ECMT

EUROPEAN CONFERENCE OF MINISTERS OF TRANSPORT

CLEANER CARS

Fleet Renewal and Scrappage Schemes

GUIDE TO GOOD PRACTICE

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EUROPEAN CONFERENCE OF MINISTERS OF TRANSPORT (ECMT)

The European Conference of Ministers of Transport (ECMT) is an inter-governmental organisation established by a Protocol signed in Brussels on 17 October 1953. It is a forum in which Ministers responsible for transport, and more specifically the inland transport sector, can co-operate on policy. Within this forum, Ministers can openly discuss current problems and agree upon joint approaches aimed at improving the utilisation and at ensuring the rational development of European transport systems of international importance.

At present, the ECMT's role primarily consists of:

– helping to create an integrated transport system throughout the enlarged Europe that is economically and technically efficient, meets the highest possible safety and environmental standards and takes full account of the social dimension;
– helping also to build a bridge between the European Union and the rest of the continent at a political level.

The Council of the Conference comprises the Ministers of Transport of 39 full Member countries: Albania, Austria, Azerbaijan, Belarus, Belgium, Bosnia-Herzegovina, Bulgaria, Croatia, the Czech Republic, Denmark, Estonia, Finland, France, FYR Macedonia, Georgia, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Moldova, Netherlands, Norway, Poland, Portugal, Romania, the Russian Federation, the Slovak Republic, Slovenia, Spain, Sweden, Switzerland, Turkey, Ukraine and the United Kingdom. There are five Associate member countries (Australia, Canada, Japan, New Zealand and the United States) and three Observer countries (Armenia, Liechtenstein and Morocco).

A Committee of Deputies, composed of senior civil servants representing Ministers, prepares proposals for consideration by the Council of Ministers. The Committee is assisted by working groups, each of which has a specific mandate.

The issues currently being studied – on which policy decisions by Ministers will be required – include the development and implementation of a pan-European transport policy; the integration of Central and Eastern European Countries into the European transport market; specific issues relating to transport by rail, road and waterway; combined transport; transport and the environment; the social costs of transport; trends in international transport and infrastructure needs; transport for people with mobility handicaps; road safety; traffic management; road traffic information and new communications technologies.

Statistical analyses of trends in traffic and investment are published regularly by the ECMT and provide a clear indication of the situation, on a trimestrial or annual basis, in the transport sector in different European countries.

As part of its research activities, the ECMT holds regular Symposia, Seminars and Round Tables on transport economics issues. Their conclusions are considered by the competent organs of the Conference under the authority of the Committee of Deputies and serve as a basis for formulating proposals for policy decisions to be submitted to Ministers.

The ECMT's Documentation Service has extensive information available concerning the transport sector. This information is accessible on the ECMT Internet site.

For administrative purposes the ECMT's Secretariat is attached to the Organisation for Economic Co-operation and Development (OECD).

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FOREWORD

The focus of efforts to reduce exhaust emissions from vehicles is through improving the performance of new vehicles. Industry invests large amounts of money in improving engine technology and reducing fuel consumption. Governments have sought to generalise and accelerate these improvements mainly through emissions regulations, and recently through voluntary agreements with industry in regard to CO_2. The full effects of these improvements, however, are not felt immediately as fleet renewal takes time – a decade on average in the Europe Union.

Fleet renewal incentives can be used to accelerate the uptake of new technologies and new vehicles. They have been employed by a number of governments around the world usually with the stated aim of improving environmental protection, and often with accompanying goals of lifting economic growth and supporting the car manufacturing industry.

This report presents a framework for analysis of the effectiveness of vehicle scrapping schemes in protecting the environment. It reviews the schemes introduced to date by governments in Europe and North America and makes recommendations on the design of effective incentive schemes.

The ECMT is grateful for the help of Michele Fontana of the Department of Public Economics, University of Pavia, and the Institute of Energy Economics, Bocconi University, Milan – principal author of the study.

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INTRODUCTION

Several countries within and outside Europe have implemented scrappage schemes during the 1990s. Incentives for scrapping old cars were given by Greece (1991-1993), Hungary (1993 up to the present) Denmark (1994-1995), Spain (1994 up to the present), France (1994-1996), Ireland (1995-1997), Norway (1996) and Italy (1997-1998). Various local governments in the United States of America and the Canadian Province of British Columbia have also implemented such schemes.

The main objectives of the schemes have usually been listed as follows:

- stimulating the national car industry and the national economy by boosting new car purchases;
- improving transport safety by introducing newer, safer vehicles;
- reducing car exhaust emissions.

Only the environmental goal was identified by *all* the schemes examined. The economic goal of stimulating the national car industry was only mentioned by those countries with a large national vehicle manufacturing industry.

The first aim of the present publication is to evaluate scrappage schemes as a policy tool to achieve an improvement in the environmental performance of the car fleet. The effects of scrappage schemes on safety are considered only to a limited extent, as there is little or no data available to assess them. In most Western countries the number of fatalities on the roads has decreased in recent years, in spite of an increase in the number of kms travelled per year. However, it is extremely difficult to determine what the contribution of improvements in vehicle design is to this reduction, compared to other road safety policies implemented by governments. Therefore, it is difficult to give any estimate of the contribution of accelerated vehicle retirement to changes in road casualties or injuries.

This publication also considers the main economic effects of scrappage programmes, as an understanding of the car market and the economic variables affecting it is essential to assessing the effect of any incentive scheme. The first section of the publication is devoted to this analysis.

The environmental evaluation of scrappage schemes firstly addresses the size of the emission reductions achieved. The analysis tries to clarify how these reductions should be computed and identify what main variables influence their size. Among the several chemical substances contained in exhaust gases, the publication focuses on those pollutants that are currently of major concern at local and global levels. At the 'local' level, these are nitrogen oxides (NO_x), sulphur oxides (SO_x), particulate matter (PM), carbon monoxide (CO) and hydrocarbons (HC),[1] together with some secondary pollutants (ozone; nitrate and sulphate aerosols) generated from the photochemical reaction of NO_x, SO_x and HC in the atmosphere. As for the 'global' issues, the report is limited to greenhouse gas (GHG) emissions, focusing on carbon dioxide (CO_2); a more precise assessment should, however, account for methane (CH_4) and nitrous oxide (N_2O) emissions as well.

Showing that an emission reduction can be achieved is not in itself enough to indicate that a given policy tool should be implemented. The cost-effectiveness of the reductions achieved is of fundamental importance to assessing the value of any environmental policy instrument. Therefore, the analysis tries to identify the main variables affecting the cost per tonne of pollutant reduced, and how the design of scrappage schemes can be shaped to improve cost-effectiveness. Finally, some consideration is also given to the cost/benefit ratio of scrappage schemes, in an attempt to establish if and when they are worthwhile.

As with any other cost-effectiveness and cost-benefit evaluation, it is very important to make as clear as possible the evaluation framework chosen for the analysis. It is useful to raise the following methodological issues.

Firstly, the costs and benefits of a scrapping programme must be assessed against a precise benchmark alternative. The simplest alternative to consider is the option of non-intervention. Other alternative policies with the same environmental goals should also be considered, e.g. enhancing the existing inspection and maintenance (I&M) programmes or changing fuel taxation to internalise externalities.

Secondly, the contribution of scrapping programmes to the given goals has to be distinguished as clearly as possible from the contributions of other policies. Transport sector regulation is complex and different policy tools interact. For instance, environmental standards, I&M programmes and fuel taxes are often used at the same time to curb transport emissions. Car scrappage schemes must be evaluated within a given regulatory context. Their assessment should account only for the *additional* contribution they give to improvements in emissions and safety.

Finally, time and spatial boundaries for the costs and benefits of the scheme considered have to be set at the beginning of the evaluation and adhered to. Car scrappage should be analysed ideally in the mid to long term. Cars are *durable* goods and a vehicle bought now is intended to be used for several years before being scrapped. Its purchase affects other purchasing decisions in the future. This implies that any evaluation of the consequences of car scrapping schemes has to cover several years and should try to explain how the different variables behave through the chosen period in response to the scheme. 'Static' or very short-term evaluations of the scheme may be too simplistic: they record the boost in scrappage and new car sales due to the schemes, but they miss possible falls in sales after implementation in the longer-term. As regards the spatial boundaries of the evaluation, since both costs and benefits can be site specific, the analyst should ensure that they are coherently evaluated according to the specific objective of the scheme. If the objective is, for example, reducing environmental damage in specific metropolitan areas, account should be taken of the fact that emissions in densely populated areas have an impact greater than the national average. Adjusting for this will produce a more favourable cost/benefit ratio for such targeted schemes when compared to national schemes. Large-scale scrappage schemes applied nationally may also affect the international market for new and second-hand cars. This may cause some economic and environmental changes in other countries. Although cost-benefit analyses are usually made at the national level, international effects should also be briefly considered, for example, to avoid ecological dumping on other countries.

The final section of this publication assesses if and how scrappage schemes might be used to achieve environmental improvements in former socialist European countries. It analyses in particular the Hungarian experience with scrappage schemes. The information gathered from this case study and from the analysis made for Western countries is used, together with information on trends in the Russian car fleet, to draw some general conclusions for Central and Eastern European and NIS countries.

Box 1. American and Canadian experience

USA. Section 108 (f) of the Clean Air Act Amendments (CAAA) of 1990 included 'vehicle buy-back programmes' in a list of Transportation Control Measures (TCM) that companies (refineries, power plants, etc.) subject to emissions limits in ozone and CO non-attainment areas should consider for reducing atmospheric emissions. HC and NO_x emission reductions achieved through car scrappage programmes are credited to the company financing the scheme which can either use them to meet the legal requirements in regard to its polluting activities or exchange them on the emissions trading market as an emission reduction credit (ERC). The ERCs achieved through scrappage schemes are valid for two or three years. Thereafter, other measures have to be taken by polluters to obtain the emission reductions required by the CAA.

In California in 1990, the oil company Unocal implemented the first - and still one of the largest - scrappage schemes, the South Coast Recycled Auto Programme (SCRAP). This was initially directed at retiring about 7 000 pre-1971 model cars (i.e. older than 19 years). This was 2% of the pre-1971 cars in circulation in the targeted non-attainment area. US$ 700 per car was offered to retire eligible vehicles. While the scheme was operating, the Ford Motor Company, some local dealers and the South Coast Air Quality Management District authority gave additional funds, so that the programme ultimately scrapped 8 376 vehicles. The California Air Resource Board also made a contribution to the programme by performing emission testing on a sample of SCRAP cars and analysing the related data to compute the net emission reduction achieved.

In 1992 two pilot projects were launched in Chicago and Delaware non-attainment areas, retiring a few hundred old cars. Several other local scrappage programmes were implemented in California from 1993 in the Joaquim Valley, San Diego and Los Angeles areas. Similar schemes currently operate in Phoenix and Chicago. The schemes are usually privately funded but in a few cases (e.g. in the San Joaquim Valley) a local authority pays. In most cases the bonuses given were US$ 500-600 per eligible car. The minimum age required for a car to be eligible for the scrappage programmes is usually 15 to 20 years (the lowest limit, in the Delaware scheme, was 12 years). The eligible vehicles were selected mostly among those that had recently failed an Inspection and Maintenance (I&M) test. *Not one* of the implemented programmes required the owner of the vehicle for scrapping to buy a *new* car in order to get the bonus.

Box 1. Cont.

In 1993, the Environmental Protection Agency produced some general guidelines for the computation and use of ERCs achieved through scrappage programmes. In October 1998, the California Air Resource Board proposed regulations for voluntary, accelerated light-duty vehicle retirement schemes.

Canada. In 1996, a pilot programme was implemented in British Columbia (BC), with the target of removing 1 100 old vehicles in the regions of Victoria and Lower Mainland. It was jointly funded by the BC Automobile Dealers Association, the Canadian Petroleum Products Institute, BC Hydro and the Vancouver and Victoria Regional Transit Commissions. Eligible vehicles had to be 1983 models or older and had to have recently failed an I&M test. They had to be driven to the scrap yard (to ensure that they were still working). The scrappage bonus was differentiated according to the choice of the replacement vehicle. The owners of eligible vehicles could receive C$ 750 (about US$ 550) if they purchased a new model car; C$ 500 if the replacement car was bought on the second-hand market (provided that the model was not older than eight years). Otherwise, owners could choose to receive a one-year free transit pass on the local public transport network, worth about C$ 1 000. The latter was the preferred option.

Box 2 - The first European scrappage schemes

Greece was the first European country to introduce scrappage schemes, from January 1991 to March 1993. The first scheme was applied in the Athens area with the purpose of accelerating the introduction of catalysed cars and improving air quality in the region. A 40-60% reduction in the excise duty on new cars was given as a bonus to anybody purchasing a new model, conditional upon the scrappage of a car older than ten years. Other reductions in car registration taxes and road charges were given outside the scrappage scheme to anybody who purchased new cars equipped with catalytic devices. The scrappage programme was then extended to the whole of Greece. Both programmes expired in 1993.

In September 1993 the city of Budapest in **Hungary** introduced a programme directed at eliminating the many old two-stroke-engine cars and vans still in use (Trabant, Wartburg, Barkas models). Owners of a two-stroke-engine car who scrapped and replaced it with one of five *new* environmentally friendly models chosen by the government, were eligible for a bonus of Ft 100 000 (about US$ 500). As an alternative option, they could obtain a one-year, free pass for themselves and their families on the public transportation network in Budapest if they did not replace their old car. The programme, which is still operating, was later extended to the whole of Hungary. In this case, incentives were awarded to the owners through car dealers and/or scrap operators, provided that they managed to purchase and scrap a minimum number of 200 two-stroke-engine cars per year. Scrappage incentives have also been given for replacing old buses and trucks (or their engines) with cleaner ones.

Denmark in 1994 introduced a DKr 6 500 bonus (US$ 1 000) for anybody who scrapped a car older than ten years, independently of the choice of replacement vehicle. The scheme lasted until the end of June 1995. The size of the incentive given progressively decreased (every six months). An overwhelming majority of vehicles were scrapped in the first six months: about 100 000 cars, slightly more than 6% of the fleet. About 11% of the owners replaced these with a new model and 19% bought another model older than ten years. A few households did not buy any replacement vehicle. The scheme was estimated to have caused between 0.6% and 1% reduction in the HC and NO_x emissions of the Danish fleet.

Box 2. Cont.

France implemented its first scrappage scheme (*Prime à la casse*) in February 1994. An incentive of Fr 5 000 (about US$ 950) was awarded if people scrapped cars that were older than ten years and replaced them with new models. This corresponded roughly to 6% of the average cost of a new car in 1994. Further discounts were offered by car manufacturers and car dealers. The scheme ended in June 1995. A second scheme (*Prime qualité automobile*) worth a bonus of Fr 7 000 ran from October 1995 to the end of September 1996. The minimum age was lowered to eight years. The bonus was reduced to Fr 5 000 for the replacement of relatively small sized cars. The two schemes retired an overall number of 1 560 000 vehicles. A maximum scrappage rate of 8% was reached in 1996. The number of cars retired *net* of those that would have been retired even without the scheme was estimated at about 700 000 (CCFA, 1997).

Almost simultaneously with France, **Spain** introduced (in April 1994) a similar scheme (*Plan Renove I*), giving tax relief ranging from Pta 85 000 to 100 000 (US$ 630-750) as a bonus for people who scrapped a car older than 10 years and replaced it with a new model. The 6 month scheme was renewed in October and ran to the end of June 1995 as *Plan Renove II*, with the minimum age for scrappage lowered to 7 years. In 1994 and 1995, respectively, 211 000 and 146 000 vehicles were scrapped and replaced under the schemes, corresponding to 11.5% and 7.4% of the fleet. The number of vehicles replaced *net* of what would have been replaced anyway was estimated to be 199 000 units in 1994, with a *negative* result of 23 000 in 1995 (Licandro and Sampayo, 1997). In 1996, a substantial reduction in the vehicle registration tax gave another incentive - independent from scrappage - to new car demand. The scrappage scheme was made permanent from April 1997 (*Plan Prever*).

Box 3. The most recent European schemes

In **Ireland**, from June 1995 those who scrapped their cars (with a minimum age of ten years) and replaced them with a new-model vehicle could reclaim £ 1 000 (US$ 1 600) of the registration tax on the new car. The scheme - initially supposed to last until December 1996 - was extended to the end of 1997. In 1995, 1996 and 1997, respectively, 5 140, 19 400 and 35 000 vehicles were scrapped - out of a fleet that had roughly 990 000 cars in 1995 and grew to 1 134 000 in 1997. The majority of the vehicles scrapped under the scheme were 10-12 years old.

In **Norway**, a scrappage incentive was introduced in 1996. NKr 5 000 (US$ 800) was given for scrapping a vehicle older than ten years. There was no compulsory replacement for the scrapped car. A considerable part of scrapped cars were replaced with second-hand vehicles. The incentive caused an *extra* 150 000 vehicles to be scrapped (7% of the fleet) with respect to the 'natural' annual scrapping rate.

Italy is the latest European country to introduce incentives for accelerated vehicle retirement. From January 1997 the government awarded bonuses ranging from L 1.5 million to L 2 million (roughly US$ 900-1 200) for each vehicle scrapped, according to the size (engine displacement) of the replacement car bought. The incentive was conditional on a *new* car being bought and on car manufacturers/dealers further reducing the car's price by an amount equal to the bonus. The programme expired in September 1997. It was then extended for 4 months with a fixed bonus of L 1.5 million for all car sizes. In 1997, about 1 148 000 old cars (about 4% of the fleet) were retired under the scheme.

From February to September 1998 a second scheme was introduced. This time an incentive of L 1.25 million or L 1.5 million was given, provided that the new replacement model had an average fuel consumption (whether diesel or gasoline) between 7 and 9 litres per 100 km or less than 7 litres, respectively. From October 1997, bonuses were also given if the new replacement models purchased were fuelled with LPG, methane or electricity. In the case of electric vehicles, the scrappage incentive is L 3.5 million and there is no expiry date for the scheme.

A year-long scrappage programme for motorcycles was also introduced by the Italian government in 1998 and renewed in 1999; a programme for scrapping buses has also begun. Further car-for-scrappage programs are currently being studied by the Ministry of Transport.

1. THE EFFECTS OF SCRAPPING SCHEMES ON THE CAR MARKET AND THE NATIONAL ECONOMY

1.1. New car sales

1.1.1. The main determinants of car demand

The demand for cars in any given time period is closely linked to the wealth of consumers. In more precise terms, it is linked to their available current income (i.e. the demand has a high-income elasticity) and to the value of all the financial and real assets inherited from the previous time period. The borrowing rate also plays a very important role in determining car purchases since most consumers have the opportunity to increase current available income by borrowing money.

The demand for cars is related to price but the decision to purchase a car is slightly different from that related to non-durable goods. It is a discrete (one-off) purchase and the relatively high cost of cars creates 'threshold effects' in aggregate car demand.

Since a car can last for many years, consumers will also have to decide *when* to replace their existing vehicles, by selling (or scrapping) them and purchasing others. They will postpone or anticipate their purchases according to the *expectations* of their future incomes, future car prices and the expected trends in other relevant variables.

All the links with current and future expected values of the economic variables described, in addition to the 'threshold effects' caused by the discrete nature of the related choice, make the demand for cars - as for most durable goods - not just heavily dependent on the economic situation, but much more volatile than economic growth (Deaton and Muellbauer, 1981).

The durable nature of cars introduces other differences with the demand for other economic goods. First of all, the demand for vehicles at any time can be split between *new*, or 'incremental' demand on the one hand and *replacement* demand on the other. Incremental demand includes all the vehicles (whether new or second hand) that are incremental to the existing fleet and, therefore, increases the overall fleet size. Replacement demand only accounts for the substitution of those cars that, for both economic and technical reasons, are considered obsolescent by their owners. Scrappage schemes only target the latter.[2]

Due to the fact that a vehicle lasts for several years, the decision to purchase it *now* will affect decisions taken by the owner in the future. For this reason, the history of past first registrations and the age structure of the fleet in use will contain important information concerning the possible future evolution of car purchases. Hence, any analysis of car demand should preferably take a 'dynamic' view covering some years, rather than a 'static' one considering only a year.

