There the discussion also includes oil market effects: fuel efficiency standards as a second best optimal oil import tariff – see work by Greene [13] – and the effects of standards on other car characteristics (speed, safety see Khazzoom [14] and Bresnahan and Yao [15]).

Our results depend on three assumptions. There is first of all the base case. We have assumed that the standard of 5 l is to be compared with a base case of 6.5 l. If the base case develops to a 5.5 l car because of changes in preferences or autonomous technical progress the costs per kg $CO_2$ saved will be lower but also the total $CO_2$ emission saving that can be attributed to the standard will be lower. This could be one of the keys to understand why the European manufacturers have actually promised to deliver 5.8 l/100 km cars in 2008. The second major assumption is that we accept consumer sovereignty and rationality from the side of the consumers and producers. We will return to this assumption when we discuss the EUCARS results. The final assumption has to do with the cost structure of making more fuel-efficient cars. Part of this cost will be R&D and here we can discuss how this cost is shared among different continents, whether the last mover gets his technology cheaper.

In conclusion, we can understand that, when motorfuel taxes are very high, the environmental policy makers propose fuel efficiency standards for cars as a measure that do not look very costly to consumers. What is more difficult to understand is that the Ministers of Finance do not object to a policy that undermines the excise tax base and is therefore more costly than it looks. One possible explanation is that the tax base effects are to be expected only in the long run: new cars have only to comply with the standards from 2008 onwards and the standards hold only for new cars. These effects are clearly beyond the office term of any Finance Minister.

## 6. Meeting an environmental policy goal by selecting lowest cost instruments

Using the EUCARS model [16], the Directorate General for Economic and Financial affairs of the European Commission has been among the first to take a cost-effectiveness approach to the selection of environmental policies for the transport sector. The EUCARS model describes European passenger transport by car and public transport using a dynamic partial equilibrium model. The model represents the behaviour of a representative EU consumer that chooses simultaneously the volume of transport, the mode and the type of car. The model has endogenous road congestion

Table 3
Comparison of alternative $CO_2$ reduction policies for cars with the EUCARS model (source: [17]).

| In % difference with baseline | $CO_2$ tax | Ownership tax | CAFE standard or gas guzzler tax – sipper rebate |
|---|---|---|---|
| $CO_2$ emissions | −10 | −10 | −10 |
| Welfare cost | 1.8 | 5.0 | 2.2 |
| Government tax revenue | 2.5 | 17.8 | −0.8 |
| Ownership costs | 3.6 | 41.8 | 5.6 |
| Variable car costs for drivers | 6.7 | 0.3 | −5.9 |
| Total mileage | −4.3 | −12.3 | 1.0 |
| Fuel use per km | −7.1 | 0 | −11.8 |

built in via a speed flow relationship: an exogenous increase of the volume of car use on the same infrastructure reduces average speed and this increases the time cost of car use and has a negative feedback effect on the volume of car use. The welfare measure used is the sum of private welfare (equivalent variation) and of the government revenues weighted by a marginal cost of public funds parameter – the environmental benefits are not included. The EUCARS model has been used for the AUTO-OIL I study to compute the cost of different measures to reduce conventional emissions and has also been used to study the $CO_2$ emissions for cars.

In table 3 we reproduce results from a table of Koopman [17] who used an earlier version of EUCARS (without road congestion) to compare the welfare effects of alternative instruments to reduce $CO_2$ emissions by cars by 10% compared to the baseline in 2010. We compare three of his scenarios:

First a $CO_2$ tax; this means an increase in excises based on the $CO_2$ content of fuels (gasoline prices +20.9% and diesel prices +27.8%). Second an annual ownership tax increase of 470%. Third a Corporate Average Fuel Efficiency (CAFE) standard modelled as a gas guzzler tax combined with a sipper rebate (300–500 ECU per l/100 km above or below the target).

