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TOPIC 18
ENVIRONMENT AND
SUSTAINABLE MOBILITY

ENVIRONMENTALLY SENSITIVE TAXATION OF TRANSPORT AND TRANSPORT INVESTMENT POLICY: SOME RESULTS FOR THE UK

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Abstract

This paper assesses mechanisms for funding investment in transport infrastructure. A simple theoretical model of transport costs and demand is used to develop and validate empirical models of the transport sector in the UK for London and inter-urban travel. Preliminary results indicate the balance of investment between different modes in different types of area may be inappropriate.

INTRODUCTION

After a period in which the main interest in transport markets and transport policy in the UK has been one of the deregulation and privatisation of public transport, the issue of roads, road pricing and road building is again coming to the fore at the same time as a realisation that the public sector will have to maintain a basic interest in the funding of investment on public transport systems. This paper aims to shed some light on these questions, and on the environmental issues which have begun to dominate public debate (House of Commons Transport Committee 1994; Royal Commission on Environmental Pollution 1994), through the development of a model of travel markets which allows for the imposition of the full social costs of transport.

The basic economics of transport identifies two critical analytical points, the existence of scale economies which, combined with lumpy investment, leads to critical questions of capacity, and the importance of congestion as an imperfect rationing device. Clear differences have developed, however, in the treatment of urban and inter-urban travel. In the former the whole network approach has dominated both within and between modes. In the latter rather less interdependence has been assumed leading to difficulties in the measurement of congestion or its impacts. Furthermore, approaches tend to be more single mode oriented leading to difficulties in the interpretation of some of the results (eg Newbery 1988, 1990, 1994). However, it is in inter-urban travel where congestion is rapidly becoming a serious problem and where increasingly policy attention is being directed to find possible solutions.

The environmental concerns arising from road use feature in much of the recent discussion of road transport policy, though often on the basis of inadequate data and leading to policy proposals which may not stand up to detailed scrutiny (Royal Commission on Environmental Pollution 1994). Whilst it is important to ensure optimal pricing to ensure optimal network use, this is not just a single mode problem. Much inter-urban travel takes place in a competitive market between road, rail and air (depending on distance and origin and destination). Correct relative pricing is important as a pre-requisite to correct investment policy (regardless of who is investing, public sector or private agencies). If correct charges are to be levied, there is a major question as to whether these should be hypothecated to investment within the transport sector (Peirson and Vickerman 1993).

This paper has three main objectives. First, we outline a simple conceptual model of travel markets in the UK. Secondly, we provide empirical evidence on the true full marginal social costs of travel and the implications of these for the allocation of traffic and potential future investment. The results from this exercise suggest that may be only limited scope for a market price solution to these problems in the UK, that there are major differences between the potential in urban and non-urban contexts, but also that there are still major gaps in our knowledge and understanding of fundamental environmental and behavioural aspects of travel. Thirdly, we demonstrate the implications of a full marginal social cost charging policy for the finances of operators and for total tax revenue from the transport sector, after allowing for necessary investment.

THE MODEL OF PASSENGER TRAVEL

The model developed here considers exclusively the passenger travel market. In practice there are two separate models reported here, one for London and one for inter-urban travel, which allow for differing mode availability, operating costs, external costs and elasticities. It is recognised that many journeys have both an urban and inter-urban dimension and that there is an interaction between passenger and freight transport. These have not been considered here since we wish to highlight the different issues in urban and non-urban contexts and we can make the initial assumption that the level of freight transport is independently determined and does not interact substantially with passenger travel. Both of these assumptions probably underestimate the external costs elements and the estimated responses in this paper.

The model is developed in three main stages as shown in Figure 1. First, evidence is assembled on the marginal internal and external costs of each mode of transport as the basis for estimating efficient prices which include estimated efficient taxes (charges for the marginal costs of external impacts). Secondly, these prices are incorporated in a simple demand model using existing evidence on elasticities to make predictions of demand by each mode for one and ten years ahead. Thirdly, the results of these predictions are considered in terms of the implications for investment, costs and revenues of each mode.