Moreover, the durable nature of cars introduces a difference between the simple purchase and *ownership* of a vehicle on the one hand and its *usage* on the other hand. The relevant costs are different - for instance, the purchase price of the car is different from the price of the fuel used to run it and the cost of holding and maintaining a vehicle for a given period. But usage and purchasing patterns interact and influence each other. For example, intense use of the car will deteriorate it sooner and may induce an earlier purchase of a newer vehicle.

It is always difficult to explain, and even more difficult to predict, the changes in car demand that result from a change in any of the variables just described. Understanding the market is rendered more difficult by the fact that the car is not a homogeneous, single good. On the contrary, the market is rather segmented according to the size of the car and its age. In particular, one can roughly outline two different kinds of car owners and purchasers. Higher-income groups are more likely to replace their vehicles with new models after anything from one to four years. They will sell their previous model on the used-car market. These models will then 'trickle down' through the second-hand market, being utilised successively either by lower-income groups or as a second or third car by the higher-income groups.[3] The market for new models and the second-hand market, though different, are closely linked. New and used cars are substitute goods, even if imperfect substitutes. Moreover, the market value of a used car owned by a consumer is part of his or her wealth (it is a real asset), therefore, it may influence replacement demand. Prices on the second-hand market are the fundamental link between these two market segments.

1.1.2. The economic effects of a scrappage incentive

It is convenient, for the purposes of the following discussion, to introduce a distinction between two main kinds of scrappage schemes. The first kind gives a reward for any scrapped car, *whatever the subsequent replacement decision taken by the consumer*. For instance, the bonus is awarded even if a replacement vehicle older than the scrapped one is purchased, or if no other cars are bought to replace the scrapped one. The second kind of scheme gives a bonus conditional upon a specific kind of replacement (typically, but not necessarily, a new model car). Both schemes are directed at influencing the *replacement* choices made by consumers. They do not target the choices of new cars, which are incremental to the actual fleet's size. However, the first one leaves the possibility for the consumer to choose other means of transport (public transport, motorcycles, bicycles, etc.), while the second one constrains the consumer to replacing his or her old vehicle with another one, within a given amount of time. Henceforth, the two groups of scrappage programmes are referred to as cash-for-scrappage and cash-for-replacement schemes, respectively. The term cash-for-replacement is used, when not otherwise specified, to indicate a scheme that requires the purchase of a new replacement vehicle - although, at least in theory, other kinds of replacements may be targeted by this programme (see example in section 3.3).

The first effect of a scrappage incentive is that of raising the value of the targeted vehicles. This increases the value of the assets owned by the consumers and ultimately raises their available incomes. According to the nature of the scrappage scheme, the increment in the available income may or may not be spent on a replacement vehicle. If the purchase of a replacement vehicle is *not* compulsory, the increase in the available income can be spent by the consumer on any other goods or even saved. Due to the high value of the transport services provided by cars, only a few owners choose not to replace their old vehicles.

If on the other hand, the award of the bonus is conditional upon the purchase of a replacement car, the effect of the scheme may be defined more as a 'price effect': it considerably lowers the cost of replacement.

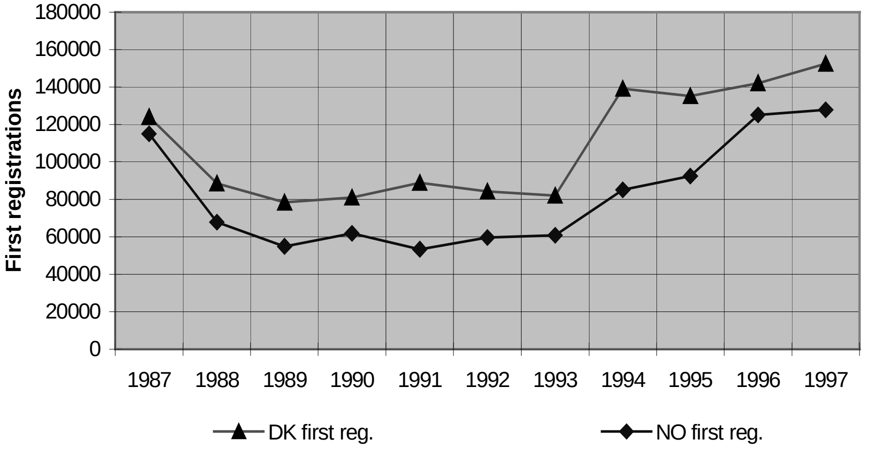
In both cases, the introduction of a scrappage incentive will have substantial effects on the market, increasing sales while the scheme is working. However, the characteristics of the cars sold under the two kinds of programmes will be different. Moreover, the time pattern of the increase in sales is also likely to be quite different.

Cash-for-scrappage schemes

In the short run, the cash-for-scrappage schemes should mainly increase the demand for second- hand vehicles. In practice incentives are given to the owners of older cars that are closer to the average retirement age. These vehicles are likely to be owned by lower-income groups or higher-income families who keep them as a second or even third car. As argued above, these groups are more used to purchasing second-hand replacement vehicles rather than new ones. There is only a minor, though significant, proportion of consumers who usually replace a car older than ten years with a new one. According to some evidence from the Danish, French and Italian markets, this proportion is 10% of the annual replacements.

Some of the owners responding to the incentives given, will bring forward their purchase with respect to what they would have done without the scrappage programmes. This bringing forward implies that, after the scheme has expired, there will be a reduction in purchases compared to what would have happened without the scheme.

Figure 1. **First registration trends in Denmark and Norway**



Source: ECMT elaboration on 1996 AAMA and ECMT data.

Figure 1 shows the effect of cash-for-scrappage schemes on first registrations in Denmark and Norway. The Danish scheme was introduced in January 1994 and lasted until June 1995. The bonuses given in the first half of 1995 were, however, much lower than those awarded the previous year and did not have any relevant effect. The graph shows a fall in cars sales, even if only small, after the sharp increase in 1994. As concerns Norway, an incentive was given during 1996. Although there was no fall in the subsequent year, the increase in first registrations was very low, contrary to the trend of the past three years. In both cases, the graph confirms that the anticipation effect lowered total car sales in the period after the scheme.

The effect should mainly concern the purchase of used cars. Of the Danish owners who chose to scrap their cars, 45% bought a second-hand replacement vehicle during the first six months of the scheme; only 11% of them purchased a new model in the same period. The other 44% used another existing car in the household, public means of transport or a bicycle (Transportrådet, 1995). There are no precise data as regards the replacement cars bought in Norway during the scheme. However, it is known that the used cars imported in 1996 were more than twice as many as those imported in the previous year (up from 7 000 to 19 000 (Transportøkonomisk Institutt, 1997).

However, the impact of cash-for-scrappage schemes may also indirectly concern the part of the market that usually purchases new cars. The demand for used vehicles will increase due to the scheme. This is likely to involve an increase in their market value. Some of the owners who are used to selling relatively recent cars (which are not eligible for the incentive) in order to buy a new model may decide to take advantage of the possible price increase and buy a new one, even if they cannot benefit from the scrappage bonus. Moreover, since the vehicles bought as a result of cash-for-scrappage schemes are mainly second-hand cars, they will have a shorter average remaining life as compared to new models. Therefore, in the midterm, they will again have to be replaced. This will give rise to another later 'wave' of replacement demands for second-hand cars, that ultimately will also increase the demand for new vehicles. This should imply that the fall in sales of new model cars due to the anticipation effect will probably have a rather limited impact and duration.

Cash-for-replacement schemes

The changes introduced by scrappage schemes will be greater when the schemes require the replacement of old cars with new models. Most of the consumers who want to participate in the scheme will have to change their habits. Not only will they have to bring forward their purchasing decisions to benefit from the opportunities offered, but they will also have to switch from used cars to new models. As some of them can hardly afford the purchase of a new car, they will probably have to choose cheaper models, relatively small-sized cars. When the incentive is given as a fixed amount of money, irrespective of the size of the car purchased, small models benefit most. The discount given by the incentive represents a much higher percentage of their total price.

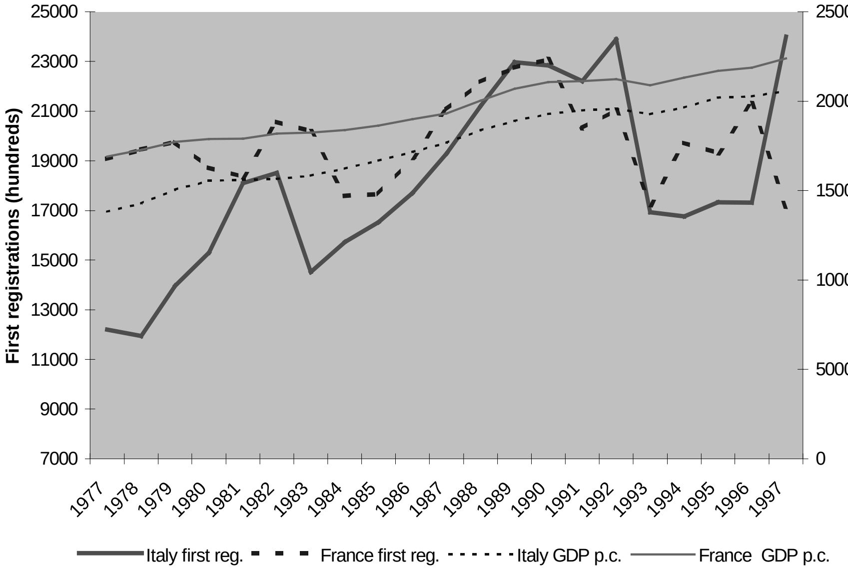
Consumers may choose a model with a size/engine displacement smaller than originally intended and/or they may bargain with the dealer to obtain a further reduction in the price of the new model they would like to buy, so as to reduce the difference between the values of the two cars. New and used cars are after all close substitutes: a fall in the price of one good also implies a fall in the other.

So, in the short run the increase in the demand for new models will be partially at the expense of a decrease in the demand for used cars. This will reduce the prices of all used vehicles that cannot get the scrapping incentive.[4] Therefore, it will also reduce the value of the one- to four-year-old cars owned by higher-income families. Their replacement decisions will also be affected. They may postpone the replacement, hoping for a more favourable situation just after the end of the scheme. Evidence from Italy shows that the demand for used cars starts increasing again after the programme - though the excess supply of used cars will take some time to be cleared. Therefore, these owners might wait for a future increase in the price of used cars.[5] The value of a used car decreases in time, so there is a cost in postponing its sale. Alternatively, they may replace their vehicle during the scheme.

Strong advertising campaigns made during scrappage schemes by car manufacturers and dealers and the general fall in new car prices may persuade even those owners not eligible for the scheme to choose the same period to replace their vehicle.[6] As a result of this, purchases of vehicles bought within the scheme as well as some vehicles bought outside it, may be brought forward. The anticipation effect may thus be even stronger than the one described above.

Figure 2 shows the first registration trends in France and Italy (left scale), together with their GDP per capita (right scale). From the early 1980s until 1993, the two countries have a very similar pattern of both GDP per capita and first registrations. In both cases there was a sharp increase during the second half of the 1980s. Then, in both countries the car market was heavily influenced by the world recession of 1993. But after that, France (where an incentive was given from February 1994 to September 1996) saw a sharp increase (from 1.7 million in 1993 to almost 2 million vehicles in 1994), while Italy remained in a deep crisis for three more years.[7] While the GDP per capita of the two countries was parallel during this period, their cars sales showed huge differences. In 1997, after the end of the French schemes, there was a sharp fall in new car sales; this was in spite of a relatively good economic climate, which can be attributed to the anticipation effect described above.[8]

Figure 2. **First registration trends in Italy and France**



Source: ECMT and OECD data, 1998.

Contrary to France, Italy saw in 1997 the highest number of first registrations ever recorded (2.4 million cars) following introduction of a cash-for-replacement scheme. Data on orders[9] placed with car dealers (Promotor, 10/1998) showed that Italy had a considerable increase in car sales in the last months of 1996 even before the scheme was introduced. This meant that the incentive reinforced an already existing increasing trend in sales.

Data related to Spanish car sales show a different trend due to significant differences in the implementation of the Spanish costs for replacement schemes. Up till now, no falls in the car sales have been recorded in the annual sales data. Annual first registrations have steadily and rapidly increased since 1994, the year when the scheme was first introduced. The Spanish scheme is still operating and it has been made permanent. There was only a very short interval without any incentive – a few months between the *Renove II Plan* and the *PREVER* plan. In these months, Spanish car sales experienced a sharp fall, compared to the corresponding months in previous years and went back to 1993 levels, year of the economic slump. Secondly, in addition to the scrappage incentive, in 1996 the government substantially reduced the car registration tax (from 12% to 7%), which gave a considerable incentive not only to replacement, but also to incremental demand. Finally, the ratio of cars per capita in Spain is significantly lower than in France or Italy (as shown in Figure 10 and 11 of section 3). In other terms, the Spanish market still offers more opportunities for an expansion in *incremental* demand. This suggests that the increase in Spanish GDP has raised 'new' demand more than in the other two countries - where the market is closer to saturation and replacement demand accounts for most of the annual car sales. The increase in Spanish incremental demand may have offset some decrease in the replacement demand due to any anticipation effect resulting from the scrappage schemes.

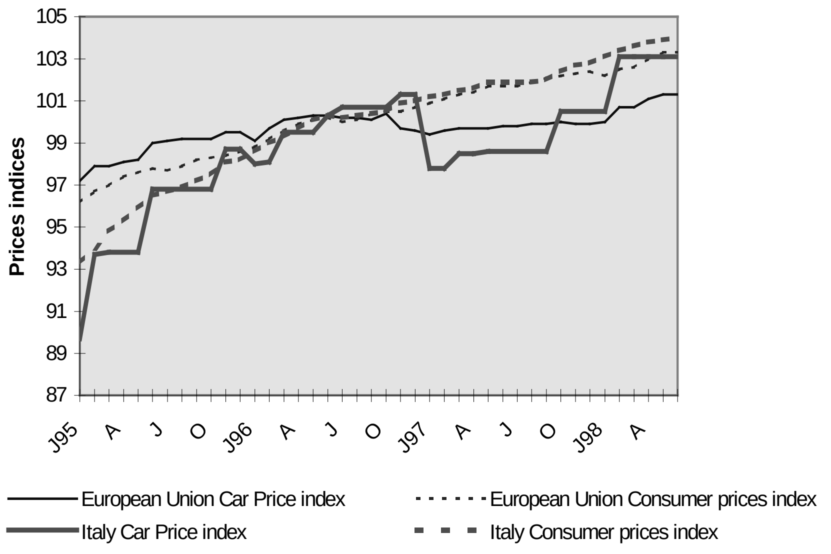
To sum up, in the very short run, cash-for-replacement schemes of the kind implemented in France and Italy increased the demand for new models much more than cash-for-scrappage schemes introduced elsewhere. However, the increase seems to be due mainly to bringing forward replacement decisions and may lead to severe subsequent falls in new car sales - particularly in those countries where the size of the fleet is stable or increasing only very slowly. When making longer term comparisons, the difference between cash-for-scrappage and cash-for-replacement schemes, as regards the increase in new car sales, may be smaller.

1.2. Prices and industry profits

Cash-for-scrappage schemes increase the demand for second-hand vehicles. This is likely to increase their prices. However, in an open economy, the increase in demand may be met by the importation of cheap, used vehicles from abroad. This will smooth the effect on prices, although it will attract relatively 'dirty' vehicles into the region. No particular change has been noticed in the new model prices with respect to the natural trend where these schemes have been applied.

Cash-for-replacement schemes that require a new model car have a completely different effect on prices. In typical OECD car market conditions, with no supply constraint and some excess production capacity they usually provoke a considerable fall in the prices of new models and of all the second-hand cars that are more recent than the age requirement imposed. First, car manufacturers and car dealers will lower the prices of bigger cars, trying to compensate for the higher demand directed at smaller vehicles. Then, due to the mechanisms explained above, there will be a decline in the prices of used cars as well. This in turn will reduce new-model prices. Moreover, often the introduction of the incentive opens a commercial war among the different car manufacturers trying to gain or just maintain their market shares. Finally, just after the scheme has expired, the anticipation effect will decrease the demand for new models with a further negative effect on prices. Figure 3 shows the fall in prices following the introduction of the incentives in Italy in January 1997.[10] The fall was about 3.5% in nominal terms - much more in real terms. The data shown in the graph represent the index for all cars sold on the market and not just those sold within the scheme (which are about 10% of the sample considered to build the index). The fall will be more severe for bigger vehicles, as their demand is likely to decrease in comparison with smaller cars. Moreover, in real terms, the fall has shown itself to be permanent and not compensated by later price increases.[11] The fall in real prices of cars has to be judged by taking into account the general decrease in world prices for this good. Scrappage schemes, however, anticipated and strengthened the trend.

Figure 3. **Price indices in Italy and the European Union (base 100 in 1995)**



Source: CCFA, 1997.

The short-term growth in new car sales should, other things being equal, considerably boost the profits of the car industry. However, this potential increase will be considerably reduced by three elements. First, the general price decrease just mentioned. Second, the shift of the new registrations towards smaller cars (shown for instance by the Italian data in Table 1), on which both the industry and the car dealers have smaller profit margins. In addition to that, profits may be lowered further in the midterm by the anticipation effect. Part of the profit increase will not be a real increase, but rather a shift in time.

Table 1. **First registrations in Italy by engine displacement (1996-1997)**

	1996		1997	
Displacement (litres)	Cars	%	Cars	%
< 0.9	89 479	5%	180 446	7%
0.9 - 1.3	626 305	35%	984 379	40%
1.3 - 1.5	245 877	14%	339 275	14%
1.5 - 1.75	350 588	20%	427 067	17%
1.75 -2.0	364 079	21%	425 869	17%
2.0 - 2.5	81 112	4%	91 730	4%
>2.5	16 989	1%	19 731	1%
Total	1 774 429	100%	2 468 497	100%

Source: ECMT elaboration on 1998 ACI data.

Finally, past experience has shown that there may be a redistribution of the market shares of the different firms in a given country. The car manufacturers that have better small vehicles at the time of the incentive will obtain a considerable share of the total registrations. Therefore, not all the industries will be able to take real advantage of the scheme.

Aside from a potential increase in profits, scrappage programmes have other undeniable advantages for car manufacturers. The car industry has rather high fixed costs and needs to produce a certain amount of vehicles to reach the optimal scale of output. A period of low sales will probably accumulate large inventories for both the manufacturers and car dealers. This will oblige them to lower selling prices and introduce privately funded, buy-back programmes for old cars in order to stimulate new purchases. If the state or some other external subject[12] pays for part of this price reduction, it will reduce considerably the costs faced by the manufacturers. It may also help them to smooth the effect of the economic downturns and to reach the optimal production scale (but the anticipation effect may give a later additional cost).

All in all, it is difficult to assess the effect of scrappage schemes on the car industry. *Cash-for-scrappage* schemes are likely to have positive though limited effects on sales and profits, both in the short and midterm. The effects of temporary *cash-for-replacement* schemes are beneficial in the very short term (while the scheme is operating), but they have a cost in the mid to long run that, particularly for some firms (those that usually do not sell small-sized vehicles), may offset the short-term advantages.

1.3. The effects on the national economy

It is commonly held that in countries with a strong national car industry, cash-for-replacement schemes may introduce some positive effects on GDP growth and employment. Moreover, it is claimed that this kind of scheme benefits public finance, since extra tax revenues (VAT, excise and registration taxes) on new vehicles could be greater than the total cost of the scheme.

On the first point, there are not many data available to assess it. An estimate made by the Central Bank of Italy (*Banca d'Italia*, 1998) suggested that about 0.4% of 1997 GDP growth (out of a total increase of 1.5%) could be attributed to the increase in car sales. 1996 to 1997 saw the sharpest increase in first registrations experienced in the last 20 years. The number of cars registered increased by about 40%, from 1.74 million to 2.47 million. But this cannot be entirely attributed to the effect of the scrappage incentive. The market, which had been stagnant for four consecutive years, was already showing some signs of recovery at the end of 1996. The orders placed with car dealers were already increasing by that time. Part of the cars replaced under the scheme would have been replaced anyway, without any expenditure by the state. Moreover, a longer-term analysis should be made for a more complete evaluation, in order to forecast any possible future fall in the car market due to the anticipation effect - there were signs of a considerable decrease in first registrations in January 1999. In conclusion, there are not sufficient data to properly assess the effect on the GDP of the scheme. It was surely positive in the short term but the longer term impact is highly uncertain.