As can be seen, the welfare costs (second line in table 3) are positive for all policies and this is to be expected when environmental benefits are not included in the welfare function. The $CO_2$ tax is the cheapest instrument and this is no surprise to economists who in general favour prices to standards. Very high ownership taxes can reduce $CO_2$ emissions too but will be a very costly measure in welfare terms as the instrument is very indirect. A fuel efficiency standard that is averaged per manufacturer (CAFE standard) has the same effect as a differentiated tax/subsidy as a function of the fuel efficiency: it raises the prices of models with lower fuel efficiency and vice versa. This instrument is closest to the ecobonus of Albrecht discussed previously. It is important to understand the difference in effects between the $CO_2$ tax and the CAFE standard. $CO_2$ emission reductions can be achieved in two ways: driving less and driving a more fuel-efficient car. A $CO_2$ tax uses both ways while a CAFE standard uses only the second way. Actually, a CAFE standard will even make the use of cars less expensive so that every new car will be used more. This is known as the rebound effect. Therefore, in order to achieve the same reduction in emissions as in the $CO_2$ tax case, the fuel efficiency improvement has to be larger (−11.8% instead of −7.1%) and this makes cars more expensive in the CAFE scenario. The reason why the CAFE standard has only a small cost disadvantage compared to the $CO_2$ tax lies in the myopia of the car buyer that is assumed in the model. In the EUCARS model the consumer's myopia is represented via high discount rates (up to 50%) in the consumer's decisions. The myopic behaviour means that consumers forego possibilities to reduce $CO_2$ emissions by buying more fuel-efficient cars and that forcing them to do this through standards makes them better off. It is difficult to check this assumption empirically. Verboven [18] used market data for gasoline and diesel cars for the European car market to assess the implicit discount rate used by car owners. He obtained a central estimate of 9% with a 95% confidence interval of (2.4–15.7%). This compares fairly well with the interest rate on the capital market for car purchases: between 7 and 12 %. There exist US studies for other durables that point to higher implicit discount rates (20–25%). In the case of cars the consumer may be better aware of fuel costs than for other durables because fuel costs are paid for very regularly while the electricity consumption of other durables is not individualised and not paid for as regularly.

In the AUTO-OIL I exercise [19], the goal was to achieve urban air quality goals at the lowest cost for society. The initial emphasis was to compare on the same basis fuel quality improvements and car emission standards but in the end a wider set of emission reduction measures was considered. The methodology of the exercise is summarised in figure 3 (taken from the AOP-II exercise [20]). First the cost of alternative ways to reduce emissions is computed for different regions and cities in Europe. This corresponds to the lowest layer of the graph where different working groups propose alternative measures. The cost of these measures is computed with a transport model (EUCARS in AOP-I, TREMOVE in AOP-II). The welfare cost concept used includes private welfare (equivalent variation) and the government revenues weighted by a marginal cost of public funds but excluded any environmental benefit in EUCARS [16]. The main differences between TREMOVE and EUCARS are that TREMOVE models every city and country separately and that TREMOVE has the possibility to take into account environmental benefits.

The cost and emission reduction potential of a measure in a particular city is an input into a wider problem: to minimise the cost of achieving urban air quality targets in European cities taking into account the transboundary effects of pollution and taking into account that some measures can be locally differentiated (public transport) and others cannot (car standards). The result of AOP-I [19] was to propose a balanced set of instruments. This set includes not only the traditional standards but also road pricing and other local traffic measures. Indeed, there are important differences