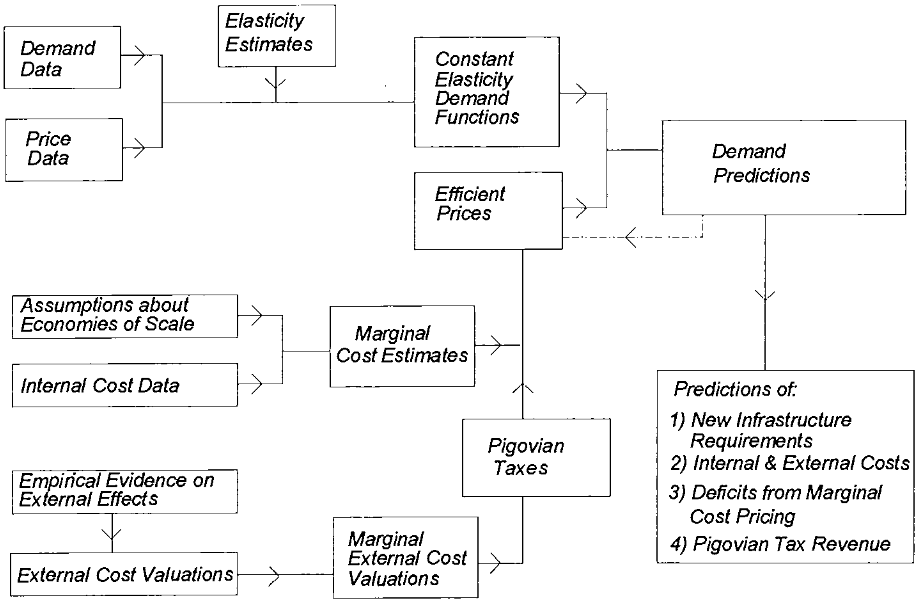

Figure 1 Modelling methodology

A key element in the derivation of the full costs is the assumption made about the existence of scale economies in each mode. This is critical in determining how far pricing based on long-run marginal costs will cause shifts in demand. Any switch to marginal costs as a basis for pricing on efficiency grounds also carries with it an implication for financing the resulting deficits of transport operators.

A principal hypothesis of this work has also been that major changes in price could be ineffective in the reallocation of demand in the short-run because of serious capacity constraints in the lower priced modes. In the short run model, the Pigovian taxes are set at the level of the marginal external costs for the transport use corresponding to short run efficient prices. In the long run, it is assumed that investment in transport infrastructure gives the optimal capacity relative to demand. Details of the modelling and results of this part of the study are obtainable from the authors. This leads to the need to make careful distinctions between the short-run and long-run implications where the latter can allow for the provision of additional investment funded by the revenues accruing to the entire system (see Peirson et al. 1994a, for a fuller analysis of this point). However, such a model, is also highly dependent on the accurate definition and measurement of the external effects of transport. In this study only existing estimates of these were used and despite attempts to obtain the most robust of these, as will be seen, there are areas of great concern in the accuracy and completeness of such impacts. For the critical estimates of congestion and accident costs, new estimates were derived from existing data.

The major sources of external impact are accidents, local air pollution and congestion. The information on which this study is based and full details of the model are given in Peirson et al. (1994a, b).

The inter-urban transport market is defined as travel in Britain undertaken by cars and coaches on motorways (the latter, mainly operated by National Express) and travel on InterCity rail (air travel is only a small proportion of this market and was omitted from the model). It thus concentrates on the main inter-urban routes rather than all non-urban and rural travel. The London market includes car, bus, London Underground and the services of the then Network SouthEast.

The demand model used takes the form in equation 1.

$$D_i=\alpha_i Y^{\gamma_i}\prod_{j=1}^{n}[P_i]^{\beta_{ij}} \qquad (1)$$

where

D_i demand for the ith transport mode in passenger kilometres

P_i price of ith transport mode per passenger kilometre

Y income

β_{ij} price elasticity of ith demand with respect to jth price

γ_i income elasticity of ith demand

In equation 1 the dependent variable is in terms of passenger kilometres, the price is calculated as described below and the effects income were estimated by assuming that in the long run income growth would be 2.5% per annum, while in the short run income was assumed to be constant. In the short run, price elasticities β_{ij} are smaller than in the long run.

A review of the literature, see Peirson et al. (1994c), yielded estimates of short and long run own and cross price elasticities and income elasticities. The main sources used were British Railways Board (1989), Douglas (1987), Goodwin (1992), Halcrow Fox and Associates (1993), Owen and Phillips (1987) and Transportation Planning Associates (1992). Information on transport demand was obtained from (Department of Transport (DOT) 1991, 1992a, 1993b and 1993c) and current price data on internal prices was taken from DOT (1981 plus revisions and 1993b) and British Railways Board (1993). Given the values of the demand and independent variables, plus elasticities β_{ij} and γ_i, equation 1 was calibrated ie α_i can be derived from the equation and then used to estimate the impacts on D_i of changing values of P_j.

