Transport and the environment

A. Key Questions

- What are the environmental consequences of various forms of transport activity? How can we evaluate these impacts? And when we do, what results do we find (that is, what are the welfare costs of the environmental impacts caused by transport activities)?
- What other external costs (other than environmental costs, narrowly deigned) arise from transport? How large are these (in welfare effect terms) relative to environmental costs per se?
- How important are environmental externalities (principally, air pollution costs) in relation to the overall price changes that efficient pricing implies?
- If the sum of true internal and external marginal costs is compared to existing variable taxes and charges, are price increases automatically implied? And do these price changes suggest that optimal pricing will result in a shift to more environmentally friendly modes, or lead to an overall reduction in travel? Put another way, to what extent are environmental problems dealt with when by transport policy that is centred on efficient (social marginal cost) pricing?

B. The environmental impacts of transport

Environmental impacts of transport can be seen in terms of **externalities** generated by the activities that comprise transport.

Major forms:

Atmospheric pollution.

Pollutant emissions from transport cause environmental and health damage. Until recently, attention tended to be focussed on the pollutants SO_2, NO_X and VOC. More recently, attention has been directed towards particulates and greenhouse gas emissions. Other relevant pollutants include ozone and carbon monoxide. (But note that hydrocarbons and nitrogen dioxide are precursors of ozone, and also note that hydrocarbons are often generated in particulate form.)

Health impacts of air pollution particularly severe in urban areas; on some estimates particulate matter from transport kills almost as many people per year as road accidents (Maddison et al., 1996).

Greenhouse gas emissions: Transport remains the most rapidly growing source of greenhouse gas emissions. In Britain, transport currently accounts for 26% of CO_2 emissions, and is expected to grow by 30% by 2020, in the absence of policy actions to prevent this (DETR, 2000).

Congestion

It is not clear whether one should regard congestion as an environmental problem per se. It is certainly an adverse externality arising from transport in some contexts. Under broad definitions, it might also be treated as having "environmental" impacts. However we label it, it is one of the main problems associated with transport activities, especially in urban areas. It can also be significantly costly in inter-urban transport.

Safety aspects/accidents

Traffic, in its various forms, is associated with substantial numbers of serious accidents causing personal injury and/or death. Statistics are readily available and will not be reported here. But given the large values usually attributed to loss of human life, it figures prominently in valuations of the external costs of transport.

Noise and Visual intrusion

Both rather localised problems, but can be substantial nonetheless given the tendency for traffic activity to be concentrated in heavily populated areas.

C. Transport demand

- Growing rapidly
- Driven by income (high income elasticity of demand) and demographic factors
- See, for examples, projections of air passenger transport demand
- Better technology and level of supply also increases demand. The latter poses a serious dilemma for transport policy, as demand tends to expand fairly quickly as supply increases. So there is something of a "cat chasing its own tail" phenomenon. One must, of course, remember that the new "demand" that materialises as new roads etc, are built does imply welfare improvements (otherwise individuals would not use the roads). But it endogenises location decisions, and so makes planning difficult, and poses problems for dealing with congestion problems.

Role of Technology

- Unclear impact
- e.g. Teleworking.
- But convenience increases demand (although see the qualification above - this is not necessarily a bad thing!)

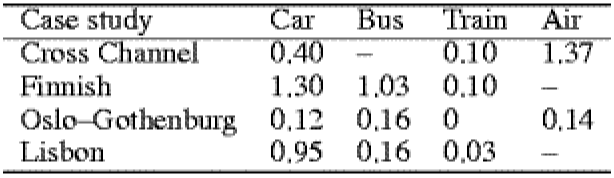
D. The Costs of Transport, and Transport Externalities in Particular

- There has been a growing number of studies seeking to place money values on the air pollution and other external costs of transport (Small and Kazimi, 1995; Maddison et al., 1996; Greene et al., 1997).
- For air pollution, the determination of costs specific to vehicle types and geographical contexts has relied heavily on the results of studies exploiting the ‘impact pathway’ approach developed in the ExternE Transport study (Friedrich et

al., 1998). This represents the output of what is by far the largest effort ever devoted to the issue in a single European research project. The impact pathway approach was based upon a bottom-up analysis of emissions, dispersion modelling, dose–response functions and monetary valuation of impacts relating to human health, ecosystems, crop losses and damage to construction materials for a range of all the major pollutants, including nitrogen oxides, sulphur dioxide, carbon monoxide, particulates and ozone. The resultant costs were dominated by damage to human health.

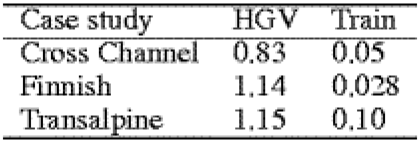
- The starting point for valuation was a value of statistical life of 0.98 million ECU at 1994 prices, used in accident analysis (Hopkin and Simpson, 1995). This was adapted to reflect years of life lost in the case of mortality, and years of reduced quality of life for morbidity.
- Nevertheless, the values for air pollution provide a clear picture of the relative efficiency of rail transport, relative to road-based forms of transport.

Table 2. Component of passenger prices related to air pollution (ECU/100 passenger km)



Case study	Car	Bus	Train	Air
Cross Channel	0.40	–	0.10	1.37
Finnish	1.30	1.03	0.10	–
Oslo–Gothenburg	0.12	0.16	0	0.14
Lisbon	0.95	0.16	0.03	–

Table 3. Component of freight prices related to air pollution (ECU/100 tonne km)



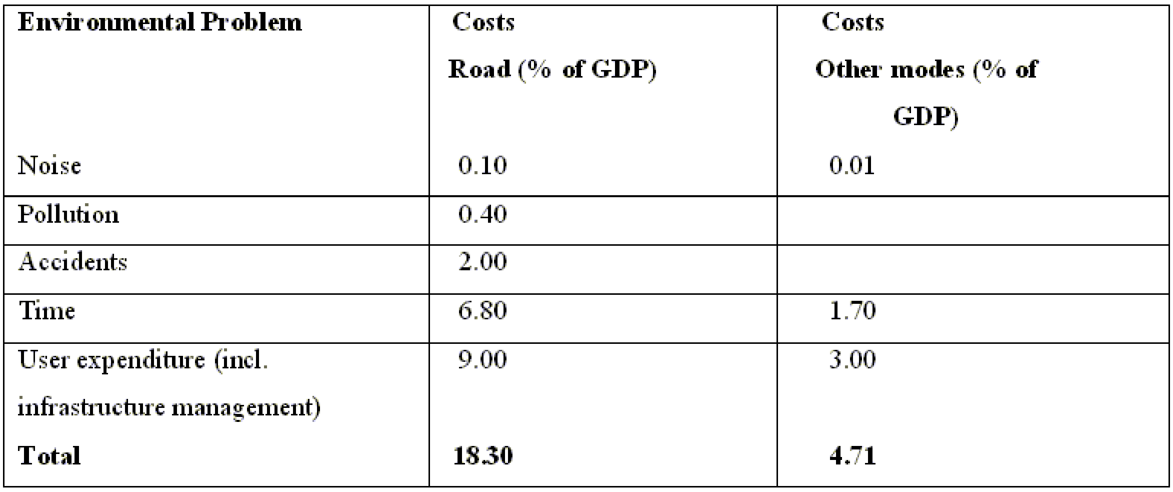
Case study	HGV	Train
Cross Channel	0.83	0.05
Finnish	1.14	0.028
Transalpine	1.15	0.10

- To put these figures in context, the values for the Cross Channel case study may be compared to those of McCubbin and Delucchi (1999) for the USA as a whole. The values of McCubbin and Delucchi clearly relate to a different context, but it remains informative to transfer their values into the same units of this study (i.e., from 1990 cents/vehicle mile to ECU/100 pkm and ECU/100 tkm in 1995 prices and 2010 values). Converting the values, excluding upstream emissions, results in estimates of: 0.42–5.60 ECU/100 pkm for light duty gasoline vehicles; 1.09–13.6 ECU/100 pkm for light duty diesel vehicles; 0.30–5.41 for heavy duty gasoline vehicles; and, 0.71–13.3 ECU/100 tkm for heavy duty diesel vehicles. Before adjusting for emission rates for the 2010 vehicle stock, the Cross Channel estimates can be seen to lie at the lower end of the range estimated by McCubbin and Delucchi. However, the effect of taking account of emission rate reductions to 2010 of PM_{10}, to 21 and 18% of the 1996 rate for light and heavy duty vehicles (DETR, 1999), would be to place the Cross Channel values close the midpoint of McCubbin and Delucchi's values.

- For noise, a comparable method to that used for air pollution was implemented, with an emphasis in the case studies on using a bottom-up approach where possible. For the Cross Channel case study, only top-down estimates were available, from INFR/IWW (1995). These were adapted on the basis of roadside dispersion modelling carried out for the London to Lille corridor (Weinreich et al., 1997), with further estimates for the other corridors in the study area based upon relative population densities. Values were increased to 2010 values according to real GDP per capita growth.

