OXFORD ECONOMIC RESEARCH ASSOCIATES

BAA EXTERNAL EMISSIONS TRADING STEERING GROUP

ASSESSMENT OF THE FINANCIAL IMPACT ON AIRLINES OF INTEGRATION INTO THE EU GREENHOUSE GAS EMISSIONS TRADING SCHEME

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Steering Group

The Terms of Reference for this analysis were set by the BAA External Emissions Trading Steering Group, building on the outputs of a major stakeholder workshop, on March 31st 2003. The workshop, independently facilitated by Lindsey Colbourne of the InterAct Network, brought together over 60 senior representatives from government, industry, and NGOs, to consider stakeholder perspectives on a credible approach to aviation's integration in an emissions trading scheme.

In addition to setting the Terms of Reference, reproduced in Appendix 2, the Steering Group has 'challenged and reviewed' the analysis herein and discussed its findings.

The analysis has been commissioned by the Steering Group as a contribution to public debate, and has been co-funded by BAA and the Department for Transport. **However, neither the steering group as a whole nor its individual members are formally committed to the analysis undertaken by OXERA, and the conclusions in this paper remain the responsibility of OXERA alone.**

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Source: BAA.

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Executive Summary

This paper analyses the financial impact of integration of intra-EU aviation into the EU greenhouse gas emissions trading scheme (EU ETS). The assessment is carried out both qualitatively and quantitatively.

The basic architecture of an emissions trading scheme consists of a requirement to surrender an allowance for each unit of emission and a rule allowing emission allowances to be traded which leads to an equilibrium allowance price. An initial allocation of allowances can be made to the participants. The decision regarding the amount of emission reductions to target is made by comparing the emission allowance price path with the cost of in-house abatement. Excess allowances can be sold to the market.

Emissions trading affects costs and revenues in three ways:

- the addition of the allowance price to the fuel costs changes the operating profit by reducing the margin, and, if passed through in the ticket price, causes a loss of volume;
- the investment in energy efficiency improvement of the fleet results in higher fixed costs;
- the initial allocation constitutes a fixed revenue.

The impact on demand for flights depends on how the additional costs are passed through in the ticket price. Two rules are conceived for two types of airport:

- *marginal cost pricing*—the ticket price for each flight is determined on a marginal cost basis (ie, on the basis of the additional cost that the operation of this particular flight incurs);
- *demand clearance pricing*—when capacity is constrained, the ticket price is set at the level which clears the demand for tickets at the given supply.

In this analysis, it is assumed that flights between uncongested airports price at marginal cost, while flights to and from congested airports adopt a demand clearance pricing strategy. The pricing strategies imply a difference in financial impact of emissions trading at both types of airport:

- *uncongested airports*—the allowance price is passed through to passengers in the ticket price, resulting in a loss of profit margin and volume;
- *congested airports*—the costs are not passed through in the ticket price, avoiding volume loss, but resulting in higher loss of profit margin.

The literature relating to the assumptions made in the paper is reviewed. The proportion of flights from congested airports is assumed to be 25%. The elasticity of demand is estimated at –0.8 for business, and –1.4 for leisure travel. The different estimates for EU allowance prices and proposals for a tax on emissions from aviation are also summarised. The range of allowance prices is estimated as €5–€30/tCO_2, whereas the tax estimates range from €10 to €70/tCO_2. In the model, assumptions of €5, €10 and €20/tCO_2 are used for both allowance prices and tax rates.

These assumptions are used in the modelling of the financial impact of emissions trading on aviation. The model tests the following three groups of options.

1. **Initial allocation** (three scenarios):

   A1 a 25% reduction compared against a baseline of 40% growth between 1990 and 2010;
   A2 an 8% reduction from 1990 emissions by 2010; and
   A3 a 60% reduction of 1990 emissions by 2050.

2. **Percentage of auctioning and grandfathering**[1] **in the initial allocation** (two scenarios):

   – auctioning of 10% of the allocation while grandfathering 90%; and
   – 100% grandfathering.