The analysis follows the standard view that, for a long run optimal solution, the appropriate measure of the internal cost is the long run marginal cost, eg see Button (1993) and Rees (1984). However, in the case of economies of scale, long run marginal cost pricing leads to deficits, the size of which and their means of financing are investigated through the model. In the short run, the use of long run marginal cost pricing is justified as the resulting predictions indicate how far the present situation is from the long run optimal solution. As there is no consensus of opinion on the degree of economies of scale in transport, three different sets of assumptions were used with the reported internal cost data to estimate long run marginal internal costs. In the results which are given here we present examples from an assumption of constant returns to scale and an assumption of large returns to scale for each mode. These are estimates of the extent to which long-run marginal cost lies below long run average cost, expressed as the ratio of lrmc to lrac. The figures for maximum scale economies assumed here are 0.5 for rail; 0.2 and 0.5 for capital and operating costs respectively for Underground; 0.7 for bus; and 0.9 for car. A more detailed explanation of the derivation of these numbers can be found in Peirson et al. (1994).

It should be emphasised that the marginal internal and external costs were estimated at present levels of demand. Changes in demand would alter the levels of these costs and the efficient prices. This is represented in Figure 1 by the line from the demand predictions to the efficient prices boxes. Such effects from the variation in congestion costs with demand were allowed for in the model.

IMPLEMENTING THE MODEL

Cost estimates

The costs required to estimate the implicit full prices depend on both the internal costs of the various modes and their external impacts. Though some of these external costs have been estimated for the United Kingdom in the past, eg Newbery (1987 and 1990) and Pearce (1993), this study has brought together previous estimates on a consistent and appropriate basis. Full details of the estimation of these are given in Peirson et al. (1994a, b).

Table 1 summarises, for each mode, the estimates of marginal external costs from each source, the long run marginal internal costs of that mode (on the extreme assumption of constant returns to scale), the efficient inclusive prices these costs imply and, in the final column, our estimate of the current prices faced by users of each mode (all in terms of pence per passenger kilometre based on estimates of average vehicle occupancy).

Table 1 Marginal external costs of passenger transport (pence/passenger kilometre)

Pence/pass km		Global warming	Air poll.	Noise poll.	Con-gestion	Accid-ents	Total MEC	LRMC*	Efficient price*	Current price
Inter-urban										
Rail		0.01	0.12	0.02	0.04	0.03	0.22	9.67	9.89	7.11
Car		0.02	0.35	0.08	0.85	0.15	1.45	5.15	6.60	7.78
Coach		0.01	0.39	0.01	0.15	0.01	0.57	3.00	3.57	3.09
London										
U'grd	peak	0.01	0.13	0.09	0.72	0.03	0.98	45.18	46.16	10.12
	offpeak	0.01	0.13	0.09	0.00	0.03	0.26	15.80	16.06	8.94
Rail	peak	0.01	0.13	0.09	0.80	0.03	1.06	20.11	21.17	6.88
	offpeak	0.01	0.13	0.09	0.07	0.03	0.32	12.55	12.87	6.88
Car	peak	0.03	1.67	0.39	15.08	1.50	18.43	7.12	25.55	11.28
	offpeak	0.02	1.25	0.39	1.65	1.50	4.81	6.54	11.35	10.04
Bus	peak	0.01	2.42	0.09	3.79	0.88	7.19	15.27	22.46	10.63
	offpeak	0.01	1.82	0.09	1.83	0.88	4.62	13.00	17.62	10.63

Note:
* Assuming constant returns to scale

These figures suggest that, on average, current prices for inter-urban travel in the UK are not very different from those which would reflect full external costs. Those for car are actually slightly lower than our estimates of current car costs, including current taxes. Clearly car has higher external costs, almost three times that for rail, determined mainly by the cost of congestion, but the high internal costs of rail, especially its costs of capacity provision, outweigh those of car. Note that these costs, although marginal in the sense of reflecting the cost to the marginal user, relate to a propensity to meet congestion averaged over the whole network. We have already noted the difficulties in modelling congestion on the inter-urban motorway network. We have made some allowance for this, but in the absence of better data on the incidence of congestion cannot make a full correction. Recent work by Newbery (1994) and McLaren and Higman (1993) presents evidence that suggests that on certain motorways the marginal car and coach congestion costs are greater than the estimates we have used based on existing data. For peak travel on the most congested motorways, we estimate car and coach marginal congestion costs to be in the region of 2 to 3 pence per passenger km and 0.5 pence per passenger km, respectively. The figures in Table 1 should therefore be taken as a base estimate, although this adjustment does not make a substantial difference to our final results. On congested urban routes the actual costs would be much higher, as found for London where the peak period full cost of car usage is as high as 22 pence per passenger km and 11 pence in the off-peak.