- For accidents, the approach adopted was to estimate the share of accident costs not borne by the individual (directly or via insurance) plus — for road traffic — the increased risk to existing traffic of an increase in traffic volumes (rail and air risk rates were assumed to be invariant with vehicle km). Unit values were based on willingness to pay approaches (for the Cross Channel study, 0.98 million ECU per fatality; Hopkin and Simpson, 1995). For rail and air transport, there is no apparent downward trend in accident risk rates for the Cross Channel corridor. However, for inter-urban road transport, recent trend changes in risk rates (−2% p.a. fatalities, +3.5% p.a. severe and slight; DETR, 1998) were extrapolated to the year 2010. A sensitivity test was conducted to examine the effect of the inclusion or otherwise of the values held by friends and family; this component is often excluded due to uncertainty as to its value and validity (e.g., Proost and Van Dender, 1999). This element is incorporated in the high valuation of externalities but not the low.
- In the case of congestion, the planned provision of road and rail infrastructure in many of the case studies meant that estimates of the 2010 external costs of congestion were insignificant. For the two case studies where road congestion was significant — Cross Channel and Lisbon — the approach used was to estimate marginal external congestion costs from the derivative of the speed–flow curve, the traffic volume and the value of time (Newbery, 1990). To achieve greater accuracy for this highly non-linear cost category, the Cross Channel case study modelled hourly time slices, taking a weighted average of the resulting marginal costs for input into the all-day model. The Lisbon case study applied an alternative approach of running separate peak and off-peak models. In both cases, the model was iterated until a new equilibrium was reached.
- For the public transport modes, the Mohring effect, whereby additional traffic provides benefits to existing passengers, will arise if the most efficient form of providing increased capacity is to increase service levels. For the Oslo–Gothenburg case study, increased capacity was provided in the form of larger individual vehicle capacity (no increased service level or Mohring effect), but where vehicle and fixed infrastructure constraints precluded higher capacity vehicles, the Mohring effect was estimated based on the values of time of existing passengers.

Table 1 Estimates of costs of transport in OECD countries as a percentage of GDP



Environmental Problem	Costs Road (% of GDP)	Costs Other modes (% of GDP)
Noise	0.10	0.01
Pollution	0.40	
Accidents	2.00	
Time	6.80	1.70
User expenditure (incl. infrastructure management)	9.00	3.00
Total	**18.30**	**4.71**

Source: Button and Rietveld (1999), page 582, which in turn cites source as Quinet (1994)

E. Salient characteristics of various modes of transport

	Passenger and business services	**Freight transport** Growing faster than GDP. Increased demand with structural change.
Road transport	Limited capacity at local levels High environmental impacts. Demands for transport services bring environmental impacts close to human habitation. Separation not possible where fuel used is hydrocarbon-based in an internal combustion engine; however, separation IS possible where fuel used is "green fuel" (electricity, etc) and so generation takes place geographically separate from vehicle use. Suburbanisation	
Rail transport	Very efficient relative to road and air	Very efficient relative to road and air
Air transport	Noise intrusion Atmospheric damage	Noise intrusion Atmospheric damage
Maritime transport		Technical Efficiency; however, some recent studies cast doubt on whether maritime transport is actually less polluting than other modes. Potential and actual spillage. Shoreline damage around ports.

F. Role of state and Transport Policy

Regulation ("Command-and-Control")

The main approach to dealing with transport externalities in the European Union (and elsewhere) has been regulatory. Following comments apply specifically to EU countries, but often apply elsewhere too.

- Emissions standards for new vehicles: progressively tightened over the years
- Requirement that all new cars be fitted with catalytic convertors: impact of this is still working its way through the system => air pollution due to traffic in towns is forecast to fall over the coming decade.
- Greenhouse gases: main policy measure at present is a voluntary agreement with the car manufacturers to reduce average carbon dioxide emissions from new cars by 25% by 2008. Is not clear how effective this agreement will be, nor indeed how the manufacturers will achieve it, as there has been a tendency in recent years for improvements in engine efficiency to be offset by a shift to heavier, more powerful vehicles.
- The political agenda was guided by progress made on three fronts: abatement technologies for cars, estimation of dose-response relationships, and valuation of the different kinds of damage. Recently, policy makers have started to call for a shift in regulation from dedicated fuel efficiency and atmospheric pollution regulation to pure transport policies (parking, road pricing, transit) that address specific transport related externalities (congestion, traffic accidents). The hope is that these policies will have large beneficial side-effects on air pollution externalities. In this paper we use an integrated approach of the urban transport market and measure the effects of different types of environmental and transport policies on externalities related to air pollution and to transport, and we trade off their total welfare effects.

The current approach to the air pollution problem in urban transport.

In the literature three main strands address air pollution by road traffic. First, there is an extensive debate on fuel efficiency of cars, which has regained attention in the present climate change policy discussion. Second, there is a literature addressing damages and emission regulation for traditional pollutants. Finally, the transport literature has focussed on optimal regulation and pricing of different transport modes.

In the US, the corporate average fuel economy (CAFE) regulation of cars was introduced after the first oil price shock, as one of the instruments to decrease imported oil dependency. Its effects have been studied in detail. e.g. Greene and Duleep (1993). Part of the positive effects have to do with a reduction of air pollution. Harrington (1997), however, finds only a loose link between fuel efficiency and air pollutants other than CO2. In the EU, fuel efficient cars emerged as a result of high petrol taxes rather than as a result of standards. The primary motive for high fuel excises was the need for revenues, combined with a desire to discourage traffic flows in congested urban areas. Recently, there has been a proposal at EU level to require a minimum fuel efficiency of 5 l/100 km for new cars from 2005 onwards. This CAFE type of regulation was motivated by climate change objectives. Surprisingly, there have been almost no economic analyses of fuel tax policies in Europe.

In the US, the use of emission standards for conventional air pollutants originated in the late sixties. The policy objective is to reach given ambient air quality targets. For ozone there are still many non-attainment areas. Krupnick and Portney (1991) find that improving air quality in non-attainment areas by technology standards is not efficient: in general the costs outweigh the benefits by a factor 10 or more. Both benefits and costs are difficult to estimate (see Hall, 1998, for a discussion of the benefits and McConnell et al., 1995, for a discussion of the costs). More recently, there is an interest in complementary policies like zero emission vehicles (see Kazimi, 1997, for an evaluation) and a better inspection and maintenance regulation (see Harrington and McConnell, 1994). In the EU, the first systematic assessment of air quality policy came with the Auto-Oil I programme. In this programme, all interested parties studied the most appropriate regulation of car emissions and fuels to achieve the ambient air quality targets at lowest cost (see Degraeve et al., 1998).

In the transport economics literature, the emphasis is on the optimal use of a fixed infrastructure. The main problem is to correct for congestion externalities in peak hours, by tolls or through second best pricing measures, such as providing cheap transit. Air quality considerations have in general been absent from these pricing exercises. The assumption was that emission regulation of cars is a sufficient instrument to address air pollution so that both problems are separable. More recently, air quality issues and congestion problems have been taken into account simultaneously in pricing proposals in the US (Cameron, 1991; Harvey, 1994). An integrated approach of policies with an urban transport model. Two features make the assessment of transport and environment policies difficult: the presence of several types of externalities and substitutability between alternative transport modes and vehicles.

Deregulation

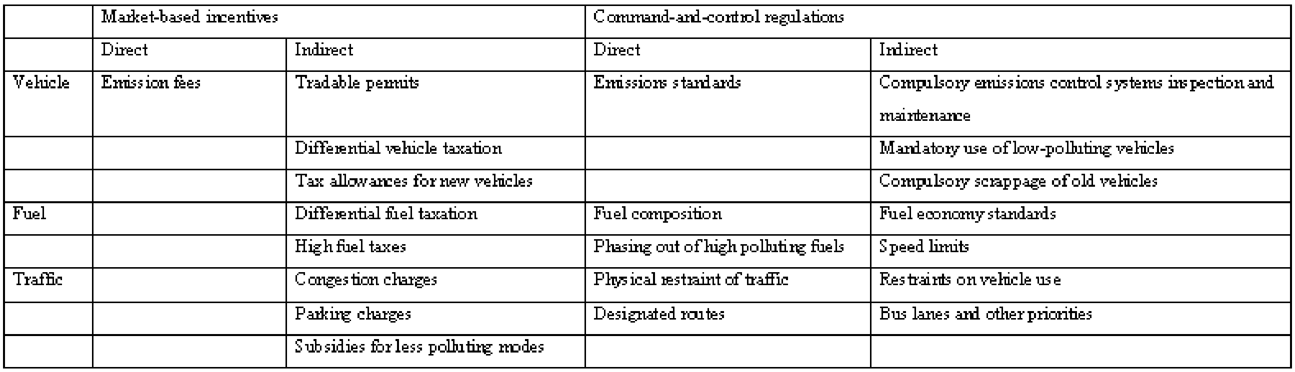
Increasing deregulation and reliance on the market. Brings down prices and - with high price elasticity of demand - increases demand for transport.