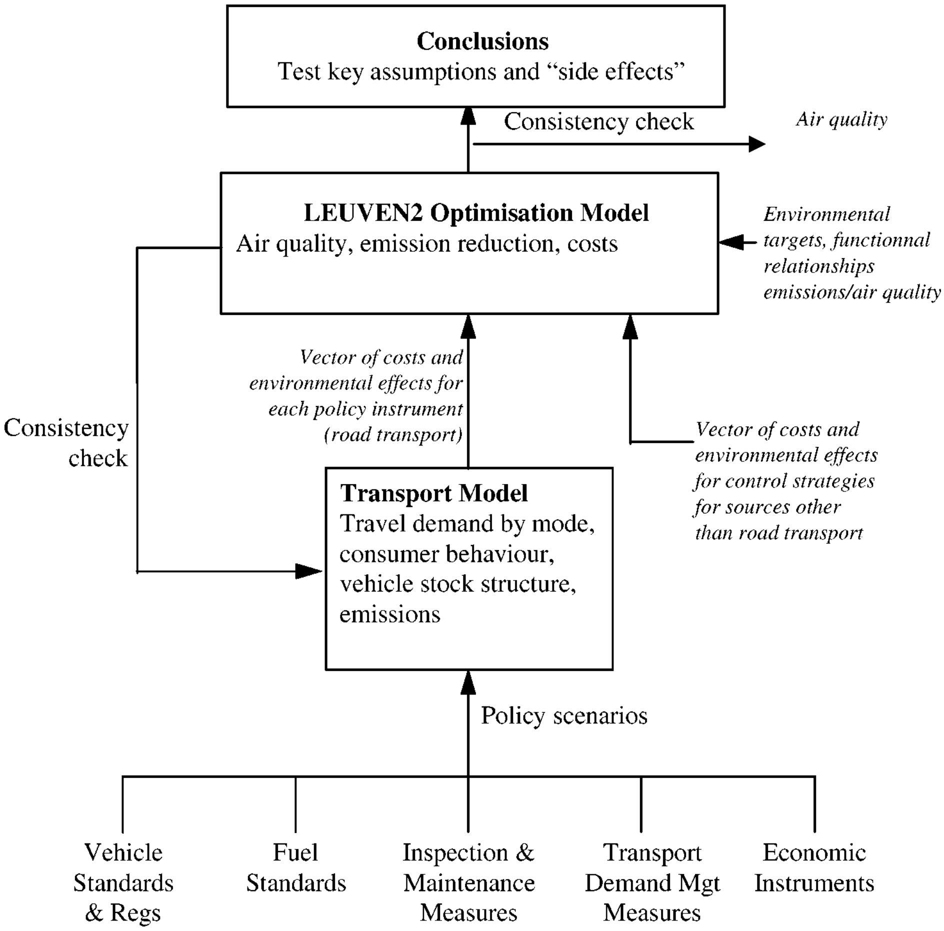


Figure 3. Cost-effectiveness methodology in AUTO-OIL II (source: [20]).

in urban air quality within Europe and they can only be addressed cost-effectively by making sufficient use of local measures. The AUTO-OIL programme is probably one of the most successful programs to study an environmental problem with the participation of most of the stakeholders. The European Parliament did not participate in this exercise and felt that in AOP-I the consultation of experts was limited too much to the car and oil industry and forced the Commission to set even stricter standards than the ones that were advised by the AOP-I program.

With ever stricter emission standards for cars, it is clear that reaching better urban air quality will necessitate more efforts from trucks, public busses and from the non-transport sector. In terms of traditional air pollutant emissions, one expects that the transport sector will have decreased in importance from 50% or more now to less than 10–20% in 2010. In the new AOP-II program, there is more emphasis on the comparison of emission reduction over sectors.

Reducing $CO_2$ emissions via fuel efficiency standards can be costly. Once we have an estimate of the cost of $CO_2$ savings via different instruments in the transport sector we need to compare it with the cost of $CO_2$ reduction in other sectors. In Proost and Van Regemorter [21], this is done with the help of the MARKAL model. From transport models they take the result that it may be optimal to reduce the present volumes of transport by 5–10% when optimal congestion and accident pricing policies are introduced. Once the market failure in the transport sector is corrected, the transport sector should be treated like any other sector. In the MARKAL model all sectors and technologies are treated equally and all energy consumption and production inside a given country is represented as an integrated system. $CO_2$ can be saved by substitution of technologies within the energy sector or at the end-use level (say, better insulation or more fuel-efficient cars) and by reduction of the level of activity in energy end-use (lowering indoor temperature or reducing total mileage). In the latter case, the cost is given by the loss of consumer surplus. For Belgium results are summarised in table 4. As can be seen, although the transport sector is responsible for a growing share of total emissions (22.9% in 2030), it is not cost-effective to reduce $CO_2$ emissions in the transport sector: only $-2\%$ once the volume of transport has been corrected.