The London figures show the importance of scale economies in an urban situation—if constant returns to scale were in operation it would be difficult to justify the Underground. Once the assumption of scale economies is introduced these figures for estimated efficient prices fall substantially.

Demand estimates

Using the evidence on long-run marginal costs assembled above, the model of equation 1 was calibrated. For each of the differing assumptions about the degree of economies of scale, the consequences for demand for each mode, are examined. It is of particular interest, given the conventional environmental wisdom, to investigate whether efficient pricing would result in large shifts to modes with lower external costs, eg rail. The results are presented in Tables 2 to 5. The demand figures are given for both the short and the long run.

Table 2 Demand changes (% current demand) in inter-urban passenger transport using long run marginal cost pricing with constant returns to scale

	Short run	Long run
Rail	-10.9	18.5
Car	7.1	48.1
Coach	0.7	5.5

Table 3 Demand changes (% current demand) for London using long run marginal cost pricing with constant returns to scale

	Short run peak	Short run offpeak	Long run peak	Long run offpeak
Underground	-11.6	-3.7	-8.5	0.4
Rail	-10.2	-12.4	1.0	17.8
Car	-2.0	4.0	30.1	49.0
Bus	-1.2	-4.2	-6.2	-2.2

Tables 2 and 3 are based on the assumptions of constant returns to scale, efficient long run marginal cost pricing and taxation of external effects. Given constant returns to scale these results are the same as for long run average cost pricing. Such a policy would lead to a short run increase in the demand for both forms of road transport and a decline in rail. This reflects the current level of road taxation, which is greater, on average, for inter-urban travel, than the levels implied by taxation of external effects, and an implicit rail subsidy. InterCity rail travel used to receive no subsidy. However, under the accounting practices adopted for the new structure of the railways, InterCity no longer covers its long run internal costs, see Ford (1994). In the long run, growth in demand is driven by the income effect. Efficient taxation of externalities does not lead to greater demand for, or a relative shift to, modes of transport with lower external costs.

Table 4 Demand changes (% current demand) in inter-urban passenger transport using long run marginal cost pricing with large returns to scale

	Short run	Long run
Rail	9.2	48.3
Car	2.9	42.4
Coach	-2.1	2.6

Table 5 Demand changes (% current demand) for London using long run marginal cost pricing with large returns to scale

	Short run peak	Short run offpeak	Long run peak	Long run offpeak
Underground	4.1	7.7	13.8	18.9
Rail	-7.3	7.5	7.4	46.3
Car	-4.3	-3.4	19.5	34.3
Bus	-5.5	-7.3	-5.6	-9.1

It was suggested above that economies of scale may be particularly important for rail. Tables 4 and 5 report the results for the maximum assumed levels of economies of scale. As the assumed economies of scale for the rail modes are increased, the results of Tables 4 and 5 show progressively higher demand for rail and lower demand for road transport. In the long run, the demand changes are driven by the income effects.

INVESTMENT, FINANCE AND TAX REVENUES

A principal premise of this research was that shifts in demand towards less environmentally damaging modes with the implementation of efficient pricing might not be possible because of supply (capacity) constraints in those modes. This reflects the popular view that people would shift from car to public transport if only public transport were "better". The model employed enabled us to assess the likely need for new capital investment, together with the implicit revenue from the optimal taxes/charges and the effects on the surplus/deficits of operators. These figures are given in Tables 6 and 7 for the case of the demand changes predicted in Tables 4 and 5. These Tables are based on the assumption of significant scale economies, since this implies the biggest impact on public transport, both in terms of its advantages and the financial impacts on operators from charging at marginal cost below average cost.

Table 6 Results of implementation of implied charges in Table 4 for inter-urban travel (£ billion)

	Infrastructure new capital requirements (i)	Price revenue (excl tax) (ii)	Annual tax revenue (iii)	Total internal costs (iv)	Surplus/ deficit (ii)-(iv) (v)
Short run					
Rail		0.64	0.05	1.29	-0.65
Car		3.90	1.23	5.44	-1.54
Coach		0.57	0.15	0.87	-0.30
Long run					
Rail	2.62	0.87	0.07	1.73	-0.86
Car	5.88	5.40	1.70	7.81	-2.41
Coach	0.01	0.60	0.16	0.90	-0.30

Table 7 Results of implementation of implied charges in Table 5 for travel in London