Economic-based transport policy

Follows from:

- Externalities
- Lack of fully allocated property rights
- Incomplete markets
- Pricing often fails to reflect costs properly (not only environmental costs, but also other costs such as congestion)
- Distortionary policy regimes: e.g. road transport has several implicit subsidies, and recent debates about subsidised air transport.

Table 2: Policy instruments for containing the environmental impacts of transport



	Market-based incentives		Command-and-control regulations	
	Direct	Indirect	Direct	Indirect
Vehicle	Emission fees	Tradable permits	Emissions standards	Compulsory emissions control systems inspection and maintenance
		Differential vehicle taxation		Mandatory use of low-polluting vehicles
		Tax allowances for new vehicles		Compulsory scrappage of old vehicles
Fuel		Differential fuel taxation	Fuel composition	Fuel economy standards
		High fuel taxes	Phasing out of high polluting fuels	Speed limits
Traffic		Congestion charges	Physical restraint of traffic	Restraints on vehicle use
		Parking charges	Designated routes	Bus lanes and other priorities
		Subsidies for less polluting modes		

Source: Button and Rietveld (1999), page 586

Key principles for the internalisation of externalities and efficient pricing

In a first best world efficient pricing requires that the user should bear short run marginal social cost.

A particular characteristic of the transport sector is that the user actually directly bears some of the costs in the form of time, and often the provision and running costs of a vehicle. It is thus more appropriate, following Jansson (1997), to speak of charging the 'price relevant cost', which is therefore marginal social cost less costs borne directly by the user (e.g., journey time).

For transport infrastructure, the price relevant cost is the sum of short run marginal cost to infrastructure provider (maintenance, operations), marginal cost imposed on other infrastructure users (congestion, accidents, opportunity cost) and marginal cost imposed outside the transport sector (environmental costs — air pollution, global warming and noise).

Some commentators advocate pricing at long run marginal cost, that is allowing for optimal adjustment of the capital stock, and therefore infrastructure capacity to traffic. Of course, if capacity is optimal, the two values are equal and it makes no difference which is measured (Newbery, 1990). Our conclusion was that very often transport infrastructure capacity is non-optimal, and may remain so for decades. In this situation, it is more appropriate to concentrate on using pricing to obtain optimal use of the existing infrastructure and rely on project appraisal methods to guide the adjustment of the capital stock.

Most transport infrastructure is subject to increasing returns to scale, but the costs of land/property acquisition limit expansion, particularly in urban areas. The result is that a surplus is likely on urban roads, whilst deficits are likely on rural roads and public transport (Jansson and Lindberg, 1998). This immediately raises two questions. Firstly, does the resultant pattern of surpluses and deficits overall satisfy public sector budget constraints? Secondly, will the resulting cross-subsidisation be seen as equitable? In either case, if the answer is no, we are likely to find ourselves faced with a need for some form of second best pricing.

For scheduled transport services, again the price relevant cost is the sum of short run marginal cost to the producer (but given the possible speed of adjustment it seems reasonable that this should be allowing the vehicle stock/timetable to vary), marginal cost imposed on other users of the service (this may be negative if the result of increased traffic is to lead to better services — the 'Mohring' effect; Mohring, 1972), marginal cost imposed outside the sector (although this should already be reflected in appropriate infrastructure use charges).

It may be noted that this approach to the internalisation of externalities focuses solely on the marginal costs of infrastructure use in determining the changes needed to existing prices. It neither considers the fixed costs of infrastructure provision, nor the upstream or downstream environmental costs associated with infrastructure or vehicles; these issues lie more firmly within the realm of decision making on aspects such as infrastructure provision and vehicle sales/disposal taxation. The counterpart of these types of cost on the revenue side, is that fixed charges and taxes are not generally considered in the analysis. These are assumed to remain unchanged from the current situation.

Problems in the design of appropriate policy instruments.

The characteristics of transport per se

- The extent of pollution damage depends upon the location of the emitting source. And with transport, this source is mobile.
- Pollution damage depends upon the timing of the emission. This interacts with the highly localised nature of much mobile source pollution. Hence emission controls on vehicles at the point of manufacture will be inefficient.

Monitoring and enforcement

- Can be very difficult and costly because of the large numbers of individual pollution sources and their mobility of the sources. This is especially relevant for emissions monitoring.

Stock effects and decay of regulatory control

- Emissions regulations can easily be implemented for new vehicles, but less easily for existing stocks. Incentives or regulations to reduce impacts of new vehicles have limited short-term effects.
- Technology controls lose effectiveness with age and use.
- The use of vehicles - not their production - is the main source of pollution.

European Transport Policy

Declared aim of the European Commission (EC) is that pricing policies should be developed that promote economic efficiency. This requires prices that cover marginal social cost. Originally, this was seen mainly in terms of charging for the use of infrastructure according to marginal operation and maintenance costs, but more recently the concern with environmental problems has led to an emphasis on the external costs of transport as well — congestion, accidents and environmental costs.

- 1995 EC Green Paper ‘Towards Fair and Efficient Pricing’ (CEC, 1995). Prices should reflect the costs that infrastructure users impose; some costs (environmental, accidents, congestion and infrastructure) at present are only partly covered, or not covered at all; and, these costs could be very large — of the order of 250 billion ECU [1] p.a.

  It argued that infrastructure cost charging should meet three criteria: firstly, the system should link charges as much as possible to actual costs at the level of the individual user. This was interpreted as marginal cost pricing; in other words each user should be charged the additional costs they impose; secondly, in total, infrastructure charges should recover aggregate infrastructure costs; and, thirdly, the system of charging should be transparent.

However, it is difficult to reconcile all of these criteria. If charges are based on marginal social cost, surpluses are likely in areas of congestion and pollution, and deficits elsewhere (e.g., Roy, 1998). There is no reason to suppose these will balance, particularly at the level of the individual mode or country; this is an empirical issue which is the subject of current research.

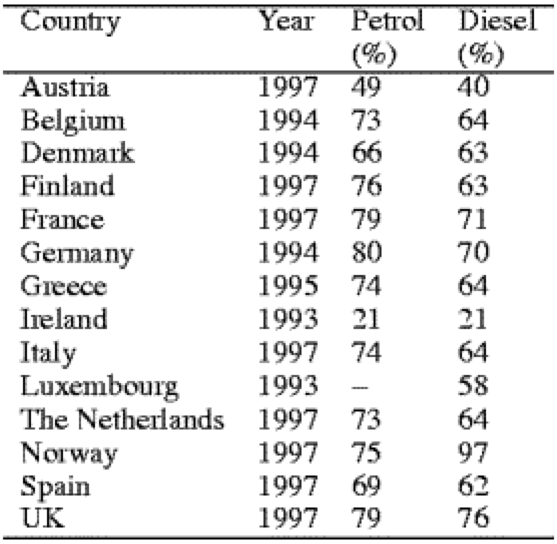
Given the above issues, the Green Paper argued that the key is differentiation, in order to reflect the differences in costs between vehicle types and parts of the network. Immediate measures proposed are: an electronic km charge for heavy goods vehicles; road tolls in congested or sensitive areas; differentiated fuel taxes, according to the environmental damage caused by the fuel in question; differentiated vehicle taxes, according to the degree to which their characteristics determine the level of road damage, congestion, accident and environmental costs; differentiated landing charges, to reflect congestion costs at airports; and, differentiated rail track charges, again reflecting differential damage costs as well as congestion on the rail network.

Following the 1995 Green Paper, a High Level Group was established to consider how to implement the proposals.

- This group produced a report (HLG, 1998) the proposals from which were taken forward in the following White Paper (CEC, 1998b), and has since prepared two further papers on how to implement the policy (HLG, 1999a and HLG, 1999b).
- At the same time, as part of the 4th Framework Programme, the Commission sponsored a large amount of research on how to implement its pricing policies, on practical and acceptability problems and on what the implications of implementing them would be.

CEC, 1998a and CEC, 1998b : EC proposals for the introduction of a common transport infrastructure charging framework, which place a further emphasis on the marginal social cost pricing approach, whilst allowing non-discriminatory fixed charges to be levied where this is not adequate for full cost recovery

The main sources of road taxation currently throughout Europe are fuel taxes, together with annual licence duty. As Table 1 indicates, for fuel taxes, the amount payable as tax varies enormously. There are also supplementary charges for the use of the motorway network in many countries, whether by tolls (Spain, France and Italy) or by purchase of a ‘vignette’ entitling the vehicle to use of the network for a stipulated period of time (Germany and neighbouring states). In addition a few countries used to impose weight-distance taxes on various classes of vehicle, notably goods vehicles. These included Norway, Sweden and Finland. This is closer to the approach advocated by the Commission, since it makes it possible to charge the appropriate marginal social cost to each vehicle regardless of how much it is used. By contrast, a fixed annual licence fee overcharges low mileage vehicles and undercharges high mileage ones. However, these countries have dropped the weight distance tax in the interests of harmonisation on accession to the European Union.



