Valuing the external costs of aviation

Contents

Context

1. Aviation, in common with other modes of transport, gives rise to a number of adverseenvironmental impacts. These include aircraft noise, contributions to local air qualityproblems and climate change, and other factors such as townscape, landscape, biodiversity,heritage and water, some of which cannot easily be quantified.

2. Under the polluter pays principle, external costs should be reflected in costs incurred bythe aviation industry, so that (in an ideal world) it fully meets its external costs. MostEuropean governments, including the UK have adopted this principle. A key principle inthe Integrated Transport White Paper issued in 1998 is that aviation should meet theexternal costs, including environmental costs, that it imposes. One of the main questionsin The Future of Aviation, the Governments consultation document on air transportpolicy, is

- How should the Government ensure that aviation meets the external environmentalcosts for which it is responsible?

The consultation document goes on to seek views on the use of economic instruments,regulations and voluntary agreements to influence noise, emissions and otherenvironmental impacts of aviation.

3. The approach set out in the South East Airports appraisal framework uses indicators whichare a mix of monetary values, physical measures and non-quantified elements.Environmental impacts will be quantified, where possible, in physical terms, but withoutusing monetary valuation. This approach recognises the uncertainty associated withvaluing environmental impacts. This may change in the future as we acquire moreinformation on values. An appraisal summary table is used to provide information aboutoptions as an aid to decision-makers, setting out all the significant consequences of apolicy option on a clear and reliable basis. The weights or values Ministers place on eachindicator will be evident when their final decision is taken.

4. This paper briefly reviews some of the economic literature of the valuation of noise, airquality and climate change impacts and considers the implications of aviation meeting itsestimated external costs for airline costs, fares and demand. Its purpose is to offer anintroduction to the orders of magnitude which have been proposed by independentresearchers, as part of the context for consideration of the issues in the consultationdocument. Nothing in this paper should be construed as an official endorsement of anyparticular set of valuations.

The valuation of externalities

5. Externalities arise where the activities of some firms or individuals affect the welfare ofothers, without the former considering these effects in their decisions. Typically, the lackof well-defined property rights is the underlying cause of the externality problem, becauseit prevents the existence of a market for external effects. For example, individuals living inthe vicinity of airports do not have clearly established property rights to peace and quietand clean air[1] . The ideal solution is to establish property rights, but it is typically notpossible to do so. Therefore it is often necessary to establish a price mechanism to ensurethat damage to society is taken into account. In the case of aviation, such a mechanismwould be used to ensure that air passengers, in choosing to fly, took implicit account of thecosts to residents affected by aircraft noise and emissions.

6. In order to assess the extent of the problem, one would ideally need monetary estimates forthe external effects. Unfortunately, as the consultation document acknowledges, there areuncertainties in estimating the environmental costs of aviation. These arise from thecurrent state of scientific knowledge and from difficulties in measuring physical impactsand (to a greater extent) their monetary valuation. There are, however, several studies inthe economic literature that have attempted to place monetary values on the externalitiesarising from aircraft noise based on individuals willingness to pay for marginal reductionsin aircraft noise. A similar approach has been applied to the valuation of externalitiesarising from air quality and climate change, though here the literature is less developed,and the scientific impacts of climate change impacts of aviation have been assessed by theIPCC[2]. Other environmental impacts associated with airport capacity, such as townscape,landscape, biodiversity, heritage and water, are not considered here as there are no relevantstudies that have attempted to place valuations on these impacts. In addition this paperdoes not consider the delay costs arising from congestion and capacity constraints.