As concerns the public finances, the view described above is over simplistic. Three fundamental elements are not taken into account by the simple difference between the cost of financing the incentive and the VAT/registration tax revenues raised by it. First of all, some of the cars scrapped will unavoidably be vehicles that would have been scrapped and replaced anyway in a rather short time. The cost of incentives for such scrapping is a dead-weight loss for the state and the community. The taxes paid on them would be paid anyway to the state, without any incentive.

They must, therefore, not be taken into account when computing the effect of the scheme on public finances.

Moreover, the scheme increases car sales and the related taxes in the very short run, but is likely to *decrease* them in the midterm. A corresponding decrease in tax revenues should be expected, compared to the benchmark alternative. Therefore, rather than an increase in tax revenues, the scheme is more likely, once again, to cause an anticipation of them.

Finally, as the consumer's budget is fixed, the increased purchase of cars is likely to reduce the income available for other expenditures, in particular as regards other durable goods. During 1997, for instance, Italian data showed a fall in expenditures related to furniture, household maintenance and construction. VAT is also paid on these items. If the scheme brings about a fall in their consumption, the state will correspondingly have lower revenues from them.

Therefore, it is rather incorrect, especially without in-depth quantitative analyses, to claim that public finances will benefit from cash-for-replacement schemes.

2. THE EFFECTS OF SCRAPPAGE PROGRAMMES ON THE ENVIRONMENT

2.1. What are the main environmental impacts to be evaluated?

There are two main factors concerning fleet renewal that may have significant effects on the environment. The first is the change in atmospheric emissions due to the replacement of old vehicles with new ones. As newer vehicles usually have much better performance than very old ones, from an environmental point of view, it is believed that speeding up fleet renewal by getting rid of the 'dirtiest' model years can substantially curb atmospheric pollution.

The second factor is the accelerated transformation of natural resources (used to build new vehicles) into waste (the leftovers of old vehicle scrappage processes) through car construction and dismantling. Accelerating the car scrappage rate may have negative environmental effects as it increases all the impacts related to the vehicle: production, scrapping, dismantling and the recycling processes.

While the first element mentioned can be considered as a 'variable' external cost, in that its dimension increases proportionally with the activity level (the mileage travelled) of the vehicle considered, the second one has to be deemed as a 'fixed' external cost, as it relates to processes made once and for all for any car.

Where the external costs produced by a vehicle through its whole life-cycle have to be estimated, the *variable* share of total costs will increase as the car's life increases. On the other hand, considering external costs *per v-km* travelled, it is clear that the share of fixed external costs will be higher the shorter the car's life.

For these reasons, the two aspects mentioned are likely to pull the environmental evaluation of scrappage schemes in opposite directions. On the one hand, shortening the life of older vehicles will have a positive effect, because it may reduce the variable external costs they produce. On the other hand, it will have a negative long-term effect, since it increases the number of production and dismantling processes involved in the car fleet's renewal; or put in other terms, it will increase the fixed external costs per v-km.

For temporary, 'one-shot' schemes, the fixed environmental costs of car construction and dismantling can be considered as a 'sunk cost'. Once the car is built, there is no way to reduce the environmental costs due to the manufacturing processes. Even if the impact due to car scrapping and dismantling could be brought forward or postponed, but not avoided, it would be generated anyway. So they should *not* be accounted for in the environmental analysis. But this is no longer true for permanent scrappage programmes or for scrappage schemes that are repeated more than once. This is why, for the general assessment of scrappage schemes, it is important to understand the relative magnitude of the damage involved by these two environmental aspects.

Previous studies have suggested that the external environmental costs due to the 'upstream' and 'downstream' parts of the car's life-cycle (i.e. car construction and dismantling) are considerably lower compared to those of car usage. Teufel, *et al*. (1993) indicate that about 30% of a car's total lifetime energy requirement is due to its production and end-of-life phases. The remaining 70% is due to usage. This shows that the analysis should focus more on the car usage phase.

However, the energy requirement is not a completely satisfactory indicator of environmental impact. For instance, the same amount of gasoline consumed can bring about a different impact if it is used within a densely populated, urban area or in the middle of the countryside. Table 2 shows some results from the ExternE Transport Research Project on the external costs of transport (Bickel *et al*., 1997).

Table 2. **Estimated external costs from car usage**

Fuel used	**Vehicle model year** (technical characteristics)	**Damage from use** (trips between cities) (ECU/1000 v-km)
Gasoline	EURO-2 engine	7.60
Gasoline	1990s with TWC	10.19
Gasoline	1980s with TWC	17.63
Gasoline	1980s non-catalysed	43.22
Diesel	1990s-diesel	24.37
Diesel	1980s-diesel	30.24

Source: Bickel *et al.*, 1997.

The external costs reported in the third column were evaluated in terms of the consumers' willingness to pay, related to the given physical damage to human health or the environment. The physical damage has been evaluated according to a bottom-up, impact-pathway methodology. In other words, it takes into account the trip's location, the atmospheric dispersion pattern of the pollutants emitted and the spatial distribution of subjects exposed to pollution. These figures do not include the effects of car accidents on human health nor the external costs of noise pollution. Moreover, the results illustrated refer to a trip between two German cities (Stuttgart and Mannheim). Trips made inside a town have shown considerably higher damage.[13] The third column can, therefore, be considered as a conservative representation of external costs of car usage.

The same study estimates the external costs due to the upstream and downstream process, based on a literature review made by Bickel *et al*. (1997). Assuming that a car lasts about 10.6 years and runs 150 000 km in all, an average cost of 6.6 ECU/1 000 v-km was estimated due to the construction, dismantling, scrapping and recycling phases. Taking a car lifetime of seven years (the lower age limit used in the French and Spanish schemes), with 100 000 km run during this time, the average cost per km rises to about 10 ECU/1 000 v-km.

All these results are subject to substantial degrees of uncertainty, yet they clearly suggest that for older model cars (from the eighties and earlier models) the upstream and downstream impacts are substantially lower, compared to car usage (6.6 against more than 40 ECU/1 000 v-km). However, this is no longer true for the most recent models that have considerably reduced emissions. The damage per v-km caused by a Euro-2 engine over the car's lifetime is of the same order of magnitude as the damage arising from its construction and dismantling phases. It must be remembered that the estimates of external costs given in Table 2 are rather conservative and average external costs from car usage may be higher than indicated, in particular when considering those trips made within densely populated urban areas. But as other studies have confirmed, (see, for example, ECMT, 1998), the order of magnitude of the estimate is unlikely to show major variations.

This means that the assessment of *actual* scrappage schemes, aimed at getting get rid of old, 'dirty' model cars, should focus more on the usage phase than on the other processes of a car's life-cycle. The same conclusion may no longer be valid if applied to a hypothetical scrappage scheme implemented some ten or fifteen years hence that tries to get rid of cars with Euro-2 engines.

The increasing amount of recycling of various vehicle parts, which is helped by the improved ecological design of newer models, is likely to decrease the upstream and downstream damage as well, so that the actual balance between the 'fixed external costs' and the 'variable external costs' might be re-established. On the other hand, recycling processes are energy consuming and produce some amounts of pollution and are definitely not without costs in environmental terms. This means that it will not be possible to reduce fixed environmental costs beyond a certain level.

To sum up, temporary, 'one-shot' schemes may have positive effects on the variable share of the environmental costs and no relevant effects on the fixed share of these. No definite conclusion on the environmental effects can be drawn at the moment as concerns *permanent* scrappage schemes, as it is too difficult to forecast technological evolution and its consequences for the environment. The present available data[14] suggest that in the near future a *permanent* scheme may even have negative environmental effects. Any actual proposal to implement such a programme should be carefully and thoroughly evaluated, taking into account both kinds of external cost and making, whenever possible, quantitative estimates. There might even be good grounds, in the future, to encourage longer car lives instead of scrapping earlier, for example to reduce demand for raw materials under possible sustainable development strategies.

The present publication focuses on the environmental impact produced during car operation (i.e. exhaust gas emissions), since it aims to evaluate current experience of scrapping old vehicles.

2.2. The estimate of the change in atmospheric emissions

2.2.1. The mechanism of scrappage programmes

The main idea behind scrappage programmes is relatively simple. Some studies[15] have shown that the distribution of fleet emissions is rather skewed. A small proportion of the fleet produces a considerable share of the fleet's total emissions, particularly as regards CO and HC (as shown in Table 3). Old-model vehicles emit much more atmospheric pollutants per km run than new cars. Most of the 'dirtiest' vehicles are very old cars.

Based on these considerations, the conclusion seems to be straightforward. If it is possible through an incentive programme to remove the small group of 'gross emitters' and replace them with more recent, cleaner vehicles, then a considerable reduction in atmospheric pollution will be achieved at a relatively limited cost, since the incentive will have to apply only to the relatively small number of 'gross emitters'. Though contrary to the 'polluter pays' principle, this may also represent a feasible way to reduce environmental costs. Via the state, the community (damaged by atmospheric pollution) pays the owners of 'dirty' vehicles to replace them with cleaner ones, thereby reducing the emissions.

The implementation of this simple idea is in reality far more complicated than this short description would suggest. First, as will be discussed in section 2.3.1, there is not a simple linkage between the vehicle's age and its average emission factor. Emissions vary greatly even among vehicles of the same model year (Hall, 1995). Second, the *total* emissions produced in a given time period depend on several variables. The scrappage programmes are directed at modifying a limited number of them in a precise way. These variables interact among themselves and are also linked to other factors affecting the owner's behaviour and, through this, overall fleet emissions. This direct and indirect interaction will influence the effectiveness and cost-effectiveness of the scrapping programme implemented and might produce a result which is far from that expected.

Table 3. **Distribution of HC and CO emissions in the car fleet of the USA**

Fleet's decile	**HC emissions** (% of total)	**CO emissions** (% of total)
10^{th}	44.2%	31.7
9^{th}	15.2%	19.5
8^{th}	10.7%	14.4
7^{th}	8.2%	10.6
6^{th}	6.6%	7.8
5^{th}	5.3%	5.7
4^{th}	3.9%	4.2
3^{rd}	2.8%	2.9
2^{nd}	1.9%	2.0
1^{st}	1.1%	1.1

Source: Glazer *et al*., 1995.

2.2.2. Main variables determining the fleet's emissions

The total emissions of any atmospheric pollutant are likely to increase with the number of vehicles belonging to the fleet, i.e. the *fleet's size.*[16] Besides that, the amount of polluting emissions will be positively correlated with the average number of *vehicle miles travelled* (VMT) per year, which in turn depends on a multitude of economic and social factors affecting transport demand and supply.

The third fundamental variable is the *average emission factor* of the car fleet, i.e. the average quantity of any given atmospheric pollutant emitted *ceteris paribus* (for any given, well-defined driving pattern) per km travelled. In strict technical terms, it is not particularly meaningful to indicate an average emission factor for the whole fleet. Some fundamental distinctions should be introduced as concerns the type of fuel used, the age cohort considered and the particular technology (e.g., catalysed or non-catalysed vehicles). Nevertheless, a representative average emission factor for the whole fleet will be maintained in most of the following discussion, because in many cases it can make the exposition clearer, without relevant loss of accuracy. More detailed comments will be introduced when relevant.

Finally, any calculation of road transport emissions has to consider the *driving pattern* of the vehicles considered, as this significantly affects the average emission rate of any vehicle.[17] The average quantity of any pollutant emitted per km may show huge variations according to the driving speed, the extent of stop-and-go driving, idling times and the number of cold starts made.

While variables such as the fleet's size and the average VMT clearly show a positive correlation with total fleet emissions for any pollutant considered, different driving patterns may have different effects according to the particular pollutant analysed. No short, synthetic description of the relationship between the average vehicle speed (used to represent the driving pattern) and the emission factor is likely to be sufficiently accurate. One important, general point must be mentioned. Congestion is more likely to happen in urban areas. In urban areas, an increase in congestion usually implies a lower average speed, more stop-and-go driving and an increase in the emission rate for most atmospheric pollutants, apart from NO_x (ECMT, 1998c). Thus, on average, atmospheric emission rates for most pollutants considered are higher under typical *urban* driving patterns than under other conditions.

The implementation of any programme to accelerate vehicle retirement may have direct or indirect effects on all the four variables mentioned. All these possible effects should be evaluated. However, as the following paragraphs will show, mainly two of them, the emission rate and the average mileage travelled, are critical for the overall assessment.

2.2.3. Estimating the size of the reduction achieved

The amount of pollution produced by a single vehicle during a given time period, say one year, depends on its average Emission Rate (ER), in grams of each pollutant emitted per km run, driving patterns and the VMT during the year. Scrapping an old vehicle before its 'natural' retirement age implies avoiding the emissions it would have caused during its expected remaining life, had it not been scrapped in advance. If there are statistical (average car's life in a given fleet) or technical reasons to suppose that the old vehicle scrapped would have lasted L more years, then the total amount of emissions avoided can be simply represented as:[18]

$$\textit{Emissions avoided by scrapping an old vehicle} = ER_{old} \cdot VMT_{old} \cdot L_{old}$$

where the subscript 'old' indicates that an aged model car has been scrapped.

On the other hand, the owners of a scrapped vehicle will have to replace in some way the amount of mileage travelled with the old car. Whatever the replacement vehicle they use, it will again produce some emissions at some average rate for a certain amount of mileage during all the years L considered above. Hence, the reduction in atmospheric emissions achieved through the scrappage will not be as large as suggested. The emissions produced by the replacement vehicle will have to be subtracted from the amount previously indicated as 'emissions avoided'. Thus, the *net* reduction in emissions achieved by scrapping an old vehicle will be as indicated below:

$$\textit{Net emissions avoided by scrapping an old vehicle} = (ER_{old} \cdot VMT_{old} - ER_{repl} \cdot VMT_{repl}) \cdot L$$

where the subscript 'repl' indicates the average emission rate and mileage travelled per year of the replacement vehicle chosen by the consumer. This assumes driver behaviour and driving patterns are not altered by the change of car. It is worth underlining that, unless the design of the scheme introduces particular requirements for the replacement vehicle, there are no reasons to assume that it will be more recent than the scrapped one. Moreover, it can also be a different means of transport. It will not necessarily be another car.

Finally, if a scrappage programme manages to get rid of a number N of old cars and replaces them with the same number of more recent vehicles, the overall amount of emission reduction achieved can be represented approximately by:

$$\textit{Net emissions avoided by scrapping}\ \mathrm{N}\ \textit{old vehicles} = (ER_{old} \cdot VMT_{old} - ER_{repl} \cdot VMT_{repl}) \cdot L \cdot \mathrm{N}$$

ER_{old}, VMT_{old}, ER_{repl} and VMT_{repl} will in this case be the average characteristics of the populations considered and will no longer represent the performances of a single vehicle.

The representation given above is a slightly simplified version of the formulas given by some American guidelines that indicate how to compute the emission reduction achieved through the scheme (see, e.g. California EPA-ARB, 1998).

Thus, to make a scrappage programme more effective from the environmental point of view, i.e. to increase the emission reductions of the pollutants concerned, decision-makers may act on four alternative variables.

First, they can try to make the difference between the average emission rate of the vehicles scrapped and the average emission rate of the replacement vehicle as large as possible. They have to ensure that the vehicle scrapped is properly *selected* among the 'gross emitters' and that the replacement vehicle is reasonably clean.

Second, they should select vehicles for scrapping that have a significant remaining life L. It must be remembered that all vehicles scrapped with an incentive *would be scrapped anyway in a few years time*, even without any intervention. If the vehicle purchased by the scheme was already very close to retirement, some money would be spent on a reduction in emissions that was negligible or even null. This will result in a dead-weight loss for the economy, whatever the body financing the scheme.

Decision-makers may also act on the VMT, trying to ensure that the vehicle scrapped was habitually run on a certain minimum amount of km per year. It would not be beneficial to pay for scrapping a vehicle that (although not necessarily close to retirement) was little used. Besides, where the replacement results in a reduction in the amount of pollutants emitted *per km,* the larger the amount of km driven per year by the owner, the bigger will be the total emission reduction achieved.

Finally, the remaining option to obtain a large reduction in the emissions considered is that of replacing a large number N of cars (always trying to select properly the scrapped and the new vehicles).

The way in which these mentioned variables are influenced is fundamentally determined by the design of the scheme.

2.3. The design of the scheme and effects on the relevant variables

2.3.1. Average emission factors

There are two main routes to increasing the difference between the average emission rates of scrapped and replacement vehicles. The first tries to pick up and eliminate the 'dirtiest', older vehicles. In practical terms, this has been done mainly through age constraints imposed on the eligibility of vehicles and through the use of inspection programmes to test emission rates. The second route focuses more on the replacement vehicles and tries to ensure that they are chosen among the 'cleanest' available models. The most common requirement introduced for this purpose has been the constraint of purchasing a new model to replace the scrapped one. One could also design schemes so that the bonus offered is differentiated according to the environmental performance of the vehicle purchased. For example vehicles meeting more stringent emissions regulations to be introduced at a planned future date could make the purchaser eligible for greater cash payments.

It is unlikely that scrappage programmes can act simultaneously on both routes in practice. In most cases, owners of old, high-emitting vehicles are very different from the potential purchasers of new-model cars. They have different socio-economic characteristics, different incomes, habits and behaviour. It is very difficult, for instance, to persuade the owner of a car - older than 15 years - who is used to purchasing rather cheap, second-hand vehicles to suddenly buy a new model. Schemes that try to achieve this particular replacement will either attract a very limited number of scrapped cars or they will have to give very high monetary incentives to persuade households to change their habits. Almost none of the programmes implemented has followed this path. The Hungarian scheme may be considered as the only exception (see Box 2 and section 3.1). It selects old, two-stroke-engine models and requires their replacement with new, clean vehicles. The scheme has scrapped a rather limited number of vehicles to date.

All programmes implemented in the USA, plus those of Canada, Denmark and Norway have chosen the first approach. They have imposed requirements on the selection of the retired vehicles rather than on the new vehicles. All the other European schemes, apart from the Hungarian one, have chosen the second approach.

'Local' pollutants

Separate consideration of the pollutants previously indicated as 'local' (PM, NO_x, SO_x, HC, CO) and the greenhouse gases (CO_2) may make the discussion about emission factors clearer.

As concerns the first group, there has undoubtedly been considerable technological progress in the last decades, which, together with the strengthening of environmental regulations, has led to substantial reductions in average emissions for most pollutants. Within the European Union (EU), the current regulation in force sets standards for CO, HC and NO_x emissions at one-tenth the level of the first limits introduced by Directives 70/220/EEC and 77/102/EEC. Further reductions have just been approved by the European Council (98/69/EC) and will enter into force within a few years. Similar considerations apply to the emission of particulate matter from diesel vehicles. The current limit is about 2.7 times lower than the one previously established in 1988. Further reductions will be required in 2001 and 2006.

The EU standards apply to new vehicles introduced into the market. They cannot be considered as representative of the average emission factors for the vehicles that are already in use. As a vehicle ages, its emission rates are likely to worsen with respect to original performance. This will happen to any vehicle and *a fortiori* in those cases where there is no proper regular maintenance. Therefore, a car belonging to an old cohort is likely to show higher emission patterns with respect to new models, not only because of the different regulations in force at the time of the vehicle's construction, but also because of its poorer condition.

These are the two main reasons why a vehicle's age is usually taken as a proxy for its average emissions characteristics and why it is commonly believed that lowering the age of the car fleet will lead to a substantial decrease in emissions for most pollutants. The scant evidence available suggests that, in addition to the main points raised above, there are some important caveats to be underlined.

First of all, other behavioural parameters may have a major influence on emission patterns. The overall distance covered by the vehicle during its lifetime (which is only approximately correlated with its age) and the type and frequency of maintenance will heavily influence a car's environmental performance due to the effects of 'wear and tear'. The kind of fuel used and other technological characteristics (e.g. presence of catalytic devices and their maintenance conditions) will also affect the quality and quantity of the pollutants emitted by each cohort. Old diesel vehicles will presumably have relatively high emissions of particulate matter, which may be negligible for gasoline cars from the same model year. The reverse is true for lead emissions.