Country	Year	Petrol (%)	Diesel (%)
Austria	1997	49	40
Belgium	1994	73	64
Denmark	1994	66	63
Finland	1997	76	63
France	1997	79	71
Germany	1994	80	70
Greece	1995	74	64
Ireland	1993	21	21
Italy	1997	74	64
Luxembourg	1993	–	58
The Netherlands	1997	73	64
Norway	1997	75	97
Spain	1997	69	62
UK	1997	79	76

Table 1. Tax component of retail fuel price

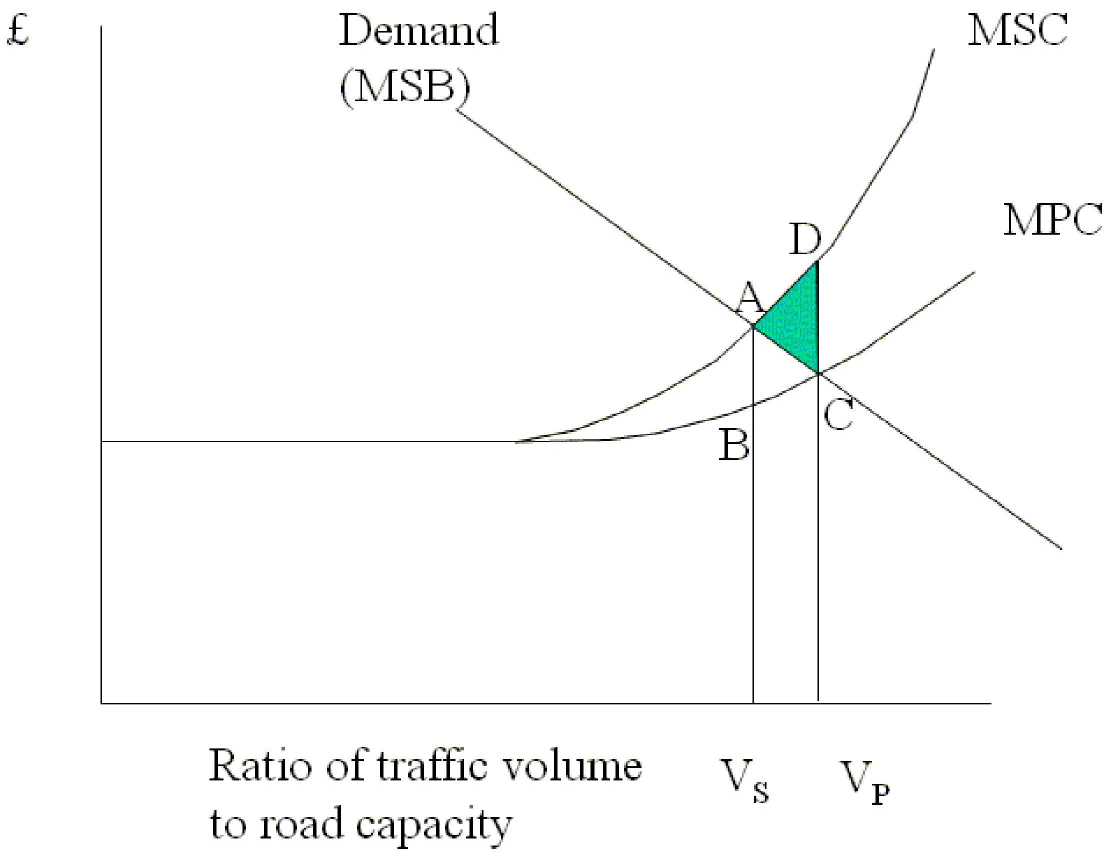
Taxing Bads by Taxing Goods (Eskeland and Devarajan, 1996, World Bank)

Taxing Bads by Taxing Goods (Eskeland and Devarajan, 1996, World Bank)

- First-best instrument for reducing polluting emissions is a tax on emissions directly.
- This follows from the incentives generated to select the optimal mix of cleaner technologies and reduction in the scale of output or in the use of inputs.
- Regulator needs no information other than source emissions rates to achieve a reduction at least cost.
- But fees require the ability to monitor emissions cheaply and effectively.
- Most pollution control techniques use indirect approaches: tax or regulate activities associated with emissions rather than emissions themselves.
- A combination of instruments –ones that reduce emissions-output ratio –and ones that reduce output - can mimic well the effects of an optimal emissions fee.
- However, this policy-mix DOES require:
    - For technical controls: Knowledge of cleaner technologies (to deal with emissions-output ratio)
    - For demand reduction: Knowledge of demand elasticities (to judge how much output can be reduced)

		Demand elasticities	
		High	Low
Control efficiency	High	Both	Stimulation of technical controls
	Low	Tax on polluting goods	Both

Congestion inefficiency (Source: Tietenberg)



Summaries of Two Recent Transport Case Studies: (1) The Nash et al (PETS) study

A summary of the Chris Nash, Tom Sansom and Ben Still paper: Modifying transport prices to internalise externalities: evidence from European case studies.

1. Price changes necessary to achieve internalisation of externalities

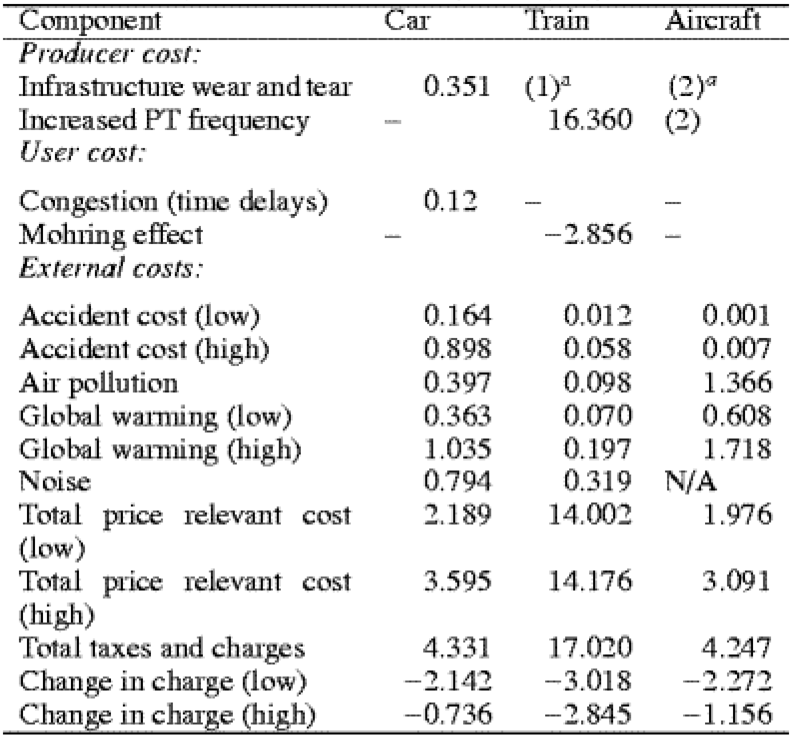
In this paper - which is worth reading in full - Nash et al estimate what they call "price relevant costs": the true social costs of various modes of transport on various particular routes in Europe. The price relevant (or social) costs include marginal infrastructure costs, operating costs, and the external costs associated with air pollution, global warming damages, noise, congestion, and road traffic-related accidental injuries and deaths.

They next compare those costs with the sum of existing variable taxes and charges in each case. Put another way, they are comparing **actual transport prices** with the **socially efficient prices** (the prices that would prevail were they equal to the true value of direct variable costs and were all externalities to be internalised).

Their study encompasses the following modes: road (passenger and freight); passenger rail; and passenger air travel. All estimates are done in the context of a simulated transport equilibrium situation in year 2010.

Table 6 sets out the comparison between price relevant (social) costs and "actual" taxes and charges for passenger travel in the Cross Channel case study that they conduct. Note that two categories of external costs have "high" and "low" estimates reflecting various uncertainties and information imperfections. The last five rows give summary findings. Where there is a negative sign in front of the number in either of the two "Change in charge" rows, this implies that actual charges exceed socially efficient prices, and so would need to be reduced if true marginal cost pricing were to prevail.