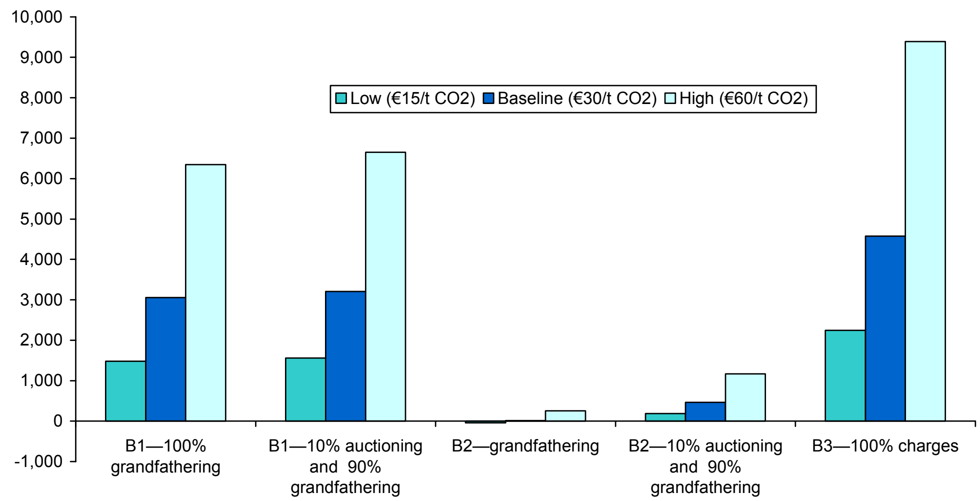
3. **Balance between emissions trading and taxation** (three scenarios):

   B1 a requirement to submit one allowance per tonne of CO_2 and a tax on the residual climate change impact of 1.5 to 2 times the CO_2 equivalent (CO_2e);
   B2 a requirement to submit 2.5 to 3 allowances for each 1 tonne of CO_2e emitted; and
   B3 a tax on the basis of 2.5 to 3 times the estimated damage from 1 tonne of CO_2e.

The analysis of different tax and emissions trading options shows that a pure trading system with a requirement to submit allowances covering 2.5 to 3 times the emitted tonnes of CO_2e is much cheaper for the industry—up to 40 times—than any of the scenarios involving a tax on part or all of the climate damage costs. In the pure trading scenario, the financial impact is almost zero, and in some cases a gain is made. The reason is that the value of the grandfathered allowances equals or exceeds the profit lost through reduced margins and demand volume loss. Under the scenario requiring one allowance to be surrendered for 1 tonne of CO_2e, combined with a tax amounting to 1.5 to 2 times the damage of 1 tonne of CO_2e, the financial impact amounts to about €2,200m–€3,200m per annum. The pure taxation scenario results in an impact of €3,800m–€4,600m. In a separate study carried out for the European Commission, CE Delft has estimated that the revenue generated by an emissions charging regime will be in the range of €1,100m to €8,600m. When a charge of €30/t CO_2 is used the estimate is approximately €3,300m.[2] However, the two estimates are not directly comparable: the OXERA estimate is the financial impact on the industry, a figure that includes profits forgone, while the CE Delft estimate is for the revenue raised by such an instrument.

[1] Grandfathering involves giving the initial allocation of allowances to the industry free of charge, whereas auctioning requires the industry to pay for the initial allocation.
[2] CE Delft (2002) 'Economic Incentives to Mitigate Greenhouse Gas Emissions from Air Transport in Europe', commissioned by the European Commission, July.

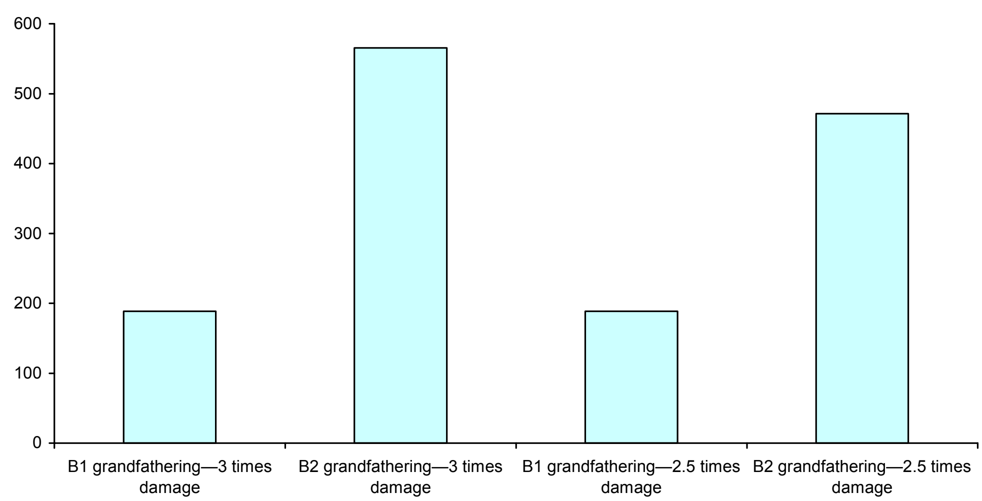
Total financial impact with different allowance prices and EU charge levels in scenario A1 assuming that total damage is 3 times that due to CO_2 alone (€m per annum)