Noise

7. Given that there is no market where peace and quiet can be traded, one indirect way ofmeasuring householders willingness to pay to reduce noise is through their house purchasedecisions. This approach, known as hedonic pricing, has attempted to identify thepremium that, other characteristics being equal, is paid for a quieter house in terms ofhigher rent or higher purchasing price. For instance, by analysing large property databaseswith the use of sophisticated statistical techniques, the impact of aircraft noise can inprinciple be isolated from other factors affecting house prices, and the relationshipbetween noise levels and property values can be estimated. The results of hedonic pricingstudies of noise are often summarised through a so-called noise sensitivity depreciationindex (NSDI), which provides a measure of the percentage change in house priceassociated with a unit change in noise quantity measured in dBA Leq (16-hour daytime).

8. Recent surveys of the hedonic pricing literature on aircraft noise by Robert Tinch[3] andSchipper, Y. (1998)[4] have tried to identify consensus values for NSDI due to aircraft noise. The figures they found ranged between 0.5% and 1% per dBA. In other words, thismeans that a 1dBA rise in the quantity of noise is likely to reduce house prices by 0.5 1%. Pearce DW and Pearce B[5] , derived estimates of the marginal willingness to pay(MWTP) for an aircraft event (landing and take-off) for each aircraft type. They startedby adopting the NSDI value of around 0.6% per dBA found by Schipper. By applying thisNSDI value to the average house price within the Heathrow Airport 57dBA daytimecontour and by multiplying for the number of resident households, they were able to derivean estimate of overall MWTP for a 1dBA Leq reduction in the area. Then, they convertedthis figure into a daily MWTP. In order to derive estimates of MWTP for the reduction ofa daily movement of each aircraft type, they multiplied the impact on Leq (16-hr) of eachaircraft type (derived from noise certification data) by the daily overall MWTP figure.Table 1 shows the resulting estimated noise damage costs per aircraft event for selectedaircraft types.

Table 1: Marginal Damage Costs by Aircraft Type: Noise

	£
A 310	34
A 340	77
B 737-400	34
B 747-400	168
B 757	44
B 767-300	54
B 777	33
MD82	49

Source: Pearce and Pearce

9. Comparable values of road noise are available from a report carried out byCSERGE/EFTEC for the Scottish Executive[6] . This produced a best estimate of about 0.2%as the value for the change in house prices due to a 1dBA change in road traffic noise.

10. It should be recognised that there are a number of sources of inaccuracy in derivingdamage costs from aircraft noise which make these estimates of noise damage costs subjectto significant margins of error. Specifically:

- hedonic pricing analysis has to contend with a great many potentially confoundingfactors which cannot be fully identified by statistical methods. In addition, thehedonic price method relies on an equilibrium assumption, whereby households areable to choose from a complete range of price levels and house characteristics and thehousing market is cleared;

- the whole disbenefit estimated by hedonic pricing, which would in principle includenight noise disbenefits, has been attributed to daytime movements. Because of thesignificance of sleep disturbance, and the typically uneven pattern of movements atnight, the disbenefits cannot necessarily be assumed to be identical between day andnight time;
- the noise certification levels used by Pearce and Pearce may be higher or lower thanactual levels, with actual take-off weight in particular having a significant impact ondeparture noise levels;

WTP values are not likely to be uniform across the population, and there is likely tobe an element of self-selection with people less averse to noise (and, of course,aviation industry workers) choosing to live around airports. This means that cautionneeds to be taken in applying the results to people not currently affected by aircraftnoise;

If average damage costs are higher than marginal damage costs, as suggested by Pearceand Pearce, estimates based on marginal damage costs will result in an underestimateof total damage costs;

- some of the studies in the literature used to derive WTP values are quite dated and/orbased on evidence from outside the UK.

11. Poor air quality in the vicinity of airports can give rise to a range of effects on humanhealth and the environment. Local air pollutants emitted from aircraft during landing andtake-off include VOCs, CO_2 , NOx, SO_2 and indirectly ozone (formed through emissionsof VOCs and NOx). Health impacts include both mortality and morbidity effects whileenvironmental impacts range from effects on crops, forest damage, damages to buildingsand materials, to reduced visibility and effects on ecosystems.