Table 6. Changes in Cross Channel passenger prices (ECU/100 passenger km)

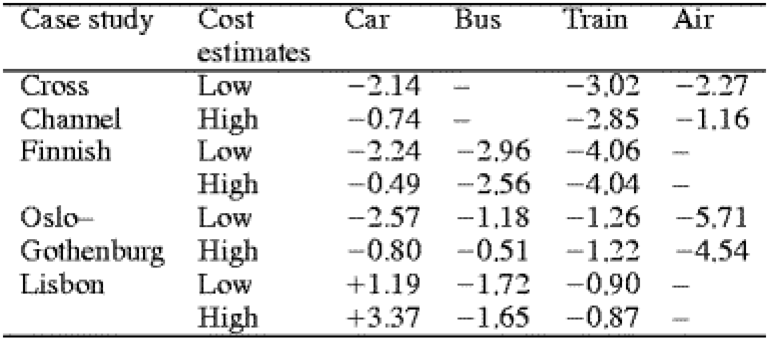


Component	Car	Train	Aircraft
Producer cost:			
Infrastructure wear and tear	0.351	(1)[a]	(2)[a]
Increased PT frequency	–	16.360	(2)
User cost:			
Congestion (time delays)	0.12	–	–
Mohring effect	–	−2.856	–
External costs:			
Accident cost (low)	0.164	0.012	0.001
Accident cost (high)	0.898	0.058	0.007
Air pollution	0.397	0.098	1.366
Global warming (low)	0.363	0.070	0.608
Global warming (high)	1.035	0.197	1.718
Noise	0.794	0.319	N/A
Total price relevant cost (low)	2.189	14.002	1.976
Total price relevant cost (high)	3.595	14.176	3.091
Total taxes and charges	4.331	17.020	4.247
Change in charge (low)	−2.142	−3.018	−2.272
Change in charge (high)	−0.736	−2.845	−1.156

Table 7 shows the change in prices implied in all of the passenger case studies. The authors write:

"It is clear that, at the low marginal cost valuations, there is a tendency to over-price all inter-urban passenger modes. However, the reasons vary across modes; for the public transport modes, the over-pricing is a result of pricing to cover total cost in a situation in which economies of scale and the Mohring effect lead to marginal cost being below average. In the case of road, over-pricing is the result of substantial fuel taxes, which exceed the low values of external costs. At the high value of externalities, the degree of over-pricing is substantially reduced, particularly for car and air. For the urban case study [Lisbon], the results are not surprisingly quite different. On average, car is under-priced even at the low values of externalities. The under-pricing of car becomes much more marked at the high valuations."

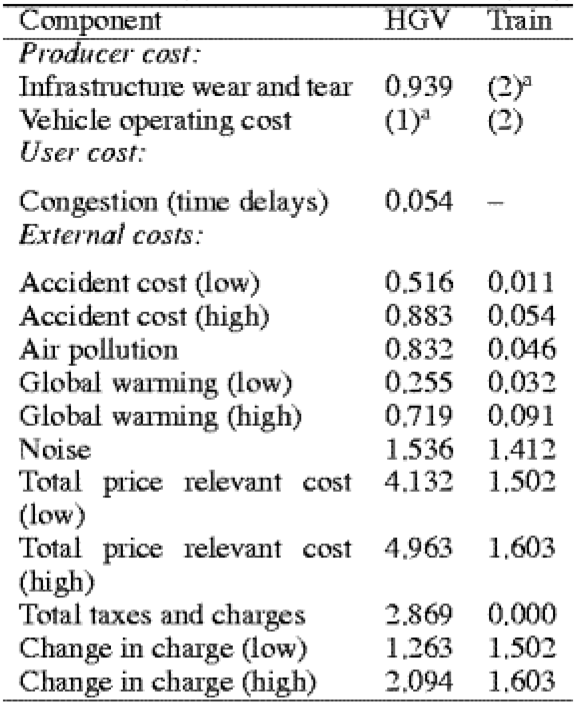
Table 7. Changes in passenger prices (ECU/100 passenger km)



Case study	Cost estimates	Car	Bus	Train	Air
Cross Channel	Low	−2.14	–	−3.02	−2.27
	High	−0.74	–	−2.85	−1.16
Finnish	Low	−2.24	−2.96	−4.06	–
	High	−0.49	−2.56	−4.04	–
Oslo–Gothenburg	Low	−2.57	−1.18	−1.26	−5.71
	High	−0.80	−0.51	−1.22	−4.54
Lisbon	Low	+1.19	−1.72	−0.90	–
	High	+3.37	−1.65	−0.87	–

Table 8 provides the comparison between price relevant costs and taxes and charges for **freight modes** in the Cross Channel case study.

Table 8. Changes in Cross Channel freight prices (ECU/100 tonne km)

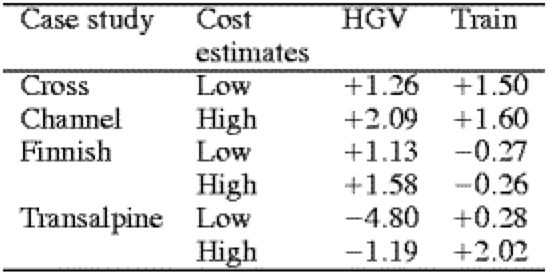


Component	HGV	Train
Producer cost:		
Infrastructure wear and tear	0.939	(2)[a]
Vehicle operating cost	(1)[a]	(2)
User cost:		
Congestion (time delays)	0.054	–
External costs:		
Accident cost (low)	0.516	0.011
Accident cost (high)	0.883	0.054
Air pollution	0.832	0.046
Global warming (low)	0.255	0.032
Global warming (high)	0.719	0.091
Noise	1.536	1.412
Total price relevant cost (low)	4.132	1.502
Total price relevant cost (high)	4.963	1.603
Total taxes and charges	2.869	0.000
Change in charge (low)	1.263	1.502
Change in charge (high)	2.094	1.603

Table 9 shows the change in prices implied in all of the freight case studies. The authors write:

"For freight, the picture is more mixed. On the Cross Channel corridor, there is a similar degree of under-pricing for both road and rail freight, although again the reasons are different. For road, the reason is a failure for the already substantial taxes on heavy goods vehicles to cover completely the external costs; for rail, it is the failure to include external costs at all in the price of rail freight on this corridor, which is already believed to be priced on a marginal cost basis because of the fierce competition with road. For Transalpine freight, rail appears roughly appropriately priced, whilst road varied from being over-priced at low valuations to under-priced at high (it should be said that in this case study the high valuations included special allowance for the sensitive nature of the Alpine region)."

Table 9. Changes in freight prices (ECU/100 tonne km)

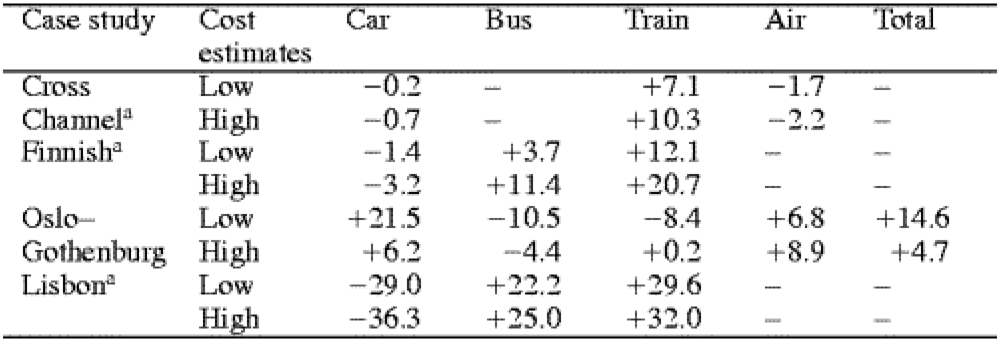


Case study	Cost estimates	HGV	Train
Cross	Low	+1.26	+1.50
Channel	High	+2.09	+1.60
Finnish	Low	+1.13	−0.27
	High	+1.58	−0.26
Transalpine	Low	−4.80	+0.28
	High	−1.19	+2.02

2. Impacts on transport demand

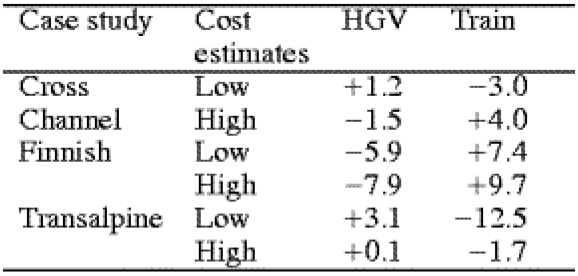
Nash et al then consider what would be the implications of the price changes shown above for transport demand? Nash et al state: "The implications are radically different between urban and inter-urban areas, as Table 10 and Table 11 illustrate".