This study includes biofuels for which the potential is limited in Belgium because it does not have a large agricultural potential. This analysis is a cost-effectiveness analysis within one country. A full analysis should include $CO_2$ reduction possibilities abroad. These results need confir-

Table 4
Cost-efficient allocation of $CO_2$ reduction efforts over sectors in Belgium (source: [21]).

| | Reference 2000 shares in total $CO_2$ emission (%) | Reference 2030 shares in total $CO_2$ emission (%) | Objective – 20% in 2030 % reduction in emisson level compared to reference |
|---|---|---|---|
| Electricity | 18.3 | 21.4 | −69 |
| Industry | 33.1 | 34.4 | −35 |
| Transport | 20.1 | 22.9 | −2 |
| Small consumers | 25.0 | 17.7 | −13 |

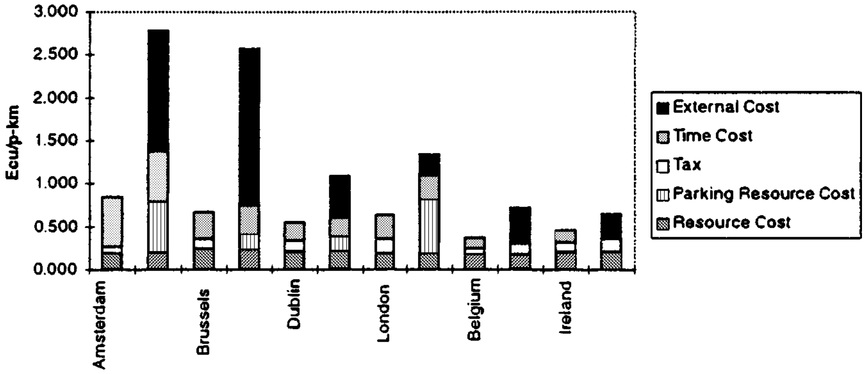


Figure 4. Peak car reference prices and costs (source: [22]).

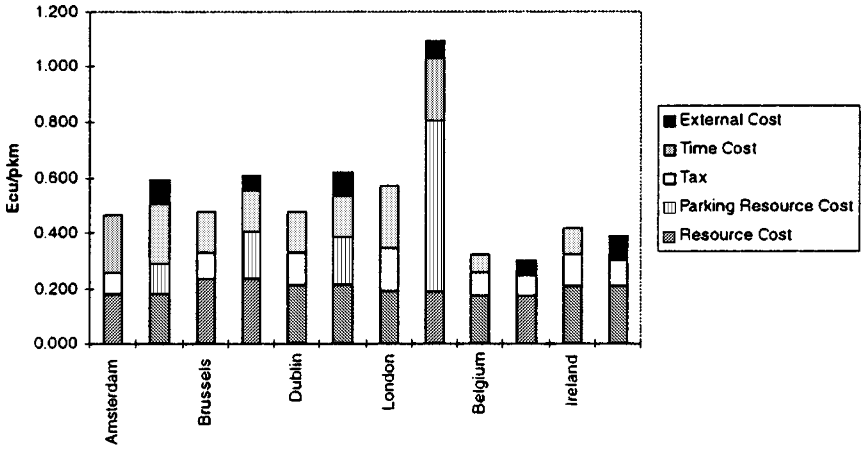


Figure 5. Off-peak car reference prices and costs (source: [22]).

mation in other countries. For other countries the relative importance of the transport sector in the national $CO_2$ emissions can be much larger than 20%. In that case, stringent national emission limits for $CO_2$ will more easily lead to national efforts in the transport sector. Again, when the analysis includes trade possibilities this argument no longer works and the optimal share of transport in total $CO_2$ reductions will be low.