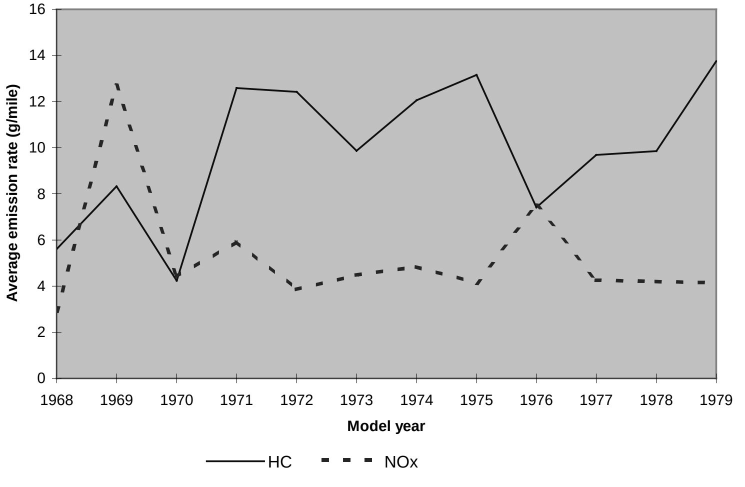
In addition, the fleet's ageing is unlikely to have the same effect on the emissions of all pollutants considered. For instance, CO emission rates show a higher correlation with car age than NO_2 - the latter depending essentially on combustion temperature, which is not so closely linked to the engine conditions.

Ceteris paribus, engine displacement will also affect the quantity of pollutants emitted. Engines with a higher displacement are likely to show higher fuel consumption and higher emission rates, compared to smaller vehicles of the same age cohort.

Data collected by the Illinois 'cash for clunkers' programme (based on a sample of about 150 vehicles) showed that the link between emissions and age is far from straightforward (see Figure 4). This suggests that using only the age indicator might not allow a scrappage programme to gather and retire the real 'gross emitters'.

Similar problems may even arise with the replacement cars. When the vehicle retirement scheme does not require the purchase of new model cars, it is usually assumed that the replacement vehicle is an 'average' model, representative of the fleet in use. The average emission rates of the fleet in use are probably lower than those of the older, scrapped vehicles. But some replacement vehicles might be 'gross emitters' themselves, if no other selection criterion is adopted by the programme (or by regulations in force) to avoid it. A survey made during the implementation of the Danish scheme, where no particular requirement was introduced for the substitution vehicle, showed that about 19% of the replacement cars purchased were older than ten years. These kinds of problems are avoided in cash-for-replacement schemes imposing the purchase of new model cars. It is very unlikely that a new model turns out to be a 'gross emitter' in its first three or four years of life; the period usually considered for the assessment of the scheme. However, cash-for-replacement schemes may bring about different complications, as will be explained in section 2.3.3.

Figure 4. **Average emission rate (g/mile) by model year of the scrapped car, as measured by the Illinois EPA's pilot programme of 1992**



Source: Illinois EPA, May 1993.

'Global' pollutants

As regards CO_2 emissions, the European historical trend for average fuel consumption (to which CO_2 emissions are strictly linked) shows that replacing old vehicles with newer ones does not always guarantee a reduction in average vehicle emissions, unless both the scrapped and the replacement vehicles are carefully selected among the most and the least fuel-intensive cars.

The thick line in Figure 5 shows a sharp decrease in average fuel consumption during the early eighties; with a minimum in average consumption reached in 1986-1987. After that, there is an evident increase that lasts until 1993. Then fuel consumption starts declining again, although rather slowly. A new vehicle purchased in 1993 was on average less fuel efficient than a new model purchased seven years before. Some national trends are even more pronounced. The Italian curve shows that a new model purchased in 1995 on average consumed more than new models sold during the twelve preceding years. In such a case, a scrappage programme that replaces a car older than ten years with a new one may lead to an increase in CO_2 emissions.

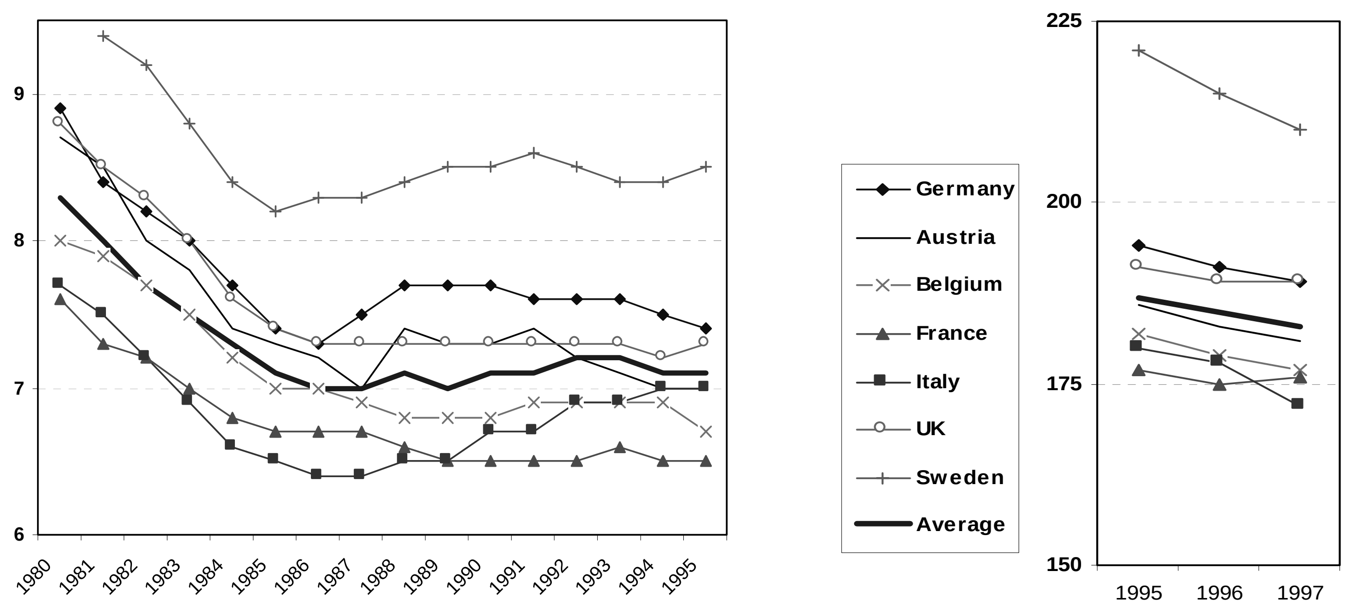
In the cash-for-replacement schemes implemented in France, Ireland, Italy and Spain data also show that most of the cars bought had a small engine displacement, suggesting that the replacement vehicles had consumption below the average. However, it is also important to note that this was not because decision-makers deliberately chose to favour smaller engines. In some cases the opposite was true. The last French scheme (*Prime qualité automobile*) and the first Italian scheme gave a higher incentive for purchasing larger cars.

No definite conclusions on the effect of the French, Greek, Irish, Italian and Spanish schemes can be drawn from the data shown in Figure 5. More detailed analysis of the engine-displacement and fuel-consumption characteristics of the scrapped and replacement cars is required. Estimates of the fuel consumption characteristics for the cars that would have been sold had the scheme not been implemented are also required. It is even more difficult to judge *ex-ante* the effect on greenhouse gases emissions of the cash-for-scrappage schemes, where the replacement car was probably an 'average', representative model taken from the fleet in use at the time of the scheme.

Figure 5. **Weighted Average Fuel Consumption and CO_2 Emissions, All New Cars**

Fuel Consumption
Test cycle - 80/1268/EEC
(Litres / 100 km)

CO_2 Emissions
Test cycle - 93/116/EC
(Grams CO_2 / km)



Note: Weighted average for 7 countries (1995-187g/km; 1996-185g/km; 1997-183g/km).
Source: ACEA/OICA, 1999.

Nevertheless, at least one important element may be added to the assessment. The graph reveals that in Western Europe care has to be taken to design scrappage schemes in ways that ensure they do not result in an increase in total fleet CO_2 emissions.[19]

2.3.2. Vehicle Mileage Travelled (VMT)

Section 2.2.3 showed that a scheme would be more successful if it managed to scrap a *substantial amount of mileage* run by 'gross emitters'. To do this, the body that organises the scrappage programme should try to ensure that the scrapped vehicles were used as a principal means of transport and not kept for marginal use only. Scrappage schemes are less effective if replacement vehicles are driven more intensively than retired vehicles and this also has to be taken into account.

Although scrapping programmes are not directly targeted at *changing* the overall fleet's VMT, it is often believed that they may have an effect on it. It is known that the average mileage travelled per car changes according to the age of the vehicle. Newer cars run considerably more km per year than the older cohorts, as suggested from data in Table 4. More uncertain and dependent on the country analysed, is the estimate of how much more new vehicles travel compared with old ones. Data from the USA seem to suggest that the ratio between the average distance travelled by a new passenger car and one ten years or older is around 2.[20] Some European data (Transportrådets, 1995) suggest a slightly lower ratio, but still of the same order of magnitude (about 1.7). Based on this evidence for VMT, it might be expected that the substitution of old cars with newer ones will substantially increase overall VMT per year, for all those years when scrapped vehicles would still have been in use had the scheme not been implemented.

Table 4. **Average annual miles per automobile by automobile age in USA (1990)**

Vehicle age	Miles
Under 1 year	19 800
1 year	16 900
2 years	16 300
3 years	14 400
4 years	13 800
5 years	12 600
6 years	12 900
7 years	12 400
8 years	12 300
9 years	11 200
10 years and older	9 300

Source: Transportation Energy Data Book, 1997.

These are, however, only statistical descriptions and do not suggest any explanation as to the causal linkages between car age and average VMT. Social and economic factors, rather than the characteristics of newer model vehicles, are mainly responsible for increases in road transport demand. Thus an increase in transport demand may tend to induce more purchases of both new and used model cars (both as incremental and as replacement demand). Households may select either newer, more expensive vehicles or cheaper second-hand ones, according to their income and transport demand. For instance, frequent travellers will tend to buy newer models, as they are usually more comfortable, safer and may also be more fuel-efficient. On the other hand, the better characteristics of newer models may also cause an increase in the average mileage travelled per car, since the owners may feel safer, spend less on fuel and find travelling more enjoyable. If this second causal link has any real effect, lowering the age of the car fleet might bring about an increase in total mileage travelled with respect to what would happen without any scrappage programme. This in turn would negatively affect the emission reduction achieved by the programme.

There are not sufficient data to evaluate the effect of lowering the fleet's age on total VMT. For those scrappage schemes that do not require the consumer to buy a new model when replacing the old car, there is now a common agreement on maintaining the hypothesis of a constant overall VMT before and after the implementation. Some surveys - based on questionnaires from the owners of cars just replaced under some USA pilot programmes (UNOCAL's SCRAP, Illinois and Delaware programmes) and under the Danish programme confirm the validity of this hypothesis.[21]

It is uncertain whether the same hypothesis is true for cash-for-replacement programmes. In some cases, the newest models made available at rather cheap prices include some options - air conditioning, air bags, hi-fi - that were once costly and rare. In these cases, the improvement in the vehicle characteristics might have some significant effects on the VMT of replacement vehicles. Moreover, the improved reliability (e.g. winter starts) of new cars may have a significant impact on frequency of use and length of average journey. No surveys have been made to obtain information on any possible change in the average VMT where these schemes have been implemented. Nor is there definite empirical evidence suggesting that an improvement in variables such as comfort and safety will increase passenger transport demand.

The case is slightly different for improvements in fuel efficiency. As for most demand curves related to 'normal' goods, empirical evidence shows that a reduction in (travel) costs leads to an increase in consumption, i.e. the mileage travelled and vice versa. The data shown in Figure 5 suggest that new models may even be driven *less* than old ones depending of course on change in the price of fuel at the pump.

In conclusion, there are no grounds to exclude the possibility that the scrapping schemes that require replacement with a new model vehicle will lead to an increase in the overall VMT. An increase in total VMT due to the scheme is possible but the points discussed above suggest that if there is any increase, it will be rather limited in size.

2.3.3. Interactions among the criteria imposed for selection of vehicles

Aside from the direct effects of scrappage schemes just outlined, there may be important indirect interactions among the different criteria imposed that affect the final result. They will mainly concern emission rates and average VMT.

To ensure that only vehicles with a high emission rate are retired, only old cars are made eligible for the schemes. The age requirements of the schemes implemented in America and Europe vary from 7 up to 15 and more years minimum age. The market value of *old,* used cars belonging to the age cohorts selected will be increased. The scrapping incentive effectively puts a lower bound on the market value of old vehicles eligible for the scheme. They will not be sold on the used-car market for an amount of money below the bonus. Moreover, if the scheme is large enough, there will also be a shortage in the local supply of this kind of vehicle. On the other hand, there will always be a lower-income group of consumers that demands these cheap, old models. As a consequence, there will be either imports of old vehicles from other regions/countries or a price increase for the model years concerned. In the first case, the scheme will not lower the age of the fleet as much as expected. In the latter case, some worse-off households, who were just about to replace their cars, will have to either direct their purchasing decisions at even older models or keep the current car for some more years. This effect may increase the remaining life of some older, 'dirtier' models with respect to what would have happened without the scheme. This may also mean that the total scrapped amount of VMT will be partly replaced using vehicles older than those retired.

In both cases, the environmental achievements of the programme will be worse than expected. In an attempt to avoid this effect (to prevent supply shortages of old, second-hand vehicles and major price changes in this section of the market), some studies suggest that the schemes should retire only a limited number of old vehicles. Moyer *et al.* (1995) estimate that the optimal rate of scrapping is some 2 000 vehicles per year per million vehicles in the population.

Further conditions on the replacement vehicles, made to ensure that they have on average lower emission rates, may also have negative effects on other variables. As mentioned in section 1.1.2, schemes that constrain owners to buying a new-model car are likely to select relatively better-off households and will exclude all those families that cannot afford such expenditure during the period of the scheme.[22] Some better-off households may scrap vehicles that were kept for marginal use (e.g., as a second or third car), running on an annual VMT below the average. This will reduce the amount of 'dirty' mileage travelled.

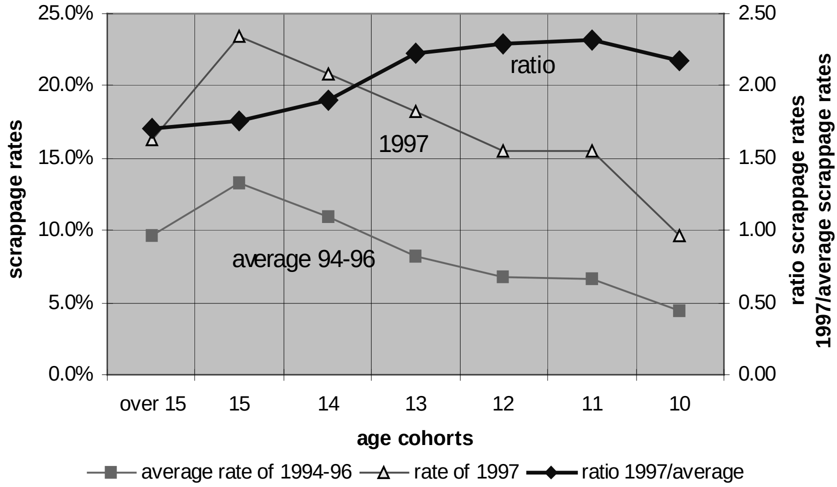
Moreover, vehicles owned by higher-income owners are more likely to be relatively well maintained. This means that their average emission rates will not be as high as expected. On the other hand, by excluding the poorest individuals, it is likely that the scheme will not manage to scrap a large proportion of the real 'gross emitters' (i.e. very old cars used as a principal means of transport).

The scant available evidence seems to confirm this. In the Irish scheme, a lower age limit of ten years was imposed and award of the incentive was conditional upon the purchase of a new model. Of the scrapped vehicles, 50% were 10-12 years old and only 10% of them were older than 16 years. However, this might also reflect the fact that this particular age cohort is relatively bigger. Therefore, to make these data more meaningful, they have to be compared with the total number of vehicles in use in each age cohort. The ratio of scrapped vehicles older than 16 years, compared to the total number of vehicles in use of the same age was rather low. Only 17% of them were retired during the scheme. But even this number, although meaningful, cannot prove anything if it is not compared to the 'usual' average scrappage rate for this age cohort.

The data available for Italy are more complete and show more clearly which vehicle age cohorts took most advantage of the scheme. The cash-for-replacement programme, introduced in Italy in January 1997, increased the proportion of retirements across all age cohorts. The overall scrappage rate, i.e. the percentage of retirements over the total number of vehicles in use was almost doubled, compared to the average rate of the four preceding years (characterised by a very low car demand). It rose from 3.7% to 6.6%. Yet, the success of the programme was much higher for relatively recent vehicles that were closer to the lower-age limit imposed (ten years). Figure 6 compares the average scrappage rates by age cohort[23] (for the four years before the scheme) with the corresponding rates resulting from the first scheme, run in 1997. For vehicles aged 10-13 years, the scrappage rate in 1997 was about 2.3 times (130%) higher, compared to the average of the previous years, while for cars older than 15 years, the ratio decreased to approximately 1.7 (only 70% higher). It is interesting to note that the scrappage rate of vehicles older than 15 years (16.3%) was very close to the Irish one.

Sometimes, the official scrappage data can be approximate, since the owners may get rid of their cars without declaring it. However, the *ratio* between scrappage rates of different years, on which the previous analysis was based, should not be particularly influenced by this problem.

Figure 6. **Comparison of Italian scrappage rates before and during the scheme**



Source: ECMT elaboration on 1998 ACI data.

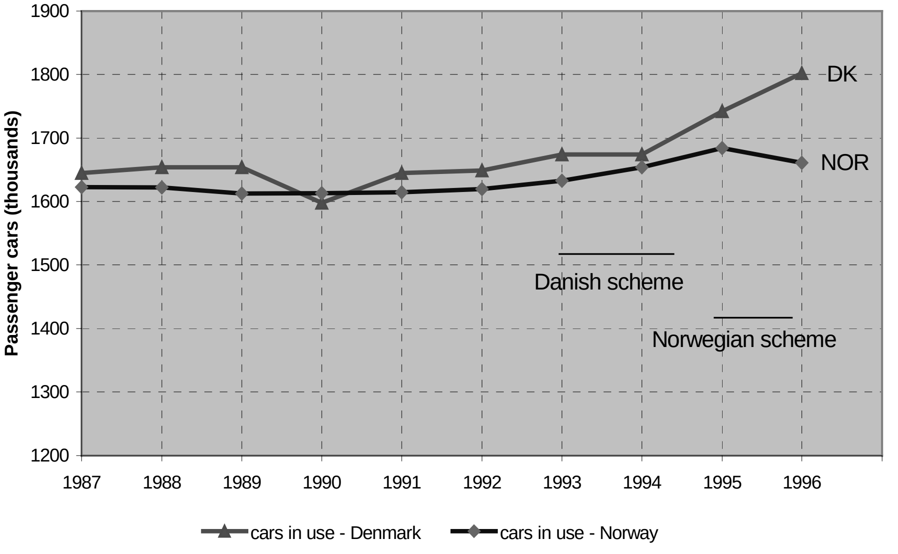
2.3.4. Other variables affecting the fleet's emissions

Size of the fleet

Because of the freedom in choosing the replacement means of transport, cash-for-scrappage programmes might have the effect of decreasing the size of the fleet and will surely decrease its growth rate, as the Danish and Norwegian cases showed (Figure 7). This is, however, only a temporary effect and is due more to the delaying of replacement purchases than to a permanent decision not to replace the scrapped car. In both countries mentioned, the fleet started increasing again a few months after the end of the scrapping programme, apparently without any permanent effect from the short-term reduction.