12. In order to measure these impacts, scientific and economic information is required on thefollowing: the nature of the relationship between concentrations of each pollutant and theassociated health and environmental impacts; the population exposed to the pollution orthe stock at risk; and the values which the public place on each of the relevant health andenvironmental impacts. It is important to note that uncertainties exist in quantification ofmany of the health and environmental effects described above which will affect what canbe valued.

13. Based on advice from the Committee on the Medical Effects of Air Pollutants(COMEAP)[7] , only a limited number of health effects could be considered to havesufficiently robust evidence to allow quantification[8] . These health effects included deathsbrought forward (acute mortality) and respiratory hospital admissions[9] . There is alsoemerging evidence of the effects of long-term exposure to air pollutants, notably particles,which would be much larger than the effect of short-term exposures considered up to now.

14. There is limited direct empirical evidence on the willingness to pay to reduce the mortalityrisks of air pollution although some empirical evidence on morbidity values (see work byEAHEAP and ExternE). One approach developed in the report by EAHEAP[10] is to usethe DETRs value for the prevention of a road accident fatality as a baseline to value acute mortality effects. In applying this baseline to the air pollution context, adjustments werethen made to reflect the perceived involuntary nature of the air pollution risks involved,that those affected by air pollution are mostly over 65 and may already be in a poor state ofhealth with a reduced life expectancy. However, uncertainties over whether deaths arebrought forward by just a few days or by months or years and how willingness to pay isaffected by the factors described above led to a very wide range of value of statistical lifebetween £2,600 to £1.4 million.

15. Pearce and Pearce quote estimates of the marginal willingness to pay for reduced airpollution based on their own work and the available literature. The values used are takenfrom a number of European studies with damage costs per tonne of emissions arrangedacross European countries and across rural and urban areas. However, the wide range ofuncertainty surrounding both the quantification of effects as well as the values and the factthat local air quality is airport specific implies that these average figures would not bemeaningful. Estimates of damage costs arising from local air pollution are not thereforeincluded in this paper. However, the potential damage costs from

local air pollution couldbe significant and further work is required to establish its importance in relation to totalexternal costs.

Climate change

16. Aviation contributes to climate change through the production of CO_2, but it alsoproduces other emissions including oxides of nitrogen, which lead to the formation ofozone, particulates and water vapours resulting in the formation of contrails. However, theuncertainties surrounding the effects of these other emissions on climate change are muchlarger than those associated with CO_2 .

17. The concept of radiative forcing has been used by the Intergovernmental Panel onClimate Change (IPCC) in collaboration with the Scientific Assessment Panel of theMontreal Protocol to measure the climate change effects attributable to the variousemissions produced by aircraft. It estimated that aircraft accounted for 3.5% of totalradiative forcing from man-made sources in 1992 (excluding the effects of aviation oncirrus clouds).

18. The IPCC[11] quoted a range of $5 to $125 per tonne of carbon (1990 US$) applied to themarginal damage costs of CO_2 emissions over the period 1991-2000. Extending the rangeto the period 2001-2010 would increase these estimates to $7 to $154 per tonne of carbon.

19. Based on a review of the relevant literature the DETR has identified a range for marginaldamage costs of $£40-$160 per tonne of carbon with a preliminary central value of $80 pertonne (all in 2000 prices). This proposed range is intended to take account of the highlevel of uncertainty concerning the impacts of climate change and their associateddistributional issues, and reflects the disproportionately higher probability of extremeclimatic events. The central figure advocated for illustrative purposes is higher than thefigure of $50 per tonne of carbon used by Pearce and Pearce to calculate damage costsarising from climate change but seems more consistent with updating the IPCC figure. Itshould be noted that these estimates of the external costs attributable to climate changeare worldwide figures that are specific neither to the UK nor the aviation industry.