Notes: Figures in parentheses refer to the marginal price (sum of allowances and charges) paid to emit 1 tonne of CO_2.
Source: OXERA modelling.

The quantitative analysis shows that the difference between the allocation scenarios is less significant than the different assumptions about the mix of emissions trading and taxes. The initial allocation of –8% of 1990 emissions (scenario A2) results in an additional cost of around €200–€550m compared with the allocation scenario of –25% (scenario A1) from projected emissions.

The increase in financial impact on the industry caused by switching from scenario A1 to A2 (€m per annum)



Source: OXERA modelling.

Auctioning 10% of the emissions leads to a greater financial impact of around €150m–€450m. Sensitivity analysis shows that the model is relatively sensitive to the assumptions about the proportion of cost pass-through at uncongested airports, and to the assumption about price elasticities of demand. Relaxing the no-cost-pass-through assumption to full cost pass-through leads to a reduction in financial impact of €1,300m. Changing the elasticity by 0.5 from –1.5 leads to a change in impact of €894m.

The 2008–12 baseline scenarios all result in a direct emissions reduction of approximately 8.5% by the aviation sector. The majority of this (5.3 percentage points) is attributable to a reduction in demand caused by higher ticket prices, while 3.2 percentage points are attributable to supply-side abatement. In addition, in the partial and full trading scenarios, the aviation sector purchases emissions reductions from other industries, increasing the effective emissions reduction attributable to aviation to around 20% for partial trading, and around 40% for full trading.

The modelling of the 2050 scenario shows that the difference between the emissions trading and tax mixes is considerably less pronounced than for the 2008–12 scenario. The total financial impact amounts to around €4 billion under a low allowance price and €16 billion–€17 billion under a high one.

Two assumptions in the modelling are worth highlighting at this point:

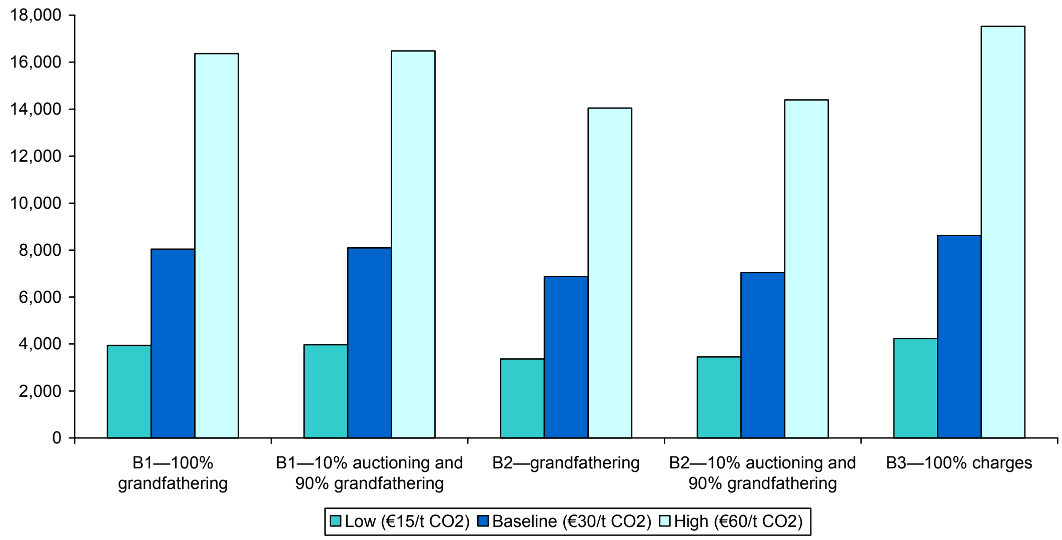
- taxes are assumed to be levied at the same level as the allowance price for the comparison graph shown below. If taxes were set equal to Defra's current estimate for the damage costs associated with CO_2 emissions, the financial impact may be much greater, at around €45 billion per annum;
- taxes are not recycled back into the industry, and therefore represent a net loss to the aviation sector.