Since the effect of cash-for-replacement schemes is that of considerably lowering the average price of both new and second-hand vehicles, this might cause an increase in the fleet's growth rate with respect to the growth rate that would have taken place without the incentive. In other words, the price decrease could stimulate not only replacement demand, but also incremental demand for new vehicles. The decision to buy an incremental vehicle is not only based on its market price. A household will buy a new car only if it has a transport demand that justifies the purchase. Therefore, this effect should be relatively less important in those countries (like Italy and France) where replacement purchases prevail in annual first registrations (where 'incremental' demand is already low).[24]

Figure 7. The **effect of the Danish (1994-95) and Norwegian (1996) schemes on the fleet's size**



Source: Eurostat Database TRAINS, quoted in LAT-DTU-INFRAS.

The effect of scrappage schemes on congestion and driving patterns

No direct effects can be caused by any kind of scrapping incentive on the average driving patterns. Some indirect effects may result, however, from induced changes in both the size of the fleet and the average VMT.

If a scrappage scheme brings about an increase in VMT, this may negatively affect congestion. However, as there is no clear evidence of the link between old vehicles' replacement and the change in VMT, it does not help the analyst to try and figure out any other more indirect and uncertain links between VMT, congestion and the average emission rate.

A decrease/increase in congestion might also be expected if the fleet size decreases/increases due to the scheme. As regards the fleet size, the possible decrease caused by cash-for-scrappage schemes can be considered as a temporary, short-term and not particularly relevant effect. So no remarkable effects on congestion can be expected due to this kind of scheme.

Where cash-for-replacement schemes may accelerate the increase in the fleet's size (through the price decrease they cause) they may also accelerate the increase in congestion. Though plausible in theory, even this is quite an indirect effect which is very difficult to analyse and quantify. The empirical evidence is quite controversial. More studies are needed to evaluate the price effect on car demand due to cash-for-replacement schemes.

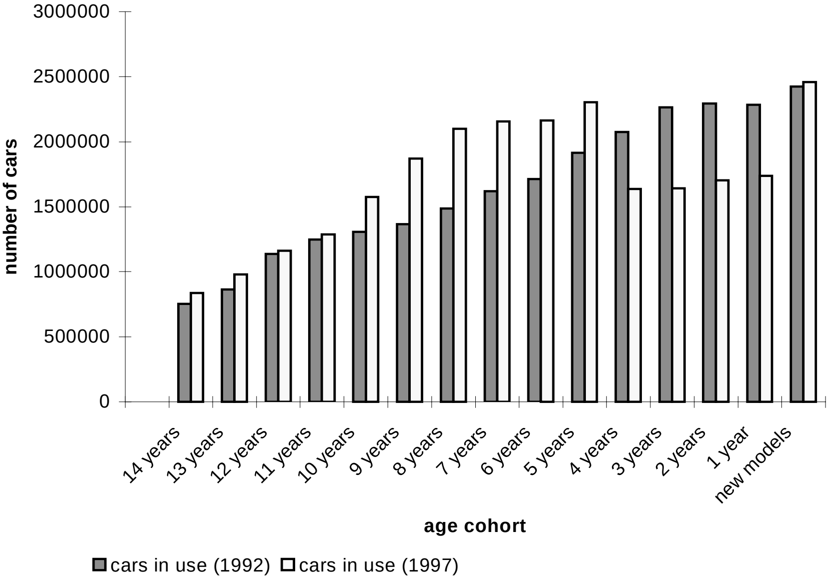
Moreover, the decrease/increase in congestion is not only linked to the number of newly registered and de-registered vehicles, but also to the particular location where this happens. The effect will be more visible if the net increase/decrease in registrations is concentrated in urban areas; something that will not necessarily happen.

2.3.5. Possible longer-term effects

The schemes described have always been assessed in the short term. The emission reduction achieved has usually been measured covering a period of about three years from the introduction of the scheme. All the evaluations reviewed (some of them are briefly described in sections 2.4.3. and 2.6.2.) claim that there are no effects of the scheme beyond this period. After three years, the fleet renewal introduced through the incentive would have been reached anyway. But the fact that there will not be *positive* effects on the environment after three years, does not exclude the possibility of having other effects in the midterm.

The first chapter showed how cash-for-replacement schemes will bring forward some replacement decisions and will result in a fall in new car sales during the subsequent period. The year after the end of the scheme, the anticipation effect will probably cause a slowing down of fleet renewal with respect to the 'natural' renewal rate. Suppose now that during this year a new, particularly clean model is introduced onto the market. The result may be that its sales will be less than what would have happened without the incentive. Some of the owners that have anticipated their purchases, because of the scheme, will now be driving vehicles with *worse* performances. They will keep on driving these vehicles, instead of cleaner ones, for several years, as cars are meant to last.

Figure 8. **The Italian fleet by age cohort (1992 and 1997)**



Source: ACI data, 1998.

Figure 8 shows the age distribution of the Italian fleet in 1992 and 1997. During 1997, there was a relative 'peak' in vehicles aged five years, due to the very high number of sales in 1992. Therefore, after the positive, short-term effect of the programme, there might be a negative environmental effect in the mid to long run.

The introduction of new, cleaner technologies is not just continuous and smooth over time. The next few years will see the introduction of cleaner vehicles, due to EU directives, and the introduction of more fuel efficient cars under agreements at European and national levels. For instance, cleaner and safer motorcycles should be sold from June 1999, due to Directive 97/24/EC; stricter EU emission standards will be introduced for new cars from the year 2001 (Directive 98/69/EC). These dates have to be kept in mind when evaluating past schemes and especially when proposing new schemes.

2.4. The cost-effectiveness of scrappage schemes

2.4.1. What is the cost of the scheme?

Cash-for-replacement schemes that require the purchase of a new car have often been judged according to their effect on public finances. However, the costs of any public intervention have to be evaluated first from the point of view of the citizens/consumers, rather than from that of the public finances. In simple terms, if public expenditure increases, it means that citizens have to pay more taxes to keep the same balance between public expenditure and tax revenues. From this perspective, all money spent on the incentive represents a cost to citizens. Moreover, any amount spent by the state has an opportunity cost, as shown in the social benefits that could have been produced by alternative ways of spending the same amount, whether in the transport sector or elsewhere. This opportunity cost may be even higher than the direct cost of the expenditure. Therefore, all the public resources devoted to scrappage schemes, (incentives and the related administrative costs), have to be accounted for as a cost of implementing the measure.

In some cases, car manufacturers and car dealers have also made an economic contribution to the implementation of the schemes, lowering their prices to attract higher numbers of purchasers. Section 1 of this report showed that these price reductions were not only voluntary but partly caused by the interaction of other economic variables affected by the scheme. Price reductions indubitably represent a cost to manufacturers and dealers and made an important contribution to the implementation of the schemes. However, discuounts should *not* be counted as a cost from a *public* perspective, contrary to the case of the state incentives just discussed. The losses to producers and dealers from price reductions represent *net* gains to consumers. Net because they were not financed through taxes. The combination of these changes represents a 'pecuniary effect', i.e. simply a redistribution of resources without net changes in the total welfare and should not be considered in a social cost-benefit framework.

2.4.2. The cost per tonne of atmospheric pollutant avoided: general statements

In most of the real cases examined, the incentive was given as a fixed amount of money per scrapped vehicle. Only in a few cases was a distinction made according to the size (in Italy, France) or the age (in British Columbia, California) of the replacement car purchased.[25]

Apart from the direct cost of financing the incentives given to car owners, any scheme faces some administrative costs stemming from all the practical details related to it, e.g., control of the eligibility of the car offered for scrapping, distribution refunds to car manufacturers, data collection on the scrapped and replacement vehicles, etc. This cost is roughly proportional to the number of cars scrapped and is far from negligible. The available USA and Canadian reports estimated this cost to be in the range of US$ 50-100 per car. For some schemes, this cost included inspection and emission testing made to identify the vehicles eligible for bonuses and in some cases the costs of controlling ex-post emission rates for the vehicles retired. European programmes did not undertake these tests.

The overall cost of the scheme may be reasonably represented as being proportional to the number of vehicles retired:

$$\textit{Total Cost of the scheme} = C \cdot N$$

where C is the average cost per vehicle and N is the number of vehicles scrapped. The average cost per tonne of pollutant reduced will be given by:

$$\textit{Average Cost per tonne of emission avoided} = \frac{C \cdot N}{(ER_{old} \cdot VMT_{old} - ER_{repl} \cdot VMT_{repl}) \cdot L \cdot \mathrm{N}}$$

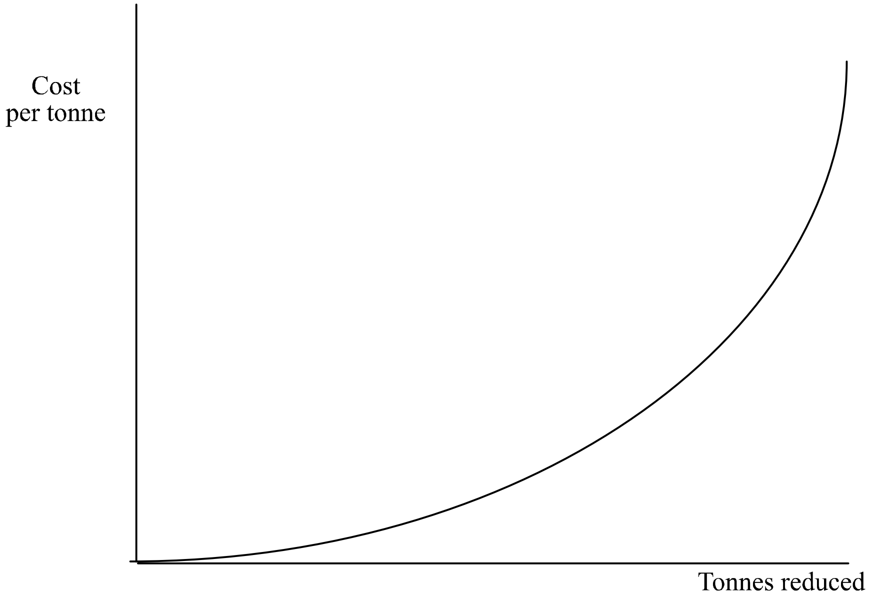
From this equation, it is possible to sketch out some first conclusions of the cost-effectiveness of different kinds of scrappage programmes.

First, it is known that cash-for-replacement schemes need a higher incentive (higher C in the formula shown above) to attract owners, compared to cash-for-scrappage schemes. Thus, they will need to achieve a larger reduction in emissions to be as cost effective as the latter. Consequently, it is extremely important that these schemes manage to select the real ‘gross emitters’, i.e. vehicles with high emission rates that are used as a principal means of transport in a family. The data and the explanations given above suggest that this is unlikely to happen. As already mentioned in section 2.3, one cannot rely just on the age of the scrapped vehicles to draw conclusions about their environmental performances. The fact that cash-for-replacement schemes have attracted mostly 10-13 year-old vehicles (shown in section 2.3.3), while the American programmes have selected older vehicles, may also be partially justified by the earlier introduction of catalytic devices in the USA and Canadian fleets. In other words, while in the USA it is necessary to select a model from the 1970s in order to retire a non-catalysed car, in Europe this can be done by imposing a lower, minimum age requirement, retiring models from the 1980s. Yet the American schemes, unlike the European cash-for-replacement ones, selected a limited number of old cars using both age requirements and past I&M data. They were designed to attract vehicles used as a principal car (with high annual VMT) by lower-income families. The selection made by European cash-for-replacement schemes was far less accurate. These programmes focused more on attracting a large *quantity* of vehicles, rather than emphasising vehicle *quality*.

Furthermore, suppose the analysts know exactly the emission rates and VMT of all vehicles belonging to the fleet. They can rank all cars according to the quantity of emissions avoided by scrapping them and buying a given replacement vehicle. Initially, there will be a group of very old, 'dirty' cars intensively used by their owners; then a group of slightly more recent and/or less-used vehicles that give a relatively lower, avoided emission and so on, up to vehicles whose retirement would minimally affect emission reduction. If the decision-makers want to reach a certain overall reduction level, they might start by giving incentives for scrappage of the first group described and then continue with the other groups, increasing the total number of vehicles retired (i.e. the size of the scrappage scheme) until they meet the required reduction target. If the cost per vehicle scrapped is fixed and does not vary according to the quantity of pollution reduced, then the marginal and average costs per tonne of pollution reduced will increase as the total quantity of pollution avoided increases. For greater emissions reductions, incentives will have to be given to more and more vehicles, going beyond the limited number of 'gross emitters'. Owners of relatively more recent and better-maintained vehicles will probably need a higher bonus to be persuaded to scrap their cars.[26] The marginal cost per tonne reduced will, therefore, have an increasing shape, like the one shown in Figure 9. Cash-for-scrappage schemes directed at the retirement of a limited, well-selected number of 'gross emitters' will be represented by a point in the left part of the curve, with a low cost per tonne of pollution avoided. Larger schemes may avoid a greater amount of total emissions, but at a progressively increasing cost.

Hence, large-scale cash-for-replacement schemes implemented in Europe are more probably placed on the right, upper part of the curve shown in Figure 9.

Figure 9. **Marginal cost of the schemes per tonne of emission reduced**



As the scheme approaches higher marginal and average costs, it will become increasingly probable that alternative policies (enhancement of inspection and maintenance programmes; retrofitting of older, non-catalysed vehicles, etc) could be more efficiently implemented.

2.4.3. Some evidence from past experiences

Up to the present, there have been only a few attempts to quantify the cost per tonne reduced of any pollutant. All of them have been made in the USA and Canada. Moreover, all of them concerned cash-for-scrappage programmes. The evaluations have been made on schemes with quite different designs and they used different hypotheses. Therefore, they are not easily comparable. An examination of the available reports gives a few useful suggestions.

In most cases, the cost per tonne reduced was measured by dividing the overall cost of the programme by the estimated reduction of *each* pollutant considered - HC, CO and NO_x - *as if* the scheme had been implemented to achieve only that reduction. The evidence from the Illinois (1992), UNOCAL (1990) and Scrap-It (1997) programmes suggested that the average unit cost was around US$ 3 500 (1997) per tonne of HC reduced; about US$ 600 per tonne of CO reduced; and about US$ 21 000 for any tonne of reduced NO_x emissions. These figures are uncertain and cannot be directly extrapolated to other scrappage programmes. However, they at least give an idea of the order of magnitude of the costs involved.

Moreover, they show the specific pollutants that these policies will more easily reduce. For instance, it is more difficult and costly to reduce NO_x emissions through accelerated vehicle renewal (as already suggested in section 2.3.1). However, it may efficiently target reductions in carbon monoxide emissions.

The Scrap-It programme run in British Columbia (Canada) evaluated separately the average cost per tonne reduced using two hypotheses: the case where the replacement vehicle was an average car taken from the existing fleet; and the case where it was a new-model car. The scheme gave two different incentives, about US$ 370 and US$ 550 (1997) respectively. For both the HC and CO the cost-effectiveness ratio was *worse* in the case of *new-model* purchases. It did not show relevant changes as regards NO_x.

Finally, one of the available studies (US Congress, OTA, 1992) also introduced a comparison with some alternative policies to reduce HC and NO_x emissions both in the transport sector and in other economic activities (stationary sources). The main alternative considered within the transport sector was an enhancement of the Inspection and Maintenance (I&M) programmes. The conclusion was that, as regards HC and CO, the cost per tonne of reduction achieved by well-designed scrappage schemes was of the same order of magnitude as that of that of I&M measures when vehicles older than 15 years are retired. The comparison was relatively less favourable when the scrapped vehicles were more recent.

Almost no empirical estimates are available for the cash-for-replacement programmes. All the elements discussed in this report and the scarce, available data lead to the conclusion that they are far less cost-effective as compared to cash-for scrappage programmes. Accordingly, the limited evidence collected suggests that they are less cost-effective than I&M enhancement policies.

2.5. What are the main policy tools alternative to scrappage schemes?

In all cases, the possibility of implementing scrappage schemes must be checked against feasible alternative policy tools that may achieve the same goal with the aim of implementing the most cost-effective and efficient measures. Unfortunately, apart from the examples mentioned above, none of the reports analysed, introduced any detailed comparison with other principal policy tools to reduce atmospheric emissions from mobile sources. This section will only discuss the main alternatives to scrappage schemes. Further quantitative analysis is needed to draw more meaningful conclusions from the comparison among these alternatives. Moreover, the section will only address those measures aimed at improving the environmental quality of the means of transport (the car fleet) and will not consider the huge existing variety of traffic control management measures.

The ultimate mechanism through which scrappage schemes achieve their results is a *change in the relative prices* of all different available cars. As explained in section 2.7.1, they put (temporarily or permanently, according to the design of the programme) a lower bound on the value of old vehicles eligible for the scheme. In so doing, they increase the relative value of these vehicles with respect to all newer ones and, therefore, render the replacements cheaper. However, this change in relative prices may also be achieved in several different ways.

A similar change in relative prices was successfully obtained in Germany by reforming the annual vehicle taxation in July 1997. The changes introduced by the German government granted tax credits for passenger cars complying with Euro-3 and Euro-4 engine standards and simultaneously increased the tax paid by non-catalysed vehicles. This has considerably accelerated the vehicle replacement rate and favoured the introduction of cleaner vehicles. Another example is the Hungarian government's introduction of policy measures over the last these six years (section 3.1). In this case, the tax burden on older vehicles was not increased *in absolute terms*, but taxes were considerably reduced for cleaner vehicles, thereby encouraging the purchasing of 'greener' cars and the replacements of old, 'dirty' vehicles.

The enhancement of existing Inspection and Maintenance (I&M) programmes may also cause economic and environmental effects similar to those of scrappage incentives. If the regulation introduces stricter environmental and safety standards for all cars and the I&M programmes manage to enforce them, there will be an increase in the average cost faced by owners to keep a vehicle in 'fair' working condition. This is likely to increase the costs of keeping an old vehicle with respect to newer ones. Once again, the set of relative prices for old and newer cars will be changed, favouring replacement purchases and shifting the car demand towards newer models. Some empirical evidence from the Spanish experience (Licandro and Sampayo, 1997) confirms that changes in the I&M programmes may have considerable effects on the trend in first registrations. Consequently, this policy might also have favourable effects on the car manufacturers and, through them, on the whole economy.

From the environmental point of view, another valid alternative to scrappage schemes may be given by *retrofitting programmes*. These can either be mandatory or implemented through economic incentives (subsidies, tax credits, etc.). Mandatory programmes will act through a mechanism similar to the one just described for I&M enhancements. They will raise the cost of holding old, non-catalysed vehicles. Voluntary, incentive-driven, retrofit programmes will involve different changes. In general, the cost of retrofitting a vehicle is considerably lower than the cost of replacing it with a cleaner, more recent one. This lower cost might enable the public authority that funds these to obtain emission reductions with lower expenditures, (compared to those incurred by scrappage programmes), with a more favourable cost-effectiveness ratio. Otherwise, with the same expenditure, it could manage to persuade a much higher number of lower-income owners of 'gross emitters' to undertake the programme, thereby achieving greater environmental benefits. Alternatively, the environmental benefits of retrofitting old cars, whose engines are in rather bad condition, may have very limited duration. After a short period, they may return to the old environmental characteristics or they may need some more costly repairs. This suggests that the two measures - scrappage schemes and retrofitting programmes - should target two different categories of vehicles. The former should be directed at older cars in relatively poor condition, that could not run for many km with well-working retrofitting devices. Retrofitting could be more efficiently directed at relatively recent vehicles with better maintenance conditions. This simply suggests that when a durable good does not work as desired (environmental performance included), there are two solutions: scrapping and replacing it or fixing it. The relative efficiency of each alternative depends on its initial condition.

Finally, retrofitting does not lead to any improvement in the safety characteristics of the vehicles; undoubtedly a valuable result of scrappage schemes, although it was not possible for this report to evaluate.

Incentives for retrofitting passenger cars have been given in Germany, since 1985 and Hungary (see section 3.1). Some Swedish and British cities (Stockholm, Gothenburg, Malmo, London) have also recently implemented retrofitting programmes for trucks and urban buses, respectively. These experiences have had relatively good results. Further studies, however, are needed to establish what their cost-effectiveness and cost-benefit ratios are, compared to scrappage schemes.