20. Using IPCC analysis of the relative climate change impacts of CO_2 and NOx, Pearce andPearce estimate a rough estimate of £1500 per tonne of NOx at altitude as being consistentwith their estimate of $50 per tonne of carbon. Using this relationship, but applying thecentral estimate of $80 per tonne of carbon, would give a value per tonne of NOx of£2,400.

21. The results from Pearce and Pearce on emissions at altitude by aircraft type have beenrevised by the DETR and are presented in Table 2 using the central estimates and theupper and lower bounds of the range.

Table 2: Marginal Damage Costs: Climate Change

Short-haul operations

	Central	**low**	**high**
B 737-400	211	106	422
A 320	254	127	508
MD82	300	150	600
B 757	368	184	736
A 310	331	166	662

Long-haul operations

	Central	**low**	**high**
A 340	3,536	1768	7,072
B 747-400	4,972	2486	9,944
B 767-300	2,445	1223	4,890
B 777	3,771	1886	7,542

Overall Environmental Costs

22. Table 3 brings together the above estimates of noise and climate change marginal damagecosts to show their combined environmental costs by aircraft type for shorthaul andlonghaul operations, but excluding damage costs from local air pollution. These figureshave also been normalised to derive estimates on a per passenger and per 1000 passengerkilometre basis.

Table 3: Estimated Environmental Costs per Passenger and Passenger-Kilometre (central estimates)

	Total (£)	**Short-haul operations £ per passenger**	**£ per 000 pass km**
B 737-400	245	2.50	2.75
A 320	285	2.18	3.23
MD82	350	3.30	3.60
B 757	412	3.01	3.27
A 310	395	2.90	3.17
	Total (£)	**Long-haul operations £ per passenger**	**£ per 000 pass km**
A 340	3,613	20.24	3.21
B 747-400	5,140	18.49	2.88
B 767-300	2,499	18.45	2.89
B 777	3,804	18.05	2.78

23. On a per passenger basis, Table 3 shows environmental costs of around £3 per passenger onshorthaul operations and £20 per passenger on longhaul aircraft. On a cost per passengerkilometre basis, the marginal damage costs are broadly similar from shorthaul and longhauloperations. It should be stressed that the environmental damage cost estimates which formthe basis for these figures are illustrative and subject to high levels of uncertainty.

24. The following illustrative calculations can be made to show the impact of including anenvironmental charge, assuming it is passed on in full to passengers through increasedfares. Based on CAA statistics, average one-way revenues per passenger for shorthaul andlonghaul operations by UK airlines were around £85 and £300 respectively in 1999. Thecentral estimates of damage cost per passenger in Table 3, suggests that they would tend toincrease shorthaul fares by around 3½ % and longhaul fares by about 6% if fully passed onto passengers. Taking an overall fare elasticity of demand of 0.8, this would reducedemand for shorthaul and longhaul travel by around 3% and 5% respectively.

1 For example, with respect to noise, section 76 of the 1982 Civil Aviation Act deliberately removes the property rights that would otherwise exist under common law.

2 Aviation and the Global Atmosphere, 1999.

3 Valuation of Environmental Externalities: Report to DOT, 1995.

4 Why Do Aircraft Noise Value Estimates Differ? A Meta-Analysis Journal of Air Transport Management, 1998.

5 Setting Environmental Taxes For Aircraft: a Case Study of the UK, CSERGE, 2000 (forthcoming).

6 The Effect of Road Traffic on Residential Property Values A Literature Review of Hedonic Pricing Study, 2000.

7 Quantification of the Effects of Air Pollution on Health in the UK, January 1998.

8 An approach which goes beyond COMEAP would be to explore quantification of additional health effects through a structured sensitivity analysis which clearly shows the level of confidence placed on quantification of these effects.

9 However, it should be noted that COMEAP has recently agreed that the long-term effects of particles on health should be quantified provided the uncertainties are made clear.

10 EAHEAP is the expert group set up in 1998 to advise on the Economic Appraisal of the Health Effects of Air Pollution.

11 IPCC Second Assessment Report, 1995.