## 7. Optimising transport policies with environmental constraints or benefits

The dual approach to an environmental cost efficiency analysis is to maximise welfare including all environmental damages. In the TRENEN II consortium [22], the expected private cost of car use and of other modes are compared to the social marginal cost of using these modes. The social marginal cost includes all resource costs together with the external cost of congestion, accidents, noise, climate change and other air pollutants. The external cost of air pollution was extrapolated from EXTERN-E results and includes climate change benefits [23]. Figures 4 and 5 compare, for different cities and non-urban areas, the cost per car kilometre for a private user who does not have to pay for his parking spot (most drivers do not) and the marginal social cost expected for 2005 when policies are unchanged. Figure 4 deals with the peak period. For each area, two bar charts are shown. The first bar represents the private car user costs that consist of the sum of the resource cost (production cost of car, maintenance and fuel cost), the price of parking (zero by assumption here) in cities, the taxes and the time cost. The second bar chart represents the marginal social cost of car use that consists of the sum of resource costs, parking resource costs and the external costs. Figure 4 shows that there is an important discrepancy between the private users' price and the social marginal cost in the peak period for cars. The major problems are the unpaid resource cost of parking (urban areas) and the external congestion costs. Similar graphs exist for public transport and freight transport. Almost all modes of transport are underpriced in the peak, some of them because of the very high external costs, others because they are heavily subsidised. The discrepancy is much less pronounced in the off-peak period where car use is sometimes overtaxed.

We analyse here more in particular the case of Brussels. In the case of Brussels the structure of the marginal external costs is given in table 5 [24].

One can see that the price inefficiencies are dominated by external congestion costs that only appear in the peak period and that, as regards air pollution, diesel is the major problem because of the health problems attributed to PM10. Each of these external costs can probably be reduced by appropriate instruments but it is already clear that the congestion issue will drive the results.

In the end, the inefficient transport market is the result of wrong tax and pricing policies. The TRENEN II model can be used to look for a welfare optimum for any given set of policy instruments. In table 6, taken from Proost and Van Dender [24], the welfare efficiency of different policy options is compared. The first column of this table reports the welfare effects. The welfare gain obtained with perfect pricing is used as a benchmark for the other policy instruments. The three other columns report different effects: change in air pollution damage, total volume of car transport and average speed in the peak period.

Table 5
Structure of marginal external costs for a small car in Brussels in 2005 (source: [24]).

| | Gasoline (ECU/Vehkm) | | Diesel (ECU/Vehkm) | |
|---|---|---|---|---|
| | Peak | Off-peak | Peak | Off-peak |
| Air pollution | 0.004 | 0.004 | 0.042 | 0.026 |
| Accidents | 0.033 | 0.033 | 0.033 | 0.033 |
| Noise | 0.002 | 0.008 | 0.002 | 0.008 |
| Congestion | 1.856 | 0.003 | 1.856 | 0.003 |
| Total | 1.895 | 0.047 | 1.932 | 0.068 |
| Tax | 0.12 | 0.11 | 0.08 | 0.07 |

Perfect pricing of external costs leads to lower air pollution damage mainly as a side effect of lower volume of car use. The lower value of car use is the result of different effects that are mainly targetted at reducing congestion: more car polling, switch to other modes and a smaller number of trips. This table illustrates that the welfare maximising policies for the transport sector are those policies that address as directly as possible the problem of congestion and unpaid parking. Congestion problems can be tackled by cordon charging (toll levied on commuters at entrance of city that is differentiated between peak and off-peak). The unpaid parking distortion can be solved by making everybody pay for his parking resource cost (at destination). Both policy instruments generate important welfare improvements. The extent of the welfare improvement is correlated to the increase in speed they can generate in the peak period.