2.6. The benefits of reducing atmospheric emissions

2.6.1. Some general statements

In order to make a cost-benefit assessment of the emission reductions achieved by the programme, it is necessary to undertake a monetary evaluation of the damage brought about by private transport's pollution of the atmosphere. This requires an evaluation of goods, like human health and environmental assets, that do not have a market value. These estimates are particularly complex and the results are subject to a high degree of uncertainty.

Nevertheless, the few attempts that interdisciplinary teams have undertaken during this decade to define the size of these external costs[27] have made considerable practical contributions to the assessment of scrappage schemes and the formulation of some policy advice. There are, in particular, two main conclusions reached by the recent literature that should be underlined for the purpose of assessing scrappage programmes.

Firstly, the external damage caused by private transport in cars is highly site specific. It varies according to the particular location of a trip. The damage is much higher when the car's trip is located within densely populated, urban areas - human health being the most valuable good damaged by pollution. Aside from population density, the damage is higher when there are unfavourable meteorological conditions (for instance, a lower mixing layer, lower wind speed, frequency temperature inversions).

Therefore, the cost-benefit ratio of any scrappage scheme will be more favourable when it manages to retire 'dirty' vehicles that are mostly used within densely populated, metropolitan areas. The USA's CAAAs of 1990 (see Box 1) targeted emissions in ozone and CO non-attainment areas (essentially metropolitan areas).

The work done by the European Commission (1995) and the Bickel *et al*. (1997) study also suggested that *ceteris paribus*, the damage caused by a tonne of a given pollutant emitted from passenger cars (and any other road transport vehicle) is substantially higher than the corresponding damage caused by the same quantity emitted from a high-stack stationary source, especially when densely populated areas are considered. This is mainly due to the different natures of the atmospheric dispersion processes. Pollutants emitted from tailpipes remain concentrated in a relatively smaller area than those emitted from chimneys which spread and dilute over a radius of a few hundred kms. If the same small area where pollutants are spread has a high population density, the differences between the externalities caused by the two sources will be considerable.

This implies that it may be incorrect to compare the cost-effectiveness of policies that reduce the emissions from transport with other measures that reduce the emissions from some industrial stationary sources. For instance, eliminating one tonne of CO emissions from cars travelling in an urban area may be better than eliminating the same quantity of CO emitted from a 200 metres-high stack placed in the same site, even if the latter option is less costly. If this conclusion is valid, the practice of trading mobile emission reduction credits with stationary sources' emission credits (as applied in the USA) on a one-to-one basis, may not be economically efficient.

All in all, the information available on the damage caused by atmospheric pollutants suggests that scrappage schemes may be much more beneficial when they manage to retire 'dirty' cars that are used mostly in densely populated, urban areas. These are the sites where scrappage schemes are more likely to remain a valuable policy option in reducing environmental pollution. Conversely, the damage caused by vehicles used only in rural, scarcely populated areas is rather small. Hence, the cost-benefit ratio for scrapping them is probably unfavourable.

2.6.2. Some evidence from past experiences

Unfortunately, there is very little information available on the cost-benefit ratios of previous scrappage schemes, since virtually nobody has used these criteria to assess them.

The only *ex-post* cost-benefit analysis carried out to date was run to assess the Norwegian cash-for-scrappage experience. The Norwegian scheme, implemented across the whole country throughout 1996, gave a bonus of NKr 5 000 (about US$ 880, 1997) to any owner scrapping a car older than ten years. It did not impose any requirements on the replacement vehicle. An estimated number of 150 000 cars were scrapped, *net* of the number of vehicles that would have been retired anyway (without any incentive). An unsatisfactory ratio of benefits over costs of about 0.5 was estimated by Transportøkonomisk Institutt (1997) for this scheme.

The Hahn (1995) study runs an interesting evaluation, trying to generalise through econometric estimates the evidence of a pilot scrappage project implemented in the Delaware area (where 125 old cars were retired). The study estimated first what the number of cars retired would be in response to different sizes of incentive - in other words, the 'scrappage supply'. Then, it quantified the amount of HC and NO_x reductions corresponding to the different numbers of vehicles scrapped, based on the hypothesis that the retired vehicles would be replaced by an 'average' car belonging to the fleet in use (with average emission rates). Finally, it assessed the net benefit of different scenarios: respectively, with US$ 250, US$ 500, US$ 750 and US$ 1 000 scrappage bonuses and different corresponding numbers of scrapped cars. The cost-benefit comparison was made under four different hypotheses concerning the monetary value of the avoided emissions. In particular, benefits were alternatively evaluated according to the four, estimated values given in Table 5.

Table 5. **Alternative values of benefits of reducing emissions used by Hahn (1995)**

	Market value of credits ($/t) (A)	EPA's estimated avoided cost ($/t) (B)	Willingness to pay estimates ($/t) (C)	SCAQMD's* estimated avoided cost ($/t) (D)
NO_x	100	2 750	5 050	8 500
HC	75	3 050	2 860	30 000

* South Coast Air Quality Management District, California.

According to the results of this study, scrappage schemes of a limited size (about 20 000 cars), with a relatively low incentive (US$ 250) will have a positive impact under almost all alternative benefit evaluations (only the evaluation made according to hypothesis (A) gives negative net benefits). With larger bonuses the net benefits of schemes become *negative*. Schemes do not pass the cost-benefit test with a bonus of US$ 500 (which corresponded to a scrapping supply of some 200 000 cars) using benefit values as in (A), (B) and (C). Large-scale schemes with relatively high incentives maintain a positive net benefit only if the external cost of pollution is very highly valued (when values from hypothesis (D) are used). Total net benefits are maximised with bonuses of about US$ 1 480 under scenario D and a corresponding scrappage supply of roughly one million vehicles.

This again confirms two main conclusions. Firstly, the small-scale programmes are much more efficient than large-scale ones. Secondly, scrappage programmes become relatively more beneficial in 'sensitive areas' where the damage due to atmospheric pollution is higher. The study, however, did not take into account the fact that an increase in the value of older vehicles (caused by the scrappage incentive) may have postponed some replacement decisions of lower-income families and, therefore, actually have caused some 'gross emitters' to live longer.

2.7. Some lessons from the schemes implemented in the past: the selection criteria

Several different selection criteria have been implemented and/or proposed in the past to ensure that the scrappage programmes achieved the desired objectives. They have been directed both at selecting the scrapping and the replacement vehicles. As for vehicles to be retired, selection is required mainly to ensure that they have high average emission rates and that they would have been used for a significant number of km during their remaining lifetime. Criteria for the replacement cars concern only their environmental performance.

Clearly, any further constraint imposed on the eligibility of vehicles for scrapping has the effect of reducing the potential number of vehicles in the scheme. If the selection works properly, on the other hand, it also has the effect of improving the cost-effectiveness of the policy.

2.7.1. Selecting vehicles to be scrapped

Size of the bonus

The amount of money given to car owners as an incentive to scrap their vehicles is the fundamental way to select the quality and quantity of the vehicles sent to the scrap yard. Owners of old vehicles usually face three alternatives. Either they keep their cars, undertaking the necessary maintenance to ensure that they are kept in fair working condition; they try to sell them on the second-hand market; or they send them to the scrap yard. Among the last two alternatives, they will choose the one that gives them the best value. In both cases, they will have to satisfy their transport demands with alternative transport means at a given cost.

The simplest economic explanation of the owners' decisions related to scrappage is that they will choose to retire the car if the value of the vehicles 'in working condition' (V) net of the repair costs necessary to keep them in this condition (RC) is lower than the value they would get from the scrap operator (SV). The owners, therefore, will scrap their cars if:

$$V - RC < SV.$$

A scrappage incentive artificially raises the scrappage value (SV) of the vehicles and through this it increases the number of retirements made in a given period, bringing forward decisions that would have been taken later on, when the value of the car is lowered due to ageing.

A low incentive will attract only older, badly maintained vehicles with a lower market value (V) and high expected repair costs. Thus, on the one hand it may have a positive effect on the scheme, since it will attract vehicles that are expected to have high average emission rates. On the other hand, the vehicles attracted by a low bonus are likely to be close to their ‘natural’ retirement with a short remaining life. Therefore, paying for their retirement could be a dead-weight loss for the economy. Moreover, a low bonus will hardly persuade low-income owners of ‘gross emitters’ to replace these with cleaner vehicles, as this involves considerable expenditure. As the size of the bonus increases, more vehicles with higher market values and lower expected repair costs will be attracted by the scheme. This, as explained, will increase the total amount of emission reduction, but will also attract vehicles with relatively good environmental performances. Thus, it will lower the cost-effectiveness of the scrappage programme. Therefore, the bonus given should be matched with other eligibility requirements that limit the total number of scrapping processes and select the ‘dirtier’ vehicles.

The size of the bonus given for cash-for-replacement schemes varies from about US$ 500 up to US$ 1 600 (1997); the most common value is around US$ 800. This corresponds to something between one-tenth and one-fifteenth of the average value of a new model. The bonus given for cash-for-scrappage programmes is usually considerably lower, between US$ 300 and US$ 700.

Age requirements

The age criterion has been used in almost all the schemes implemented up to the present. Only vehicles older than a given age are accepted for the programme. The lowest minimum age required, seven and eight years, was used, respectively, by the Spanish *Renove II* scheme and the second French scheme, *Prime qualité automobile*. In both cases, very few cars aged between seven and nine years entered the programme. The highest age requirements have been implemented in the USA.

The risk of scrapping very old, rare cars has brought complaints from car collectors’ associations, in particular in the USA. To avoid irreversibly destroying old, valuable cars, the Californian EPA-ARP (1998) report proposed that a list of vehicles eligible for scrappage be provided for the public before the cars are dismantled, so that collectors can buy them from the original owners. Vehicles bought by collectors are not eligible for the bonus.

As explained above, the age requirements alone are not sufficient to ensure that the 'dirtiest' and more intensively used vehicles are retired. Other criteria have often been used as well.

Selection through Inspection and Maintenance (I&M) programmes

Most of the American schemes have selected the vehicles through inspection and maintenance programmes, testing their average emission rates and selecting the worst-performing ones. It has been argued that this kind of selection may have the effect of encouraging some owners to tamper with their vehicles, artificially raising their emission rates in order to get the scrappage bonus or to even to bribe test operators. Although this kind of cheating may worsen the results of the schemes, this problem should not be overstated. The size of the bonus will always exclude the owners of relatively cleaner, better-maintained vehicles. Since the market value of their cars is probably much higher than the incentive, they will not have any interest in cheating. Moreover, if the inspection is properly done, cheating will become more difficult. Certainly the scrappage of some vehicles that perform much better than the average of their cohort cannot be avoided. However, this defect alone is unlikely to change substantially the results achieved.

Some programmes, like the Canadian Scrap-It scheme, have also used results from I&M, made in the one or two years *preceding* the implementation of the scheme, as a selection criterion. When this option is available, it avoids the problem of cheating. On the other hand, an inspection made one or two years earlier cannot give much information on the actual condition of the vehicles, so it may not work as wished.

In a few cases the I&M programmes have also been used to ensure that the retired vehicles had a significant remaining lifetime and were usually run on a given number of km. Under the Illinois 'cash for clunkers' pilot project, the judgement on the expected remaining life was made by a group of mechanical experts. The Canadian Scrap-It programme used odometer readings to select vehicles that had been run a given amount of km in the past years. In these cases, cheating may represent a more serious problem. However, there are no alternative ways to avoid this kind of free riding. Any scrappage scheme will unavoidably attract a number of vehicles that would have been scrapped anyway.

Insurance and registration requirements

Usually, it is required that the vehicle proposed for scrappage be registered regularly and insured for a given period, prior to the scheme. This is to prevent vehicles that are no longer in use or already de-registered getting the incentive. Most of the American schemes have also required that the vehicle be driven to the scrap yard.

The type of registration (e.g., for commercial use rather than 'private' use only) may also be used to select vehicles with higher average VMT.

Finally, the location of the vehicle's registration has also been used as a selective criterion. This has been done with two different goals. The first is to avoid importing old, polluting cars from other regions or countries in order to obtain the incentive. The second is an attempt to ensure that the scrapped cars were mainly used within a given targeted area, e.g., in metropolitan areas where the emissions are more damaging or in non-attainment areas where a given emission reduction target must be achieved.

Technological requirements

Some schemes have specified the technology of the vehicles eligible for the incentives. The Hungarian programme has been directed at retiring only the old two-stroke engines still in use (Trabant, Wartburg and Barkas models). Some European car manufacturers and car dealers are proposing to retire non-catalysed cars, irrespective of their age.

Other technological requirements may be imposed according to the kind of pollutant targeted. Scrappage of a limited number of old, 'dirtier', diesel vehicles may be implemented if reductions of particulate matter are targeted.

A way to ensure that the scrapped vehicles have driven a considerable number of km per year, is by *targeting HGVs and buses*. These vehicles have an average VMT, which is about twice as much as the average passenger car. But, the average expenditure that is necessary to replace one of these vehicles is also higher, so a higher bonus would be required to persuade the owners to undertake such a scheme. The cost-effectiveness ratios that would result from schemes to reduce the main pollutants is uncertain. Moreover, the feasibility and efficiency of these schemes should be assessed by keeping in mind that the owners of these vehicles are not households but firms. They may have different purchasing powers and their transport decisions might be influenced by other variables. Further studies are, therefore, needed to evaluate this possibility more in depth.

Parts sales and re-use

The proposed regulation on accelerated vehicle retirement in California (California EPA-ARB, 1998) prohibits the resale and re-use of all parts of those cars retired to generate mobile, source-emission reduction credits. This presumably was established to avoid prolonging the average life of old, 'dirty' vehicles - by the supply of spare parts coming from retired cars - not attracted to the voluntary scrappage scheme. The ultimate purpose was, therefore, to accelerate the scrappage and replacement of old vehicles even if they did not join the programme. As stated in section 2.1, such an acceleration of the replacement process may lead to two different effects. On the one hand, it may increase the number of cars scrapped, dismantled and recycled and enhance the construction of new cars during a given period; hence, increase the related environmental 'fixed' costs. On the other hand, it may accelerate the retirement of some 'gross emitters',[28] thereby avoiding the corresponding emissions. It is difficult to establish if the overall net environmental effect is positive or negative.

2.7.2. Selecting replacement vehicles

Age requirements

In most of the European schemes it is required that the replacement vehicle be a new-model car. The Canadian Scrap-It scheme allowed, among other options, the purchase of second-hand vehicles, provided that the year of their first registration was not earlier than 1988 (i.e. vehicles no more than eight years old).

All the other schemes implemented did not place significant constraints on the age of the replacement vehicles. They just assumed that the scrapped cars would be replaced by 'average' vehicles in the fleet. Hungary imposed a ban on the importation of cars older than four years. However, this was done independently of the scrappage scheme. It influenced its results, but cannot be considered as part of it.

Other requirements

Technological requirements have been the most common criteria used to select replacement vehicles.

The purchase of replacement vehicles in Greece has been limited to catalysed cars only. The second Italian scheme (implemented in the first seven months of 1998) awarded the incentive to new vehicles according to their fuel consumption, which had to be below 9 litres per 100 km (including both diesel- and gasoline- fuelled cars). Another fuel-related scheme has been implemented in Italy, giving the incentive to replacement vehicles that use methane, LPG or electricity. Its success has been quite limited, up to the present, partly because of the lack of infrastructure (fuel stations) providing methane and electricity.

Specific models (SEAT Marbella, Suzuki Swift, Opel Corsa, Renault and Volkswagen Polo) have been selected as the only eligible replacement vehicles in the programme run in Budapest from 1993. The models were selected by a committee according to certain engine characteristics, the existence of catalytic devices and the price and credit conditions made available by the dealers.

Incentives to use public transport

The programme run in Budapest and the Canadian Scrap-It scheme offered as an alternative scrappage incentive a free pass on the public transport network. In this case, the owners of the scrapped vehicles were encouraged to use public means of transport as a replacement for their vehicles. This kind of incentive clearly tries to influence the modal split within urban areas.

The programme run in Budapest was not particularly successful. The owners of two-stroke engines were offered free passes for themselves and members of their families, (up to a maximum of four persons). The value of an annual free pass was about Ft 30 000. On paper, therefore, the value of the incentive was of the same order of magnitude as the alternative award of Ft 100 000 (given if they bought a new model). However, in practice the option was not so attractive. Many of the owners of these cars were retired people and *any* person over 65 years could get an annual free transit pass on public transport in Budapest. Other owners were younger and would have enjoyed some real advantages from a free pass. But they could not rely just on public transport, so they preferred keeping their *unique* old vehicle instead of scrapping it.

In contrast, the Canadian experience was positive. Among the three alternative incentives proposed (C$ 500 for a used, replacement car, C$ 700 for a new model, or a one-year free transit pass on the local public transport) the transit pass was the most preferred option, chosen by 52% of the owners participating in the programme. Some of them (about a third) were persons that had never or very rarely used the transit pass before. In most cases they declared themselves 'very satisfied' with the public transport pass after having used it. Quite surprisingly, the estimated cost-effectiveness of the programme was worse in the case of the choice of a transit pass, compared to the alternatives of either purchasing a used car or a new model. The emissions due to public transport were computed according to the average emission per passenger-km caused by the public means of transport in the area considered. This is partially explained by the fact that the average cost of the transit pass offered was considerably higher than the other two alternatives, about C$ 1 000. Conversely, it may also be argued that, since public transport runs anyway, marginal emissions per passenger-km can be considered null.

3. CAN SCRAPPAGE SCHEMES BE USEFUL IN FORMER SOCIALIST COUNTRIES?

Most of the former socialist countries show rather different economic, social and institutional conditions to the nine Western countries where scrappage schemes have been implemented. They also have different rules and standards regulating the environmental impact of the road vehicle fleet. The possibility of successfully implementing scrappage schemes in these countries cannot be assessed without taking these differences into account. Therefore, the conclusions drawn from the nine experiences analysed cannot be *directly* extrapolated to them. Moreover, even among the group of former socialist countries economic and institutional characteristics vary greatly. There are huge differences, for instance, between Slovenia and the Russian Federation as concerns any of the variables relevant to the present analysis. In addition, as mentioned in sections 2.2-2.3, the assessment of the schemes from an environmental point of view relies heavily on knowledge of the average emission factors of the main pollutants and on vehicle mileage travelled by the various vehicles belonging to the fleet according to age, maintenance conditions and technological characteristics. It is not easy to get precise data on these variables for Eastern European countries.

For all these reasons, it is difficult to give detailed policy advice that is valid for all these countries. Nevertheless, an understanding of the principles on which scrappage schemes are based, together with a more detailed analysis of the Hungarian experience may be used to draw a few concrete suggestions for East European policy-makers.

3.1. The case of Hungary

In 1991, about 90% of the Hungarian car fleet was composed of models produced in former socialist countries. This part of the fleet was quite old, with an average age of 9.7 years. The vehicles in use produced in Western, industrialised countries were slightly more recent (8.9 years on average). Many cars in use had poor environmental characteristics; in particular, the old, two-stroke engine cars and vans (Trabant, Wartburg and Barkas), which comprised about a third of the Eastern European models (i.e. 30% of the whole fleet).

Since then, the Hungarian fleet has grown steadily: from about 2 million passenger cars in 1991, the fleet reached 2.3 million in 1997 (Table 6). The fleet's growth has continued parallel to two other phenomena. Firstly, the fleet has rapidly aged: the average age has grown from 9.6 years in 1991 to more than 12 years in 1997. Secondly, the proportion of cars in use produced in Western countries has increased every year, reaching 44% in 1997. Not only has the overwhelming majority of the *incremental* demand been satisfied by the importation of Western models, but there also has been a considerable *replacement* of the old vehicles produced in Eastern European countries. It can be estimated that approximately 330 000 owners have replaced their Eastern models with a Western vehicle between 1993 and 1997. The majority of these old models have been scrapped. However, some of them might have been sold to lower-income individuals in foreign countries. Unfortunately, there are no data to state how many of these vehicles were exported.