	Infrastructure new capital requirements (i)	Total price revenue (excl tax) (ii)	Tax revenue (iii)	Total internal costs (iv)	Surplus/ deficit (ii)-(iv) (v)
Short run peak					
Underground		0.39	0.10	1.45	-0.95
Rail		0.51	0.23	1.03	-0.52
Car		1.24	3.32	3.16	-1.92
Bus		0.11	0.09	0.23	-0.12
Long run peak					
Underground	1.84	0.43	0.02	1.59	-1.16
Rail	0.78	0.59	0.04	1.19	-0.60
Car	5.07	1.55	4.14	4.18	-2.63
Bus		0.11	0.06	0.23	-0.12
Short run offpeak					
Underground		0.24	-0.01	0.90	-0.65
Rail		0.12	0.00	0.26	-0.14
Car		1.72	1.30	2.32	-0.50
Bus		0.24	0.08	0.39	-0.15
Long run offpeak					
Underground		0.26	-0.01	0.98	-0.72
Rail		0.17	0.00	0.34	-0.17
Car		2.88	1.90	3.20	-0.32
Bus		0.27	0.08	0.39	-0.12

The figures for the new investment in capital required (column (i)) are given as a total for the whole ten year period, while the other figures are all given on an annual basis. The capital investment is based on the interaction of the calibrated demand function of equation 1 with the long-run marginal cost in order to identify the optimal capacity to bring these into equilibrium in the long-run. This is priced at the current price of capital in the various long-run cost estimates. All new infrastructure capital requirements are allocated to the long-run peak period. In both the short and long run, the price induced shifts in demand are not large and do not give substantial reductions in the levels of total external effects. In the long run, the levels of all externalities increase because of the income effects on demand. Only in the London long run model is the taxation of external effects sufficient to cover the deficits incurred as a result of long run marginal cost pricing. The level of investment required in new infrastructure can not easily be covered from the revenue raised by taxation. This leaves the transport sector as not a net contributor to general tax revenue. The vast majority of this revenue comes from the taxation of car traffic.

CONCLUSIONS

In this paper we have presented some results from modelling the effects of imposing efficient pricing on both inter-urban passenger travel in the UK and passenger travel in London. The long run marginal internal costs of the main modes were estimated, to which were added estimates of marginal external costs from various sources in order to obtain the true opportunity cost of using each mode. All subsidies and current taxation were removed from the current prices which were then compared with the efficient prices in order to predict the changes in demand for each mode, together with implied tax revenues and operators' aggregate surplus or deficit.

The important conclusion to be drawn from this paper is that efficient pricing and taxation of externalities is not sufficient to give substantial shifts to modes of transport with lower external costs. De Borger et al. (1994) have found similar results from an urban passenger transport model of urban areas in Belgium. Their model does not, however, consider scale economies, the costs of infrastructure provision or long-run demand. In the long run, demand changes are driven mainly by the growth of income. The assumption made about the appropriate scale economies present is an important determinant of the degree of change and overall effects. The present levels of taxation of car users are such that the current prices of inter-urban road transport are nearly at the efficient level. In London, especially in the peak, car is currently underpriced by a substantial amount, although so are other means of transport, albeit to a lesser extent. The deficits incurred by public transport operators in moving to long-run marginal costs pricing including all external effects, could not easily be financed from the revenue raised by efficient taxation of car travel. After financing such deficits, the transport sector is not a major net contributor to government revenue.

The conclusion that, in the short run, efficient pricing does not result in large shifts in demand to the modes of transport with lower external costs has important implications for transport policy. The lack of large shifts could be interpreted in four ways. First, the full costs of the external effects of transport could have been under-estimated. As these estimates were based on existing methods and presently available data, the implication would be that the current methods of estimation are inadequate—we think this is likely, especially for congestion in inter-urban transport, and for both global warming and local air pollution effects. Secondly, the assumed economies of scale for rail and bus/coach transport may be underestimated—we have used the best available evidence and these seem plausible. Thirdly, the responses of demand and technological innovation and application to transport taxation may be underestimated. The evidence on own and cross price elasticities is poor and the effects of price induced technological developments unclear—this falls into the area of calls for a change in life-styles advocated by the recent Royal Commission report. Fourthly, the results could be interpreted as evidence of the ineffectiveness of efficient pricing in reducing the level of external effects of transport. This last interpretation has important implications for transport policies that are based on the market mechanism.

This model is only a partial one of the transport sector. It does not include the interaction between freight and passenger traffic using the same infrastructure. It also fails to allow for the fact that most inter-urban journeys by road involve urban segments at each end of the journey, such that their overall cost is higher than implied here. There is an interaction between the London and inter-urban models which would be feasible, but complex, to incorporate. What has been shown here is that it is possible to shed some empirical light on the questions raised in current debates, but also that transport policy may need to be much more pro-active if it is to achieve a lasting change in the balance of use.

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