The emission standard scenario assumes that one can get cars with lower emissions of conventional pollutants at an investment cost per vehicle that varies between 225 and 824 ECU per car. These are data taken from the AOP-I results [19]. The welfare effect varies slightly depending on whether the consumer or the government pays for the cleaner cars. There is a difference because government funds have a marginal cost higher than one and because there is an income effect for the consumer that affects demand for transport. Such standards can give rise to important reductions in the emission of conventional pollutants but the total welfare gain is smaller, even negative. The explanation lies in the high marginal abatement cost that is not compensated by air pollution benefits.

Table 6
Welfare efficiency of alternative transport and environment policy instruments for Brussels in 2005 (source: [24]).

| | Change | | Total volume of passenger car units | Speed of cars in peak (km/h) |
|---|---|---|---|---|
| | In welfare (mio ECU/day) | In air pollution damage | | |
| Reference | 0 | | 100 | 23 |
| Perfect pricing | 100% (= 0.703) | −0.015 | 78 | 40 |
| Cordon pricing | 52% | −0.001 | 89 | 33 |
| Parking charges | 32% | −0.005 | 95 | 26 |
| Emission standard (consumer paid) | −0% | −0.006 | 100 | 23 |
| Emission standard (government paid) | −0% | −0.006 | 100 | 23 |
| Fuel efficiency standard (consumer paid) | −17% | −0.016 | 98 | 24 |
| Fuel efficiency policy (via fuel tax) | 5% | −0.016 | 95 | 26 |

The fuel efficiency standard scenario corresponds to the introduction of the 5 l car in 2005. The second fuel efficiency scenario means that the use of a 5 l car is stimulated via higher fuel taxes rather than through a standard imposed by government. Both scenarios generate approximately the same gain in air pollution benefits. These air pollution benefits consist mainly in the reduction in diesel fuel and in the lower emissions of PM10. The fuel efficiency standard is a less interesting policy than the fuel tax policy because in the former there is almost no effect on the volume of transport and on congestion. This confirms the EUCARS results reported in table 3.

## 8. What have we learned?

We have surveyed different types of environmental policy analysis of the European transport sector. This sector is characterised by many different problems like congestion and accidents. In monetary damage terms, air pollution is not always the dominant type of externality (congestion and accident can be important). The major problem for good environmental policy making in the transport sector is the correct integration of these different concerns. The two possible approaches, a cost-effectiveness analysis of alternative policies to reach environmental targets in the transport sector taking transport benefits into account and transport policy studies that take environmental benefits into account are in theory equivalent. In practice it is probably more difficult to take the first approach because the transport benefits are more difficult to estimate in a non-transport model.

From the studies surveyed we can draw three policy conclusions:

(1) The emphasis of current European policies on fuel efficiency of cars (via standards, ecobonus, etc.) is wrong. This is not a cost-effective policy. It is mainly an excise tax saving policy that looks attractive for the final consumer but is not beneficial from a society point of view. The main reason is that the fuel efficiency of present cars has already been designed as a function of excises on motorfuels that represent a disguised $CO_2$ tax of 300% or more.

(2) The major problem in the transport sector is to address correctly the other external costs (congestion, accidents) and not so much air pollution. This requires other instruments than the present fuel taxes: road pricing, parking charges, better structured insurance payments, registration taxes that are a function of conventional emissions, price reform for public transport, etc. It also means ending the policy of favouring diesel cars. Addressing congestion and accident externalities can generate some free $CO_2$ emission reductions.

(3) In certain urban areas there are still important air quality problems. They can be addressed by a combination of local and global emission measures. Due to the strict emission standards that are already in place for the car transport sector, a cost-effective solution could require important efforts from other emission sources.

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