Table 6. **Characteristics of the Hungarian passenger car fleet**

Year	Passenger cars in use	Average age	Cars produced in Western countries (incl. Japan)	Cars produced in former socialist countries	Two-stroke engines over all Eastern models
1991	2 015 000	9.6	11%	89%	34.0%
1993	2 094 000	10.3	23%	77%	33.7%
1997	2 298 000	12.1	44%	56%	37.2%

Source: ECMT and data from the Hungarian Ministry of Transport, Infrabook series.

The increase in the average age concerned not only the Eastern models, but also Western cars. In 1997 this reached 9.7 years (against 14.1 years for Eastern models). The rapid ageing process is explained by the fact that, as shown in Table 7, a substantial amount of the cars imported during the period analysed were old, *second-hand* vehicles. Table 7 shows that the average age of the total *first-registered* cars has been progressively decreasing. This has been due to two main reasons. Firstly, as the Hungarian economy (and the average household available income) has grown, people could afford to buy newer models. Secondly, this trend has been considerably reinforced by the introduction of an upper-age limit for the importation of used vehicles. This limit, initially set at ten years maximum age in 1991, was progressively reduced to 8, 6 and finally 4 years in 1997.

Table 7. **Proportion of imported, second-hand Western vehicles to total first registrations of passenger cars in Hungary (1993-1997)**

	1993	1994	1995	1996	1997
Western used cars	80 025	56 472	62 925	34 083	10 968
(% of first registrations)	(62.8%)	(53.6%)	(52.6%)	(34.9%)	(12.8%)
Total first registrations	127 337	102 502	118 912	96 725	81 735
Average age	6.1	5.1	4.9	3.5	1.2

Source: Hungarian Ministry of Transport, Communication and Water Management, Infrabooks series.

A scrappage incentive for the owners of two-stroke engines, briefly summarised in Box 2, was introduced in 1993 in Budapest (where about 25% of the Hungarian car fleet is concentrated) and then extended to the whole country. The first scheme was supported by the city of Budapest, while the second was funded by the Hungarian Environmental Authority. These schemes were not successful. The total number of Eastern-brand cars was already decreasing *before* the introduction of the incentive. There was no substantial acceleration of this trend from 1993. In particular, the proportion of two-stroke engines amongst Eastern models in use (last column of Table 6) did not show any substantial reduction. On the contrary, it *increased* slightly from 34% to 37% of total Eastern models from 1993 to 1997. This suggests that during this period their scrappage rate was even lower than that of the other (non-targeted) Eastern models.

As already discussed in section 2.3, one reason for the limited success of this programme can be found in the specific requirement to purchase a *new model* as the replacement car. The average net annual income of a Hungarian worker in 1997 was about one-fourth of the price of a new vehicle of average size (1.4l to 1.5 l engine displacement). The incentive given by the state for scrapping a two-stroke-engine car corresponded to 2-6% of the price of a new vehicle of that size. Although attractive, this incentive could hardly persuade a lower-income family to replace the old vehicle. To make a rough comparison, the first French scheme, *Prime à la casse,* (see Box 2) gave an incentive of some 5-6% of the average expenditure for a new model, (the same order of magnitude as in the Hungarian scheme). However, the net average annual income of a French worker in 1997 was slightly *higher* than the average price of a new car. In fact it corresponded to 41 weeks of wages [CCFA, 1998 (a)].[29] As most two-stroke-engine car owners are lower-income individuals, it is very unlikely that they will be able to buy a new model, even with the incentive. They will rather try to purchase second-hand replacement vehicles, preferably old, Western cars, as in most cases they are more comfortable and more reliable than Eastern European models of a similar age. However, the 1991 age limit on imported cars, that subsequently has considerably tightened, has seriously constrained the supply of these replacement cars and consequently, might have increased their market value. As a result, many lower-income owners may have kept their old vehicles for some more years, postponing the replacement decision to a future date (when they expect to be able to spend more).

The scrappage schemes simultaneously introduced for heavy duty vehicles (buses and trucks) have been more successful. A state incentive of Ft 750 000 (about US$ 3 600, 1997) has been given for either swapping an old bus (no lower age limit was imposed) with a new one complying with the most recent emission regulations, or for changing just its engine. Similar incentives were given to exchange old trucks or their engines for new, low-emitting models. The owners of the old vehicles could buy rather cheap replacement vehicles produced in Hungary, which could also obtain some benefits from the scheme.

During the same period, several other policy measures were adopted to improve the environmental performance of the Hungarian car fleet. Some of them targeted the environmental and safety quality of *new* registrations. The emission standards for newly registered vehicles have been considerably tightened. From May 1995, only catalysed vehicles may be put into circulation. From 1997, all cars registered for the first time must comply with ECE R.83.01 standards. Meanwhile, the import tax on foreign vehicles was reduced for cars fitted with catalytic devices. Passenger cars without catalytic converters still represent the majority of the fleet, but their percentage over the whole fleet is decreasing rapidly. They accounted for almost 90% of the fleet in 1995 and 82% by the end of 1997.

Other measures had broader targets. Economic incentives have been given to promote the introduction of catalytic devices for all cars, whether newly registered or already in use. A 25-50% reduction in the annual vehicle registration tax was awarded to cars provided with catalytic devices, depending on the quality of the emission control technology applied to the vehicle. A similar tax reduction was granted to trucks fulfilling the most recent Economic Commission for Europe (ECE) regulations.

A third group of measures was directed more to the vehicles already in use. From 1995, a compulsory yearly inspection, checking also emission rates, was introduced for non-catalysed vehicles. Vehicles that fail to pass the inspection are not allowed to be driven.

Last but not least, since 1994 the government has given a subsidy to any owners who retrofit their cars with catalytic devices. The subsidy, initially covering about 60% of the retrofitting cost, was later changed to a lump-sum amount of Ft 25 000 (roughly, US$ 120) per car, which almost entirely covered the cost of retrofitting. The retrofitting programme has been quite successful, as it has involved about 100 000 cars from the date of its introduction. It has been estimated that retrofitting old, two-stroke and four-stroke models produced in the East European countries (Trabant, Wartburg, Barkas, Dacia, Lada, Skoda) led to an average emission reduction of some 50% (Meretei *et al*, 1996). The reduction is much higher than 50% for hydrocarbons, just over 50% for CO and less than 50% for nitrogen oxides.

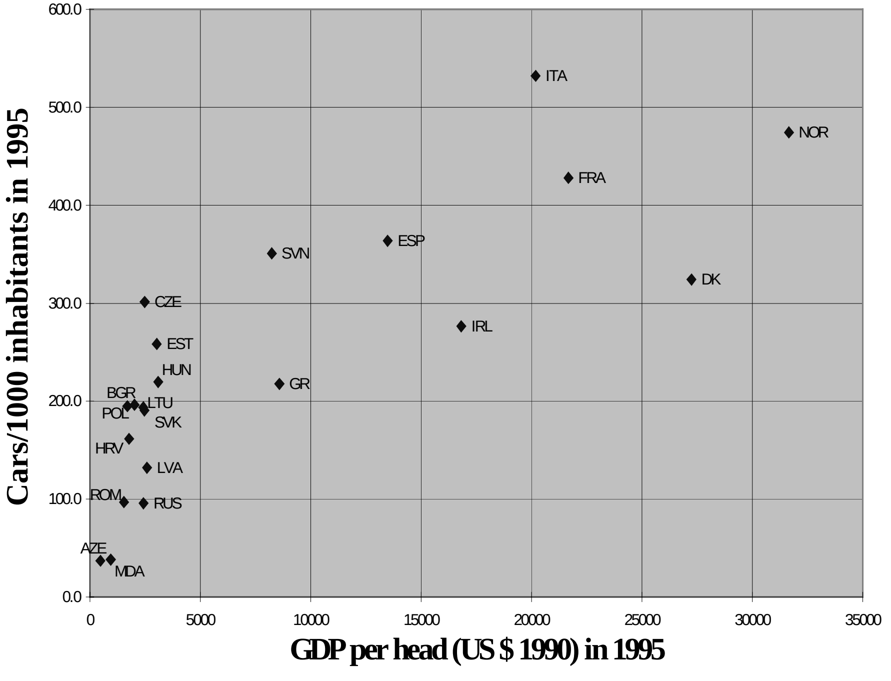
3.2. The general context: some characteristics of the recent evolution of Eastern European car fleets

3.2.1. The rate of growth of Eastern European fleets

Figures 10 and 11 give some basic data concerning GDP per head, motorization (cars per 1 000 inhabitants) and fleet growth rates for some Eastern and Western European countries.[30] As regards Western countries, the graph only represents those which have implemented scrappage schemes.

First of all, cross-section data given in Figure 10 show a positive correlation between GDP per head and the number of passenger cars per 1 000 inhabitants. The scatter also seems to suggest that the relation between GDP and motorization is steeper for lower-income levels and becomes progressively flatter as the GDP per capita grows. The motorization index in 1995 is below the level of 50 cars per 1 000 inhabitants for Moldova and Azerbaijan, these being countries that also have the lowest GDP per head among those considered. Then it increases extremely rapidly with GDP. For instance, Estonia and the Czech Republic have almost three times the motorization level of Russia and Romania, while their GDP per capita is just 30-50% higher. The increase in the motorization level then becomes progressively lower when a country approaches the GDP per head and motorization values of the Western countries considered. Yet even among the latter, there are rather big differences, as shown, for example, by the dispersion of data concerning Greece[31], Italy, Denmark and Norway.

Figure 10. **Motorization as a function of GDP per head in some Eastern and Western European countries**

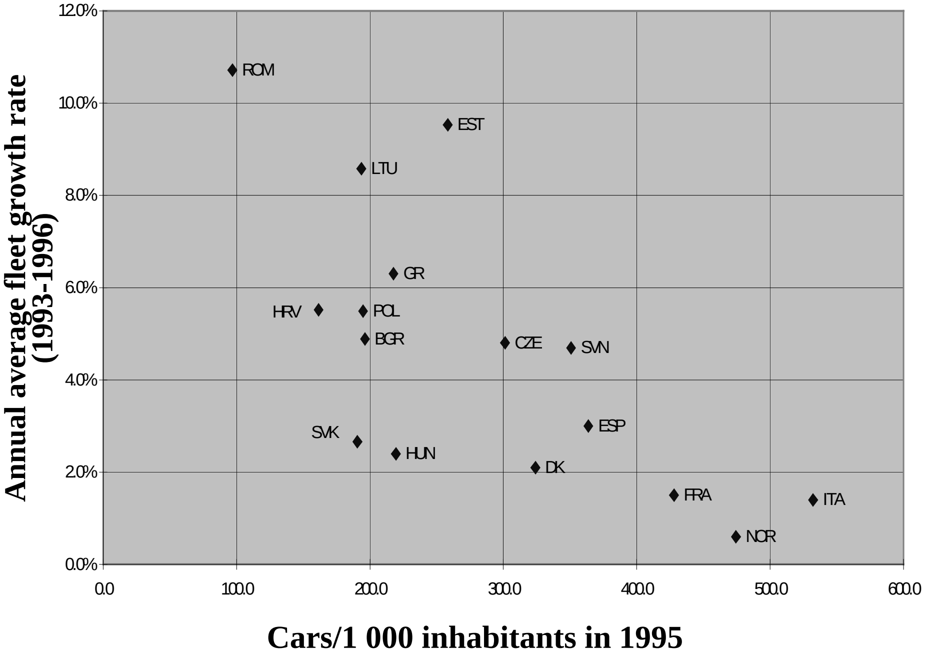


Source: ECMT, based on data from Eurostat/UNECE/ECMT (1998), IEA (1998) and ECMT (1998b).

Although there are relevant differences among them, most of the Eastern European countries are actually going through a phase of accelerated growth rate in the passenger car fleet. Some countries (Moldova, Azerbaijan) have not yet started, while others (Slovenia) might in the next few years approach a growth rate slowdown. However, *on aggregate* they have an average fleet growth rate substantially higher than most of the Western European countries. That also means that, compared to Western European countries, in these regions the proportion of car purchases that are *incremental* to the existing fleet (see the definition of incremental and replacement demand given in section 1.1.1.) within total first registrations is substantially higher then that of *replacement* purchases.

Figure 11 confirms this trend. Average fleet growth for the years 1993-1996 is represented in the graph together with the motorization level for 1995. In spite of considerable differences among single cases, countries that were placed in the lower-left corner of Figure 10, such as Romania, are now placed in the left, upper part of the graph,[32] meaning that their passenger car fleet is growing rapidly. By contrast, the lowest growth rates among the countries considered are shown by France, Norway and Italy, which already have a high level of motorization. In these countries, the proportion of replacement purchases among total first registrations should be higher, compared to most of the Eastern European states. Figure 10 and 11 also suggest that the growth rate of Eastern European car fleets may be expected to remain relatively high for the next few years, as there still is a considerable gap between their motorization levels and those of most Western European countries.

Figure 11. **Fleet growth rate as a function of motorization in some Eastern and Western European countries**



Source: ECMT, based on data from Eurostat/UNECE/ECMT (1998), IEA (1998) and ECMT (1998(b)).

3.2.2. The quality of the motorization process in Eastern European countries

If the Hungarian case is somewhat representative of the whole group of former socialist states, it can give some further indications as to the *quality* of the fleet's development in these countries. The starting point is characterised by a rather old fleet, (around ten years for the average age), where the vast majority of vehicles in use have been manufactured in former socialist countries.[33] Then, the first phase of the evolution sees the importation of large numbers of second-hand models produced in Western industrialised countries, the *average* age of which is around 6-8 years. Some of these vehicles are incremental to the existing fleet, while others are bought to replace old, Eastern models, that are either scrapped or sold to other low-income households in foreign countries. The country of destination might have been, especially in the first period, another Eastern European one. However, many of these countries quickly introduced either a ban or a high customs tax on the importation of older vehicles. Possible alternative destinations are some Asian or African countries.

The beginning of this first phase may come at different times and may be more or less pronounced according to the specific characteristics of the country considered. For instance, the cold winters and bad conditions of some roads in Russia may make it more difficult to use Western-produced vehicles, whose characteristics have been conceived for very different situations. Moreover, it may also be difficult to find spare parts for Western models, making the maintenance costs high. This could deter some consumers from importing second-hand Western cars. Nevertheless, the data available confirm that, on aggregate, the qualitative trend described is valid for the bulk of Eastern European countries.

As the majority of annual, first registrations consists of second-hand vehicles, the fleet during this phase will rapidly grow older. This does not necessarily mean that the average emission rates of the fleet become correspondingly worse. For instance, a second-hand, Western-manufactured vehicle may have a similar or even better environmental performance, compared to an Eastern vehicle of about the same age or slightly more recent. Hence, the massive introduction of Western cars *might* even have decreased the average emission rate for many pollutants.[34] Actually, no definite conclusion can be drawn on the change in the average emission patterns implied by this trend without having more precise information on the average emission rates of Eastern and Western vehicles according to their age.

In subsequent years, the average age of *first-registered* cars declines continuously. Most of the cars first registered are now new models, while second-hand imported cars are in the minority, although they are considerable in number.[35] The age of the fleet continues to grow, but more slowly, since the newly registered vehicles are more recent. The proportion of Western cars among first registrations remains rather stable (what changes is the ratio between new and used imported vehicles). The proportion of Western cars in the total number of vehicles in use continues to grow. This trend will change at a future stage only if the safety, reliability and comfort characteristics of Eastern-produced vehicles becomes comparable to those of the West.

At the same time, concern for environmental problems has grown and various measures have been taken to curb the fleet's atmospheric emissions. The emission standards for newly registered cars are being considerably tightened, in order to close the gap with Western Europe's most recent regulations. In this phase, bans or taxation on the import of older vehicles are often introduced.[36] Technical inspections of the vehicles in use are more frequent and include tests on emissions. As a result, the environmental performance of Eastern fleets may improve considerably. For the time being, however, there still remains in circulation a relatively large number of very old, Eastern European model cars[37] that are in a rather deteriorated working condition with poor environmental performance.

3.3. The possible role of scrappage schemes in Eastern European countries

As underlined in section 2.2.1., scrappage schemes can be particularly useful when there is a relatively small percentage of vehicles responsible for a large part of the overall fleet's emissions, the so-called 'gross emitters'. In this case, the incentive may manage to eliminate a relevant quantity of atmospheric emissions by retiring a rather limited number of selected vehicles. This would avoid major market perturbations and would keep the overall expenditure for the scheme at a lower level.

The 'gross emitters' may not necessarily be the oldest cars of the fleet, although this is often the case. They could also be more recent vehicles that, because of poor quality and/or bad maintenance, have a particularly low environmental performance. It is also important to underline that the concept of 'gross emitters' is a *relative* one. Even a fleet with a very low average age may have a group of cars that are 'gross emitters' *compared* to most of the others. In this case, the *absolute* value of the emission rates of the worst vehicles will be much lower, compared to those of an older fleet, and the 'gross emitters' may not represent a problem. The opposite situation is found in the former socialist countries. Although there is an ongoing, spontaneous tendency to replace old Eastern-produced cars with more recent Western models, there still remains a large number of old low-quality models with bad environmental performance, especially if compared to Western European fleets. However, it would not be feasible and it would be too costly to implement scrappage schemes that target all these low-quality cars. The programmes might be more successfully applied if they managed to select the smaller number of the 'gross emitters' that are *relatively* more polluting, in particular those with a high average mileage per year.

Just as for Western countries, recognising a potential role for scrappage schemes does *not* mean that *any kind* of programme will necessarily lead to environmental improvements, nor that it will achieve these improvements at an acceptable cost for society. It remains absolutely fundamental to study carefully its design, taking into account the particular economic, institutional and technological conditions of the country where the programme could be introduced.

As concerns Eastern European countries, the economic conditions currently prevailing (together with the results of the Hungarian experience) suggest that cash-for-replacement schemes that require a switch to a *new-model* car are not going to be successful. New cars are very expensive with respect to the average purchasing power of Eastern European households. In general, those families who can afford to buy a new model do not own an old, poorly maintained car[38] or if they do, they would soon replace it anyway, even without the incentive. On the contrary, the owners of the 'gross emitters cannot afford to purchase new models. The incentives they need in order to buy these would be too high to make the scheme feasible and efficient.

The situation would be slightly different if cash-for-replacement schemes were directed only at heavy-duty vehicles. Buses and lorries are usually owned by firms, whose purchasing power is high relative to low-income households. There is, however, very limited experience with scrappage schemes that target trucks and buses. Therefore, it is difficult at the moment to draw meaningful conclusions as to their possible success or the cost-effectiveness of reducing atmospheric emissions. These kinds of schemes are worth further examination especially in light of the positive Hungarian experience.

Within this economic context, cash-for-scrappage schemes may be more useful. The low-income owners of the 'gross emitters' would probably use the incentive to buy old, second-hand, Western vehicles. Although these models will surely not comply with the most recent EU environmental standards, they might still have average emission rates considerably lower than those of the old, Eastern models eligible for the incentive; particularly if the eligibility criteria are properly defined, targeting the 'gross emitters'. The possibility of implementing useful and efficient schemes relies heavily on the average characteristics of the scrapped and replacement vehicles. The former may be influenced through the selection requirements. As the USA schemes have shown, this selection can be considerably helped by the use of the existing inspection and maintenance programmes. As concerns the replacement vehicles, they will probably have the characteristics of an 'average' car belonging to the fleet in use. For this reason, it is of vital importance that the fleet in use be properly maintained; that it complies with the environmental standards in force; and that the average environmental performances and mileage travelled by the cars in use are known with reasonable approximation.

All in all, this means that scrappage schemes can be implemented successfully *only if* the set of fundamental transport and environmental policies and regulations (i.e. a set of emission and safety standards for both vehicles in use and first-registered cars; technical and environmental I&M programmes) are already carefully implemented.

As concerns the average quality of the replacement vehicle, it would be particularly important to check carefully the environmental and safety characteristics of the second-hand imported cars, preventing the importation of poor-quality models. But, as it was argued for Hungary, too strict requirements (or complete bans) for imported, second-hand vehicles may actually raise the average price of the replacement cars and so hinder the scrappage of older 'gross emitters' owned by lower-income individuals. There is a trade-off between the improvement in the quality of newly registered vehicles that can be achieved through import restrictions (which increases the average price of replacement cars) and the renewal rate of the worst performing cars of the fleet. A possible suggestion may be to control the importation of a limited number of cheap, second-hand cars that are carefully checked and selected through inspection and maintenance programmes and then made available to the owners of vehicles eligible for the scrappage incentive. In this case, the scheme would be structured as a special cash-for-replacement programme, in which the replacement vehicles would not be new, but selected according to their environmental and safety characteristics, together with their market price. Such a scheme, however, might be particularly exposed to the risk of bribes and corruption of I&M operators.