Table 10. Changes in passenger demand (% change compared to 2010 base situation)



Case study	Cost estimates	Car	Bus	Train	Air	Total
Cross Channel[a]	Low	−0.2	–	+7.1	−1.7	–
	High	−0.7	–	+10.3	−2.2	–
Finnish[a]	Low	−1.4	+3.7	+12.1	–	–
	High	−3.2	+11.4	+20.7	–	–
Oslo–Gothenburg	Low	+21.5	−10.5	−8.4	+6.8	+14.6
	High	+6.2	−4.4	+0.2	+8.9	+4.7
Lisbon[a]	Low	−29.0	+22.2	+29.6	–	–
	High	−36.3	+25.0	+32.0	–	–

Table 11. Changes in freight demand (% change compared to 2010 base situation)



Case study	Cost estimates	HGV	Train
Cross Channel	Low	+1.2	−3.0
	High	−1.5	+4.0
Finnish	Low	−5.9	+7.4
	High	−7.9	+9.7
Transalpine	Low	+3.1	−12.5
	High	+0.1	−1.7

Here is how the authors summarise these estimates:

"In the Lisbon [the 'urban'] case study, efficient pricing would lead to a substantial diversion of traffic from car to bus and train. This would have a significant impact on local air pollution in major cities where the problem is most severe. However, a relatively small part of total road traffic is to be found in major cities, so the contribution to the problem of global warming would be much less significant.

Nowhere else is a dramatic change of mode split to be found. In the Finnish case study, there is a diversion of 6–8% of heavy goods vehicle traffic to rail, and of 1–3% of car traffic to bus and rail. On Cross Channel routes a very small proportion of car traffic and a slightly larger proportion of air traffic switches to rail. In terms of freight, at the lower valuations of externalities, there is diversion from rail to road on both Cross Channel and Transalpine routes. At the higher valuations, road traffic is little affected.

Overall it must be concluded that, even at the higher valuations of externalities the degree of change in mode split, and the contribution to air pollution and global warming targets, that can be expected from the transport sector outside urban areas is small."

3. The Conclusions of Nash et al (in their own words)

"We have presented estimates of the marginal costs of air pollution and global warming based on the best estimates now available, but they still show a wide range between high and low values. On both valuations, they are certainly a significant component of the case for changes in price but in no case are they the dominant one.

In terms of the impact on prices, and the resulting shifts in transport demand, the pattern of efficient pricing is by no means universally the popular image of big increases in price on the major polluting modes leading to large shifts in demand to rail and other public transport.

The results of the case studies confirm many well-known and obvious conclusions, but provide some surprises as well. Thus it is well known that inter-urban car transport is typically over priced and urban under-priced, particularly at the peak. This is the consequence of dependence on fuel tax as the major form of charging. It would be more efficient to lower fuel tax and to implement some form of supplementary charge in urban areas. The case for introducing tolls for cars on inter-urban roads appears weak, except where there are particular problems of congestion.

For road freight, the results are more variable, more because of the big variations in tax rates between countries than because of differences in cost, but it appears that on some cases there is a degree of undercharging, and in some cases overcharging. However, this cannot be accurately corrected using existing taxes, as it applies particularly to heavy axle vehicles covering high mileages. Adding to annual vehicle taxes would penalise vehicles used on low mileages, and even fuel duty cannot discriminate sufficiently between vehicle types. Therefore, there is a strong argument for the view of the European Commission that, in addition to urban road pricing, there is a case for a new mileage related tax on heavy goods vehicles varying with the characteristics of the vehicle concerned. Such a system would also solve the problem of unfair competition between vehicles based in countries with very different tax rates if it were possible to identify the mileage undertaken in each country and charge accordingly.

For inter-urban public transport, the result was more surprising in that typically existing prices were too high. This was because of following commercial pricing practices in a sector subject both to producer economies of scale and to the Mohring effect. All the flows in the case studies were subject to relatively high rail tariffs. However, for rail this result would certainly not hold throughout Europe. For rail freight the result was more mixed, with charges marginally above marginal social cost in one case study, but excessive subsidies in others.

For inter-urban transport, however, in no case were the changes in mode split from the introduction of efficient pricing very large; the belief that proper allowance for air pollution and global warming would lead to major diversion from road and air to rail does not appear to be supported by empirical analysis. On the other hand, very much more diversion could be expected in urban areas, but more as a result of charging for external costs of congestion and accidents than for air pollution and global warming.

In conclusion, then, the impact of optimal pricing on transport volume and mode split appears likely to achieve a significant improvement in air quality in major congested urban areas, but to make little contribution to more general air pollution or greenhouse gas reduction. However, it should be stressed that in this research we were only concerned with overall traffic levels and mode split. Selective taxes according to vehicle emission characteristics and amount and type of fuel used may have much more significant effects on energy efficiency and air pollution from transport."

3. Evidence from other case studies

Nash et al also provide a very useful summary of evidence from similar case studies carried out by other authors or teams. The following is extracts from Nash et al's review (largely in the authors' own words):

1. European Commission 4th framework research programme: TRENEN II STRAN study (Proost and Van Dender, 1999).

- Designed, like the Nash et al study, to examine the extent to which existing prices differed from marginal social costs, and to look at the consequences for traffic and mode split of moving to marginal social cost pricing. It also examined a range of intermediate pricing reforms.
- Five urban case studies and two interregional case studies.
- In urban areas, TRENEN shows that urban motorists pay only one-half to one-third of their full marginal social costs. This is due both to externalities and to unpaid parking costs. (Nash et al write: "The PETS [that of Nash et al] urban case study shows a similar but somewhat smaller underpayment of marginal social cost but PETS did not consider unpaid parking costs as relevant, regarding these as essentially fixed in the short run (however, parking space may well have a scarcity cost that should be taken into account)."
- Interregional passenger transport pricing inefficiencies are in general less important than in the case of urban transport. Prices of peak period car use do not cover marginal external congestion costs. The congestion cost itself is however smaller than in urban areas. In the off peak period, cars pay slightly more than their marginal social cost. Public transport pricing inefficiencies exist but are less important per kilometre than in urban markets. Non-urban bus transport is heavily subsidised and under-priced in both cases.
- For trucks, the prices are smaller than the marginal social costs in the peak period. The major external cost is again congestion.
- When subsidies are not excessive, as they are in Ireland, the prices of rail are closer to the marginal social cost.

- Because external costs of inland waterways are small, prices and marginal social costs are roughly in line with each other.
- It should be noted that the results of TRENEN and PETS are not directly comparable because of methodological differences. In particular, PETS (Nash et al) simulations are for year 2010, while TRENEN uses a recent (but still past) year. Also TRENEN models 'average' conditions in the networks concerned, whereas PETS models specific long distance corridors.

2. Dings et al. (1999) for The Netherlands. (1998 Base Year)

- Use same categories of external costs as does PETS
- But some significant methodological differences from PETS, including the following: the costs in Dings et al estimated are based on current demand levels, as opposed to a new equilibrium with changes in demand (as in PETS).
- Dings overall conclusion: "not a single category of goods or passenger vehicles covers its external costs". Nash et al write: "Passenger price increases range from 1 Euro/100 pkm (petrol cars) to 15 Euro/100 pkm (city buses and mopeds). For goods transport, the range of price increases lie in the range 1 Euro/100 tkm (inland shipping) to 7 Euro/100 tkm (aviation, small goods vehicles). However, it should be re-stated that the exclusion of demand responses to price changes means that these increases considerably over-estimate the congestion costs that would be present in a new equilibrium situation."

Summaries of Two Recent Transport Case Studies: (2) The Proost and Dender study

The Proost and Dender study: Proost, S., Van Dender, K., 1999. TRENEN II STRAN Final report for publication. Centre for Economic Studies, Katholieke Universiteit, Leuven.

1. Overview

Proost and Dender compare the effectiveness and welfare effects of alternative fuel efficiency, environmental and transport policies for a given urban area. Four different marginal external costs are computed in the present equilibrium: air pollution, accidents, noise and congestion.

The effects of a typical air quality policy (regulation of car emission technology) and two typical fuel-based policies (minimum fuel efficiency policy and fuel taxes) are compared with the effects of three alternative transport policies (full external cost pricing, cordon pricing, parking charges).

2. Introduction

The TRENEN-URBAN model contains a representation of transport demand, transport supply, indirect tax revenues and external costs for an urban environment (Brussels in 2005). It focuses on congestion and environment problems, and is only concerned with transport within the urban territory whatever the origin and destination of trips.

3. Policy assessment module

Effects of policies on consumer and producer surplus, on tax revenues and external costs for all the urban transport markets are summed into one Kaldor– Hicks type of social welfare measure with equal weights for all changes in the real income of **individuals**. The changes in **tax revenue** receive a higher weight than changes in consumer and producer surplus, as it is assumed that the tax revenue is used for a reduction of labour taxes which reduces distortions and so creates efficiency gains.

The model can be used in two ways. First, it can be used to compute the welfare effects of a given policy proposal. This enables comparison of different policy packages in terms of the resulting welfare effects (and traffic volumes, pollution, etc.). Second, the model allows the design of optimal policy packages. In this approach the welfare function is optimised by selecting the optimal transport and environmental policy variable values. The optimal values are the result of trade offs between external costs, valuation of transportation by its users, and tax revenue considerations. This optimisation can be performed under different sets of restrictions on the policy instruments. For example, different assumptions can be made about which pricing and regulation policies are technically and institutionally feasible. When there are no restrictions on the policy instruments, one has first-best policies in which transport users pay the full marginal social cost consisting of the marginal resource cost and the sum of all marginal external costs. When there are restrictions on the instruments, one obtains second best results that trade off in a complex way the deviations from full marginal cost pricing in the different transport markets. A typical example is the optimality of subsidies to public transportation in the peak when prices for car traffic cannot be differentiated between the peak and the off-peak period.

4. Estimating the external costs

The model takes marginal external air pollution costs, congestion costs, accident costs and noise costs into account. It focuses on passenger cars, not on trucks, so that road maintenance costs are irrelevant.

In looking at the external costs of air pollution, the study relies mainly on the European Union ExternE project (Bickel et al., 1997).

There have been proposals by the European Commission to impose a minimum fuel efficiency for 2005 of 5 l/100 km for gasoline cars and 4.5 l/100 km for diesel cars. We call this case the improved fuel efficiency case (IF). The increase in car ownership cost of this fuel efficiency improvement has been estimated at 19.5% for petrol cars and at 17% for diesel cars (Proost, 1997).

Details of methods and data sources for the valuations of air pollution and other external costs can be found in the paper.

5. Policy Analysis

The efficiency of transport prices is assessed by comparing consumer prices to marginal social cost, for the given level of regulation. The first and most straightforward way to draw attention to the main inefficiencies of the current urban transport equilibrium is to examine the external costs of the different types of vehicles and to compare them with the current tax levels and regulations, for the case where consumers pay for all resource costs (including those of parking). This comparison between external costs and taxes tells us whether, for given air pollution and fuel efficiency standards, the existing transport alternatives are used and priced efficiently. The main tax instrument used is fuel taxes. When a certain transport option has a tax below its marginal external cost, this can be corrected in two ways. First, for externalities related to the volume of transport (congestion), one can correct the use of that transport option by increasing the tax. For the other types of externalities (air pollution, noise, etc.) one can impose the use of a cleaner car.

The relative magnitudes of the external costs will strongly influence the efficiency of different policy instruments. All instruments that improve the congestion externalities will have a larger effectiveness in welfare terms. The total welfare effect of air pollution and fuel efficiency policies will depend strongly on their side effects on congestion.

6. The effects of alternative policies

This section assesses the impact of policy instruments on the urban transport situation in general and on the level of atmospheric pollution in particular. We first discuss the effect of regulations on emission technology (Section 6.1) and the effect of imposing improved fuel efficiency for cars (Section 6.2). In this same section we also discuss the effect of higher fuel taxes. Section 6.3 briefly presents three transport approaches to the reduction of urban transport inefficiencies: full external cost pricing, cordon pricing, and parking charges. These policies address the main inefficiencies, mentioned in Section 5, directly, while they also influence atmospheric pollution. In Section 6.4 the different policies are compared.

6.1. *Air quality policy*

This section deals with the welfare impact of imposing the use of improved emission technology through regulation.

Imposing the improved technology through regulation on all the vehicles does not yield net welfare gains. Probably only imposing enhanced technology for diesel cars would bring a small net benefit. The air pollution damage estimates are only relevant for a medium sized city like Brussels. In more densely populated areas, improved emission technologies may still be justified.

6.2. *Fuel efficiency policy*

In this section, the objective is to analyse two scenarios: one in which passenger cars are made more fuel efficient via regulation (scenario A) and one where the same level of fuel efficiency is reached through increased fuel taxes (scenario B).

In the two fuel efficiency scenarios, the fuel consumption decreases from 7.5 l/100 km to 5 l/100 km for gasoline cars and from 6.5 to 4.5 l for diesel cars. In the second fuel tax scenario we use a fuel tax increase of 1.02 EURO/l for gasoline and of 1.26 EURO/l for diesel. These increases are necessary to make the supply of more fuel efficient cars (5 l/100 km and 4.5 l/100 km, respectively, for petrol and diesel) interesting for producers and consumers of cars (Proost, 1997).

Increased fuel efficiency has a positive impact on non-congestion externalities (pollution, accidents, noise). They decrease by 5% in scenario A. External costs of air pollution diminish by nearly 13%. The overall welfare impact of a fuel efficiency regulation is however negative. The fuel tax scenario, on the contrary, has a positive effect on pollution levels and on overall welfare. To explain this result, we need to look at the welfare components.

A minimum fuel efficiency regulation comes down to obliging the economy to invest in more expensive cars that save fuel. Since fuel is already heavily taxed in Europe, a fuel efficiency regulation has important losses of tax revenue as side effect. This loss has two components: there is the direct effect of consuming less taxed fuel per kilometre and there is the indirect effect of reduced car use. The latter effect is relatively less important. The losses of tax revenue have to be seen as a welfare loss to society. The savings in fuel of more fuel efficient cars should thus be measured at the price before tax.

Summarising we have:

- On the cost side, an investment in fuel efficient cars. The marginal cost of this fuel efficiency improvement will be high because high taxes on fuel have already depleted the cheapest fuel saving options.
- On the benefit side, a decrease of fuel resource costs (measured before tax, i.e., approximately one-third of consumer prices in the EU) plus a decrease of air pollution costs plus a decrease of other externalities. The decrease in other externalities, in particular of congestion, will be limited because there is only a small net rise of the generalised user cost of car use, and because the user cost increases in peak as well as in off-peak periods.

In the fuel tax scenario, consumers receive a wrong incentive in the sense that they start investing in saving highly taxed fuel so that they overestimate the benefits of fuel savings. At the same time however we make car use much more expensive. This has important positive side effects on congestion certainly in peak periods. This can be seen in the consumer surplus term which decreases only slightly: the direct reduction in net purchasing power due to the high cost of more fuel efficient cars is nearly fully compensated by decreased time losses due to reduced congestion.

Regulation of fuel efficiency leads to an important decrease in the level of air pollution costs mainly via a reduction of CO_2 emissions and via decreased emissions of PM. These two pollutants are not addressed directly in the improved emission regulation scenarios. Overall welfare decreases however. Foregone tax revenue from fuel taxes is the main cause of this loss.

6.3. *Transport pricing policies*

In the *full external cost pricing* scenario, taxes are set such that all initial inefficiencies are alleviated. The main inefficiencies are that drivers do not pay for marginal costs of congestion, pollution, accidents and noise, and that a majority of drivers do not pay for the resource cost of parking. The optimal consumer prices will reflect perfectly the marginal external costs and marginal resource costs. Both the parking price and the marginal external costs are raised by a tax. The marginal external costs in the external cost pricing scenario are these of the new equilibrium, not of the reference situation. In addition, tax levels are partly determined by the marginal cost of public funds. This will lead to taxes above marginal external costs. Full external cost pricing is not a feasible policy option at present. The results of this scenario should be seen as a benchmark, defining the maximal welfare gains that could be achieved through a perfectly efficient urban transport market.

In the *cordon pricing* scenario all commuters driving to the city centre pay a second-best congestion fee, which is differentiated between peak and off-peak hours. Since the cordon is placed around the city centre, trips within the city centre are not charged. Cordon pricing is a realistic policy option: the technology required to charge drivers automatically when a cordon is passed is available and the cost of this technology is not prohibitive. The instrument is not perfect: only trips passing the cordon are charged, inefficient parking charges remain in place, taxes are not adapted to environmental characteristics of cars, and public transport prices do not change.

It was shown in Section 5 that, besides congestion externalities, imperfect parking charges are the main cause of inefficiency in the current transport situation in Brussels. We will analyse the impact of abolishing free parking. Whereas in the reference situation only 30% of all drivers pays for the resource cost of parking in the city centre, it is assumed that all drivers will incur this cost under *improved parking charges*.

Implementation costs of these pricing policies are not taken into account: we compute gross benefits. Cost estimates of the various pricing measures are hard to come by. The estimates that are available suggest that automated congestion toll mechanisms yield substantial net benefits (see, for example, MVA Consultancy, 1995).

Table 5 summarises the main effects of the three types of transport policy. The maximal welfare gain with respect to the reference situation is 1.3%. Part of the gain derives from a substantial decrease in the damage from air pollution, accidents and noise. This damage decreases by 13.4%. Damage from air pollution diminishes by 12%, that of noise by 5%, and external accident costs decrease by 20%.

Cordon pricing brings slightly more than half of the maximal attainable welfare gain. The decrease in the level of non-congestion external costs is relatively lower. The impact of cordon pricing on air pollution costs is small, as compared to the total welfare gain attained by this policy. Charging all drivers for the resource cost of parking improves welfare by 0.42%, which is close to one-third of the maximal possible gain.

It should be noted that these transport policies require strong pricing measures. In the full external cost pricing, taxes on car use in the peak are increased by ca. 480%. In the cordon pricing scenario, the optimal increase of the user costs of a car in the peak is even higher because only the commuters can be taxed. In the ‘paying for parking’ scenario, the non-payers face an increase of users costs for car use of some 60%.