As suggested for Western countries, also in this case, the policy-makers should carefully check the possibility of implementing scrappage schemes against other feasible alternative policy tools that may achieve the same goal. It is extremely difficult, however, to make generalisations as to which measures may obtain the desired results in the most efficient way.

Since most Eastern European countries are currently experiencing very rapid fleet growth with a relatively high number of new registrations every year, policy-makers should steer their attention generally more towards measures that boost the purchase of *cleaner* cars, *independently of scrappage decisions*. These measures could either be environmental regulations, e.g. stricter emission standards for newly registered cars, or economic incentives to buy (and use) 'greener' vehicles. These policies would offer the opportunity of obtaining, in the mid to long term, the advantage of high motorization levels, while simultaneously avoiding some of the environmental disadvantages that have characterised Western fleets in the past. Scrappage schemes may still have an important role in getting rid of old 'gross emitters', both from the environmental and the industrial point of view. However, they will be relatively less relevant, compared to their role in Western European countries.

As concerns the environmental characteristics of existing vehicles, retrofitting programmes remain a valid alternative to scrappage schemes even in Eastern European countries. Previous experiences (Hungary) seem to be rather positive. However, the environmental benefits of retrofitting old Eastern cars have quite a limited duration. The catalytic devices deteriorate after 20 000 to 80 000 km, depending on the particular model to which they have been attached (Meretei *et al*, 1996). After that, if the vehicle is not scrapped it may begin to have high emission rates.[39] The duration is shorter for older, poorer technologies (two-stroke engines) and for badly maintained vehicles. For these, scrappage schemes still represent a more valid alternative. Moreover, scrappage programmes may still represent a useful policy tool for some categories of vehicles - buses and trucks - that are used for a high mileage per year and on which the productivity and performance of firms depend.

CONCLUSIONS AND RECOMMENDATIONS

All scrappage schemes implemented to date put improvement of the environmental performance of the car fleet among their main goals. The present report attempts to assess schemes mainly according to this criteria. It includes some additional analysis of the impact of scrappage schemes on the vehicle manufacturing industry, on markets for other durable goods and on the benefits of improved vehicle safety. Surprisingly few of the scrappage schemes examined included a quantitative assessment of their impact on the environment or their cost effectiveness with regard to environmental protection. Most assessments were limited to the impact of schemes on the automobile manufacturing industry and in some cases on GDP and employment.

General conclusions

Scrappage schemes have two main possible impacts on the environment. The first is positive: they may reduce the load of atmospheric emissions caused by the car fleet since they substitute older, more polluting vehicles with newer, cleaner ones. The second is negative: they shorten the average car's life and, therefore, if the schemes are permanent or repeated over time, they increase the amount of energy and materials used and emissions caused by all the processes involved in car construction, dismantling, scrapping and recycling.

As the difference in environmental performance between some older vehicles and most newer ones is currently substantial, the positive effect is likely to prevail for most of the schemes implemented. Newer vehicles are also more durable and maintain design emissions levels over greater mileages than older vehicles. The increasing incorporation of on-board diagnostics, which should reduce the likelihood of new vehicles performing below design emissions standards as they age, is also a positive factor. Scrappage schemes are likely to involve substantial reductions in emissions, per km driven, of hydrocarbons and carbon monoxide in particular. To a more limited extent, they may also reduce NO_X emissions. The effects of scrappage schemes on greenhouse gas emissions are very uncertain, however, and may even be negative (i.e. some schemes might have increased the overall amount of CO_2 emitted). The sign and size of changes in CO_2 emissions will greatly depend on the detailed design of the schemes. Reductions in specific emissions of all kinds may also be partially off-set by rebound effects — consumers benefiting from cash-for-replacement schemes may take the opportunity to purchase a more powerful car and use the new vehicle more intensively.

The emission reduction achieved by *temporary* schemes will itself be temporary and the improvement achieved short-lived. The natural renewal rate of the fleet, without any incentives, would replace the same old vehicles in any case some two or three years later.

The possible gains from *permanent* scrappage schemes rely on improvements in average emissions from new generations of vehicles and engines. Scrappage programmes will achieve net environmental benefits only if *future* vehicles have emission rates substantially better than older models *and* if, at the same time, the environmental impact of vehicle construction and dismantling processes is reduced. The introduction of three-way catalytic converters resulted in significant reductions in specific emissions but technological improvements since then have resulted in only more modest reductions. The window of opportunity for achieving large benefits from scrappage schemes is therefore narrowing, as an increasing part of the existing fleet comprises vehicles equipped with catalysers. New technological breakthroughs, for example one that reduces cold-start emissions, could alter this trend if commercialised in the future.

Assessments of scrappage schemes cannot be made only on the basis of emission standards or average emission factors for different model years, but depend on economic variables affecting the behaviour of car owners and on the cost of the scheme. Where the cost per tonne of pollutant reduced is high, other environmental policy measures should be considered instead of scrappage programmes. The structure of taxation in relation to the ownership and use of vehicles is a key element in determining the overall economic incentive for vehicle stock turnover. The cost-effectiveness of scrappage schemes may be undermined if they run counter to incentives arising from the existing structure of taxation (for example, if older vehicles pay lower annual vehicle charges than new cars).

Both the size of the emission reduction achieved and cost-effectiveness depend heavily on the detailed design of scrappage programmes.

Some lessons from the different types of programme implemented to date

Two broad groups of scrappage schemes have been identified. Under the first kind, cash-for-scrappage, incentives are available *whatever the subsequent replacement decision* taken by the consumer. The second type of scheme, cash-for-replacement, provides an incentive payment that is *conditional* upon a specific kind of replacement vehicle being chosen (typically, but not necessarily, a new-model car).

When the selection of vehicles to be retired is made carefully, cash-for-scrappage schemes may achieve useful emission reductions at a reasonable cost, i.e. at a cost comparable to the main alternatives for reducing fleet emissions.

The number of vehicles retired by either type of scheme should not, however, go beyond *a limited number* of vehicles selected among the 'gross emitters' in the fleet. Otherwise the cost per tonne of emissions avoided increases considerably. Moreover, by bringing forward a large number of scrappage and replacement decisions, the schemes may cause considerable perturbations to the car market.

The cash-for-replacement schemes implemented up to the present time appear to have been much less cost-effective. In most cases, they constrained the consumer to purchase a new car. In doing so, they have excluded lower-income groups who cannot afford to purchase new cars even with an incentive bonus. This makes the schemes somewhat inequitable, but more importantly prevents them from attracting many of the oldest cars in the fleet, used typically by lower-income families, intensively, as their principal means of transport. These schemes, therefore, have *not* properly selected the vehicles to be retired, leaving in use a large proportion of the 'gross emitters'. Moreover, higher payments are necessary to influence the decision to purchase a new car, rather than simply scrap a car (which might be replaced with a used car or not replaced at all). As a consequence, these schemes have a high average cost per tonne of pollution avoided and they do not compare favourably with other alternative policy tools on purely environmental grounds.

Timing is important. The available data suggest that the average fuel consumption of European new-model cars was higher in the early 1990s than during the second half of the 1980s. This implies that some of the cash-for-replacement schemes implemented in the early 1990s may have resulted in an *increase* in total CO_2 emissions. On the other hand, these schemes increased the percentage of small vehicles in total first registrations. This might have counterbalanced the increase in fuel consumption of the average car. The net effect on CO_2 emissions was of uncertain size and sign. Since the early 1990s, average CO_2 emissions from new cars have fallen back to near the low point recorded in the mid-1980s in most countries.

Cash-for-replacement schemes might have positive economic effects on the country that introduces them, particularly if it has a significant national car industry. The increase in new car sales might bring about an increase in GDP and employment. However, this increase will again be of only a temporary, short-term nature. It will also probably have some negative counter effects. First, it will involve a fall in sales following the end of the scheme and possibly just before a scheme is introduced and second, increased expenditure on cars will subtract from available income for purchases of other durable goods. The overall change in GDP and employment resulting from these effects is difficult to assess. Macroeconomic analysis is required and this should evaluate schemes over the mid to long term, extending the time frame beyond the direct positive short-term effect on car sales.

The possible uses of scrappage schemes in former socialist countries

Most Central and Eastern European countries are currently experiencing steady growth in their car fleets with average growth rates considerably higher than in most West European countries. This means first of all, that during the current phase, most first-registrations in these countries do not concern the *replacement* of existing old vehicles. Instead they represent net additions to the fleet. As scrappage schemes aim to influence replacement decisions, their role - both in economic and environmental terms - will be more limited, compared to schemes introduced in Western economies.

On the other hand, although the Eastern fleets are rapidly changing in both quantitative and qualitative terms, there remain a rather large number of older cars manufactured in former socialist countries, whose environmental and safety performances are poor. Because of this, there may still be a potential role for instruments that accelerate vehicle retirement.

Income constraints make cash-for-replacement schemes particularly difficult to design successfully in the newer ECMT Member countries. ‘Gross emitters’ are typically run by households on the lowest incomes, and the cost of a new car represents an even higher proportion of income for this segment than in Western Europe. There may be better opportunities to introduce cash-for-replacement schemes for commercial and public vehicles. Enterprises, unlike households, have the financial capacity and longer-term planning horizons to make use of relatively small cash incentives, tax credits or depreciation allowances. Moreover, trucks and buses typically contribute an extremely large share of total fleet emissions in the early stages of fleet growth and economic restructuring. In Western Europe too, buses often represent a discrete group of ‘gross emitters’ in cities.

Before targeting an acceleration of fleet renewal, the government of any country must ensure that the fundamental set of transport and environmental policies regulating emissions are already effectively implemented and enforced. These include an adequate framework of legislative and economic instruments including registration documentation, fully implemented emissions regulations and their effective enforcement through pre-sales testing and after sales inspection and maintenance. Not all of the former socialist countries fulfil this condition. In Russia, for instance, inadequacies include emissions regulations that are not always enforced in manufacturing and insufficient inspection and maintenance capacities. Overall, there is a major failure to enforce environmental regulations. For countries such as Russia, incentives for accelerated vehicle retirement might become useful at some later stage after the fundamentals have been addressed, when they might be applied to specific urban areas with higher than average levels of motorisation.

Other policy tools

The specific aim of this report is to assess scrappage schemes. Other possible instruments for improving fleet environmental characteristics have been mentioned but not analysed. This does not mean that they are considered less useful. On the contrary, effective emissions control policies are prerequisite to the introduction of scrappage schemes. It was possible to implement the programmes evaluated only because of emissions regulations, which over the last twenty years have considerably reduced emissions from new cars and consequently significantly improved the average environmental performance of the fleet.

At least three different policy tools provide alternatives to scrappage schemes — in the sense that they may bring about the same qualitative changes in environmental impact. In some cases, they may also even result in an increase in first registrations.

Firstly, scrappage incentives are ultimately just a way to change the relative prices of older cars with respect to newer models. The same effect may be obtained, in a permanent way, by changing the structure of annual vehicle taxation. German experience suggests that changing the structure of taxation to tax older cars more heavily than new ones, on the basis of emissions characteristics, can accelerate considerably the replacement of older cars with cleaner vehicles.

Secondly, an enhancement of inspection and maintenance programmes (in particular as concerns environmental requirements) can also render the operation of older cars more costly and will therefore encourage their replacement. Enhancing inspection and maintenance programmes may be particularly attractive because this approach leaves the owner of a vehicle that has failed an inspection to chose between replacing the car or repairing it, without changing relative market prices directly.

A final option that is worth considering before implementing a scrappage scheme is retrofitting. Retrofitting vehicles with catalysers or other emissions control systems or converting engines to run on alternative fuels can in some circumstances be more cost-effective than replacement. The potential safety benefit of replacement is, however, forgone.

NOTES

1. A more precise term for this group of pollutants is that of reactive organic gases (ROG): these include non-methane hydrocarbons and reactive oxygen-containing organics such as aldehydes. In common use, they are more often indicated as hydrocarbons (HC) and Volatile Organic Compounds (VOC). Most of the carcinogenic micropollutants emitted by passenger cars belong to this group, which is referred to as hydrocarbons in this report.

2. There can also be substantial (indirect) effects on the incremental demand through the price effects described in section 1.2.

3. The number of households owing more than one car in the industrialised, European countries is quite considerable. In France, for instance, it has been estimated that in 1995 about 28% of families owned two or more cars. The same proportion was 15.5% in 1981 (Morcheoine and Orfeuil, 1998).

4. In most cases that means all cars aged from one to nine years, since the lower age limit set has usually been ten years (see Boxes 1-3).

5. This would imply that these owners have complete information on the effects of the scheme on future car prices trends, which in reality is not the case.

6. As suggested by Licandro and Sampayo (1997), a reduction in price of new-model cars has the effect of shortening the average life of the existing ones. If newer cars cost less, people will replace them more rapidly. Therefore, the price fall will reinforce the effect of the scrappage incentive on the replacement rate.

7. This occurred, although GDP per capita started increasing again from 1994. Increased taxation needed to reduce the state deficit and finance pensions decreased disposable income during this period. Moreover, the effects of *Tangentopoli* - the corruption scandal - on the economy, as well as pessimistic future expectations, may have contributed to keeping demand relatively low.

8. Data related to Greece seems to confirm the existence of the negative anticipation effect: the number of first registrations showed a sharp fall after the end of the scheme (March 1993). It is difficult to interpret this fall, however, since 1993 was the year of a general economic slowdown. It is difficult to distinguish how much of the fall in car sales was due to the anticipation effect.

9. Registrations usually follow orders some two to four months later.

10. The French data confirm this conclusion.

11. There were two increases in nominal prices, in October and January 1998, i.e. immediately after the end of the first and second phases of the 1997 scheme. The car price index remained, however, below the general consumer price index.

12. E.g. private companies that want to buy emission reductions to comply with legal requirements, as happens in the USA.

13. The damage can be up to one order of magnitude higher in the worst cases. See, for example, the case-studies of Milan and Paris evaluated according to the same methodology in Fontana and Frigerio (1997) and Rabl and Spadaro (1998).

14. The conclusions presented in this paragraph concerning permanent schemes are also confirmed by the analysis of Van Wee and Meurs, (1994).

15. See Glazer, *et al*., 1995; Lawson, D. (1995), "Passing the Test - Human Behavior and California's Smog Check Programme." Journal of Air and Waste Management Association, Vol.43, 1993, quoted in Hall, 1995.

16. There is no definite relationship between the two variables. What is suggested here is that greater availability of cars will *probably* lead, to some extent, to greater use and, therefore, to a greater amount of emissions.

17. Overall fleet emissions also vary according to environmental conditions (in particular HC emissions vary according to average ambient temperature). This is, however, a variable that is not within human control and it will not be considered further.

18. For the sake of simplicity, it is supposed that neither the emission factor nor the mileage travelled would have changed during the remaining lifetime L. The same assumption is also made for the replacement vehicle. Moreover, only running emissions are considered in the formula. A more precise evaluation should also take into account evaporative hot-running losses and resting emissions, whose rates are usually given in grams per trip and grams per day respectively. The short representation given has been chosen because of its relative simplicity. Evaporative emission reductions are, in fact, among the main achievements of replacing old vehicles. The simplification made does not, however, change the qualitative results of the report.

19. This danger may be lessened in the future by the voluntary agreement reached by the European car constructors with the European Commission. According to this agreement, CO_2 emissions will be lowered from 186 g/km in 1995 to 140 g/km by the year 2008. On the other hand, this may be partly counterbalanced by the

progressive spread of energy-consuming options on board, in particular air conditioners. Of the French cars first registered in 1995, 16% were equipped with air conditioning (Morcheoine and Orfeuil, 1998).

20. See also US Congress, OTA, 1992; California EPA-ARB, 1996.

21. Such questionnaire results are usually not considered very reliable, as there might be an incentive for respondents to be strategically biased in their answers, trying to influence the outcome of the study. On the other hand, it is extremely difficult to obtain information from any real data (through so-called revealed preference methods), as the influence of the vehicles' characteristics on VMT cannot easily be disentangled from all the other economic and social variables that influence it.

22. As the schemes implemented usually have a very limited duration and are not announced in advance (to avoid major market perturbations), participation in the programme is difficult for lower-income families for two reasons. Not only does it require a considerable amount of money, but it also needs a considerable 'liquidity'. In other words, the owner of the old vehicle must be able to gather the sum in a few months. Only better-off families are likely to be able to afford this.

23. For each age cohort, the scrappage rate was computed as a ratio between the cars scrapped during the year t and the number of registered cars in use at the end of the year t-1.

24. On the other hand, the fleet growth rate in Greece, where the incremental demand was relatively high, decreased during the scheme, compared to the rate of growth before and after the scheme.

25. The Illinois 'cash for clunkers' pilot project that retired about 200 cars also introduced a differentiation according to the estimated emission rates of the scrapped vehicles. The scrappage of 'dirtier' cars was encouraged by a higher incentive. No similar attempts were made in any other scheme.

26. In France and Spain, the incentive was taken up by very few owners of vehicles aged 7-10 years.

27. See Bickel *et al*, 1997; ZEW, 1996; IWW– INFRAS, 1995; ECMT, 1998.

28. However, this measure also incurs the risk of worsening the performance of 'gross emitters' in the short term. Some owners may not make the necessary repairs, because either they cannot find the necessary spare parts or because scarcity has increased their costs too much.

29. The ratio was even lower for the USA, where during the same year the average expenditure on a car was equal to 23.5 weeks of the average net wage.

30. Not all the Eastern European countries of interest are represented on the graphs, as compatible data were not available. The aim of these graphs is not to give detailed information on single countries, but rather to illustrate the general trend. GDP per head is just one of the variables that can be considered to explain car purchase decisions. Other factors among those sketched out in section 1.1.1. may also play a substantial role. The representation given by these figures is, therefore, rather simplistic. However, it gives a rather clear qualitative picture of some basic trends.

31. The data shown in Figure 10 for Greece needs some further comment. As the average taxation on private vehicles was particularly high in this country, many owners registered their cars as commercial vehicles for which they pay lower taxes. By including this category of vehicles, the motorization index becomes slightly higher, about 255 cars per 1 000 inhabitants (Baltas *et al.*, 1995). Still, this does not significantly change the general information contained in the graph.

32. There were no data from the same source and for the same years (1993-1996) concerning Russia. However, according to the UNECE (1998), the fleet growth rate of this country in 1995 and 1996 was around 10%. This places the Russian Federation very close to Romania in Figure 11.

33. This hypothetical starting point can be more or less recent according to the particular country considered. Slovenia, Estonia, Hungary and the Czech Republic are probably in advance with respect to other Eastern European states on the path of evolution described.

34. There is some evidence to show that there has been an improvement in the quality of air in Budapest between 1990 and 1993 regarding ambient concentrations of lead, CO and formaldehyde (Meretei *et al.*, 1996). Meanwhile, the fleet's age has been increasing. Unfortunately, there are no data concerning traffic volumes for the same period.

35. Data from Poland confirm this trend. In 1991, 1993 and 1996 about 52%, 29% and 24% respectively of annual first registrations were accounted for by imported second-hand vehicles. The share of imported new models has simultaneously increased from 17% to about 38%.

36. To our knowledge, bans or import taxes have been introduced in Hungary, Poland, Estonia and Russia. This list of countries is probably not exhaustive.

37. For instance, at the end of 1995, 48% of the passenger cars in use in Latvia were either UAZ or Moskovich models. Two-thirds of the Latvian car fleet was older than ten years, while only 5% had been manufactured in the last five years. Only 5.3% of the cars first registered in 1995 were new models. (Eurostat, 1997).

38. Compared to Western European countries, a very low proportion of Eastern European households own two or more cars.

39. Retrofitting might also decrease the fuel efficiency of the vehicle by up to 3% or even more if the retrofit devices are of poor quality (Meretei *et al*, 1996).

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