6.4. *Policy comparison*: *global welfare impact and impact on non-congestion externalities*

Comparison of the three policy types (focussing on transport, emission technology, and fuel efficiency, respectively), shows that transport policies produce by far the best welfare results. Their superior performance is due to the fact that they address directly the two most important sources of inefficiencies (excessive congestion in peak and non-paid parking) without negative side effects on the other sources of externalities. These policies are efficient because they use the price mechanism in a focussed way: via tolls in the peak period and by making car drivers pay for their parking place.

It is striking that the policy of full external cost pricing is also among the best to reduce the external air pollution costs. This need not always be the case. Given the structure of the external air pollution costs, the best policy is a policy that reduces the use of diesel cars and cars with only one occupant in general. This is done in this scenario, as the use of diesel cars is reduced by approximately 22%, compared to a 10% reduction for petrol cars.

When we consider the two other types of policies, it is clear that a policy that uses a tax instrument (fuel efficiency) or one that makes car users pay for the investment (emission technology) gives better results than when the government foregoes tax revenues. The large external costs of car transport in the reference equilibrium are the principal reason for this. Any policy that increases the consumer prices of car use will then perform better than a policy that does not make car use more expensive (such as government paid improved emission technology). When taxes are used to increase consumer prices, additional welfare gains are obtained on condition that the revenues are used appropriately. Here, we have assumed that the revenues are used to cut labour taxes.

One may wonder why the improved emission technologies perform rather poorly in terms of air pollution reduction. There are two reasons. A first reason is that the foreseen technical improvements address pollutants like VOC, NOX and CO but to a much smaller extent the more damaging particles. The second reason is that after the introduction of the pre-heated three way catalytic converter, one has probably reached the zone of diminishing returns from further abatement.

7. Conclusions

We have compared welfare changes and air pollution reductions achieved by various types of urban transport policies, by emission technology regulation and by three types of policies: fuel efficiency regulations.

The general findings are that:

- Regulation policies on emissions or on fuel efficiency do not cause large shifts in total travel by private vehicles. These policies may achieve substantial reduction of urban air pollution, but their effectiveness does not depend on the reduction of automobile travel. Congestion externalities are hardly affected by environmental policies.
- Regulation policies for emissions may have reached the zone of strongly increasing marginal abatement costs and this can make them less effective in welfare terms.
- Transport policies do cause large shifts in the modal and time distribution of urban traffic. Through the impact on traffic demand, these policies can have important beneficial environmental effects as well.
- The comparison of transport policies and air pollution regulation measures confirms that large welfare gains can be obtained through policies which focus on the dominant inefficiencies in current urban transport markets (congestion, provision of free parking space).

In summary, the analysis shows the need for integrated policy development. Isolated measures, e.g., focussing on air pollution only, may well be welfare decreasing.

References

Christensen, P., Beaumont, H., Dunkerley, C., Lindberg, G., Rothengatter, W., Doll, C., 1998. Internalisation of externalities, Pricing European Transport Systems deliverable 7. Institute for Transport Studies, Leeds.

Commission of the European Communities, 1995. Towards fair and efficient pricing in transport, Green paper, COM(95) 691 final. Commission of the European Communities, Brussels.

Commission of the European Communities, 1998a. Kyoto Protocol, COM(98) 96 final. Commission of the European Communities, Brussels.

Commission of the European Communities, 1998b. Fair payment for infrastructure use: a phased approach to a common transport infrastructure charging framework in the EU, COM (98) 466 final. Commission of the European Communities, Brussels.

Department of Environment, Transport and the Regions, 1998. Transport Statistics Great Britain 1998 Edition. The Stationery Office, London.

Department of Environment, Transport and the Regions, 1999. Design manual for roads and bridges, volume 11, environmental assessment. The Stationery Office, London.

Department of Environment, Transport and the Regions, 2000. Climate change: draft UK programme. DETR, London.

Dings, J.M.W., Janse, P., Leurs, B.A., Davidson, M.D., 1999. Efficient prices for transport: estimating the social costs of vehicle use. Centrum voor energiebesparing en schone technologie, Delft.

Eyre, N., Downing, T., Hoekstra, R., Rennings, K., Tol, R.S.J., 1997. Global warming damages, ExternE global warming subtask final report. IER, University of Stuttgart, Stuttgart.

Friedrich, R., Bickel, P., Krewitt, W., 1998. External costs of transport. IER, University of Stuttgart, Stuttgart.

Greene, D.L., Jones, D.W. and Delucchi, M.A., 1997. In: *The Full Costs and Benefits of Transportation — Contributions to Theory, Method and Measurement*, Springer, Berlin.

High Level Group on Transport Infrastructure Charging, 1998. Report of the high level group on infrastructure charging. Commission of the European Communities, Brussels.

High Level Group on Transport Infrastructure Charging, 1999a. Final report on estimating transport costs. Commission of the European Communities, Brussels.

High Level Group on Transport Infrastructure Charging, 1999b. Transport charging instrument options. Commission of the European Communities, Brussels.

Hopkin, J.M. and Simpson, H.F., 1995. In: *Valuation of Road Accidents*, Transport Research Laboratory, Crowthorne.

International Road Federation, 1999. World Road Statistics, 1999. IRF, Geneva.

INFRAS, IWW, 1995. External costs of transport. Union of International Railways, Paris.

Jansson, J.O., 1997. Theory and practice of transport infrastructure and public transport pricing. In: de Rus, G. and Nash, C., Editors, 1997. *Recent Developments in Transport Economics*, Ashgate, Aldershot, UK.

Jansson, J.O. and Lindberg, G., 1998. Transport pricing principles. In: *Pricing European Transport Systems deliverable 2*, Institute for Transport Studies, Leeds.

Jule, R., 1999. Oslo–Gothenburg case study. In: *Pricing European Transport Systems deliverable 11b*, Institute for Transport Studies, Leeds.

MacKerron, G. and Pearson, P., 1995. In: *The UK Energy Experience: A Model or a Warning?*, Imperial College Press, London.

Maddison, D., Johansson, O. and Pearce, D., 1996. In: *Blueprint 5: the True Costs of Road Transport*, Earthscan, London.

McCubbin, D.R. and Delucchi, M.A., 1999. The health costs of motor-vehicle related air pollution. *Journal of Transport Economics and Policy***33**, pp. 253–286.

Mohring, H., 1972. Optimisation and scale economies in urban bus transportation. American Economic Review, papers and proceedings.

Newbery, D.M., 1990. Pricing and congestion: economic principles relevant to pricing roads. *Oxford Review of Economic Policy***6** 2, pp. 22–38.

Peura, J. and Otterstrom, T., 1999. Finnish case study. In: *Pricing European Transport Systems deliverable 11a*, Institute for Transport Studies, Leeds.

Proost, S., Van Dender, K., 1999. TRENEN II STRAN Final report for publication. Centre for Economic Studies, Katholieke Universiteit, Leuven.

Roy, R., 1998. In: *Infrastructure Cost Recovery Under Allocative Efficient Pricing*, International Railways Union, Paris.

Sansom, T., Still, B. and Nash, C., 1999. Cross Channel case study. In: *Pricing European Transport Systems deliverable 9*, Institute for Transport Studies, Leeds.

Small, K.A. and Kazimi, C., 1995. On the costs of air pollution from motor vehicles. *Journal of Transport Economics and Policy***29** 1, pp. 7–32.

Suter, S. and Neuenschwander, R., 1999. Transalpine freight case study. In: *Pricing European Transport Systems deliverable 10*, Institute for Transport Studies, Leeds.

Viegas, J., Macario, R. and Martins, P., 1999. Lisbon case study. In: *Pricing European Transport Systems deliverable 12*, Institute for Transport Studies, Leeds.

Weinreich, S., Rennings, K., Gessner, C. and Schlomann, B., 1997. In: *QUITS: Quality Indicators For Transport Systems: External Quality Validation*, Centre for European

Economic Research, Mannheim.

Regional Science and Urban Economics

Volume 31, Issue 4, Pages 379-522 (July 2001)

1.**Editor's Introduction** *Pages 379-381* PDF (22 K)

2. **The welfare impacts of alternative policies to address atmospheric pollution in urban road transport** • *Pages 383-411* Stef Proost and Kurt Van Dender, PDF (190 K)

3. **Modifying transport prices to internalise externalities: evidence from European case studies** • *Pages 413-431* Chris Nash, Tom Sansom and Ben Still. PDF (84 K)

4. **Reducing emissions from transit buses** • *Pages 433-451* Paul Schimek
PDF (88 K)

5. **Should diesel cars in Europe be discouraged?** • P*ages 453-470* Inge Mayeres and Stef Proost PDF (88 K)

6. **Discrete choice models and optimal two-part tariffs in the presence of externalities: optimal taxation of cars** • *Pages 471-504* Bruno De Borger
PDF (167 K)

7. **Public support for pollution fee policies for motor vehicles with revenue recycling: survey results** • *Pages 505-522*. Alan Krupnick, Winston Harrington and Anna Alberini. PDF (224 K)