A further reason for the different pattern and the higher costs is chiefly that the initial allocation of allowances is very limited, but also because the model assumes unabated growth in aviation emissions. This assumption might not be compatible with industry responses to a sustained high allowance price in terms of abatement. In addition, there is a considerable amount of uncertainty surrounding the 2050 scenario—in particular, the likely level for taxes and allowances is far from clear for this time horizon. It is possible that intra-EU aviation may have become part of a wider global ETS by 2050, potentially affecting allowance prices. However, the modelling presented here assumes that it is part of an EU-based ETS.

Only the full trading scenarios (B2) result in a 60% reduction against 1990 levels in emissions from society as a whole in the modelling for 2050. The 60% target helps to determine the allowance price in the entire emissions trading market, not just the aviation sector. Therefore, the reductions from different sectors can be greater or less than 60%, but the delivery of 60% emissions reductions from society would be achieved.

The taxation scenarios (B3) do not result in such large emissions reductions; instead, the industry largely chooses to continue emitting and pay the charges. To achieve a 60% reduction in emissions from the baseline using taxation, the tax rate would have to be higher than the range examined here, and/or the revenues from taxes may have to be used to purchase and retire allowances from an emissions trading market.

Total financial impact with different allowance prices and EU charge levels in scenario A3 assuming that total damage is 3 times that due to CO_2 alone (€m per annum)



Notes: Figures in parentheses refer to the marginal price (sum of allowances and charges) paid to emit 1 tonne of CO_2.
Source: OXERA modelling.

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1. Introduction

This paper examines the financial implications of the integration of intra-EU aviation in the EU Emissions Trading Scheme (EU ETS). The impact on profits, passenger demand and fares is examined quantitatively for the period 2008–12 and the year 2050. The integration of intra-EU aviation in emissions trading is compared with the credible policy alternatives of a charge levied on emissions from intra-EU aviation, or a mixture of emissions trading and taxation.

First, the paper sets out the framework for analysing the financial impact of emissions trading in the particular context of aviation through the impact on demand and supply of flights. Pricing models are discussed in the context of congested and uncongested airports.

In section 3, the model is introduced and the various parameters discussed. An aggregate modelling framework is used in order to estimate the financial impact of an allowance trading and taxation scheme. The model allows for a quantification of the total financial impact—lost profit due to lower passenger volumes, the costs of abatement, and the costs of emission allowance purchases—but does not allow route-specific effects to be analysed. The literature on the degree of cost pass-through, the elasticity of demand, the allowance price and tax level, and the abatement cost function is examined. For each issue, the assumptions made in the base-case scenario of the model and the sensitivity analyses are summarised.

The modelling results are presented in sections 4 and 5. Section 4 provides the results of the modelling analysis for the 2008–12 scenarios (scenarios A1 and A2). Section 5 provides the results of the modelling analysis for the 2050 scenario (scenario A3).

Section 6 briefly discusses the institutional, legal, and political steps that are likely to be required to bring intra-EU aviation within a mandatory, open, cap-and-trade, EU emissions trading regime.

Finally, section 7 concludes.

2. Framework for Analysing the Financial Impact of Emissions Trading

Integration of intra-EU aviation in emissions trading is likely to affect the industry through the demand and the supply sides. The cost of compliance consists of the cost of demand volume loss, and, on the supply side, of abatement reduction and/or emission-allowance acquisition. These are discussed in more detail below.

2.1 Demand, supply and profits

Any emissions trading system would affect the aviation industry in two ways: through the demand side, in the form of reduced passenger numbers, and through the supply side, in the form of changes to the technologies and the cost of the net allowance acquisition. The aggregate effect gives the total impact on profit.

The demand-side effect for airlines consists of the change in demand in response to a change in ticket price following the imposition of an emissions trading scheme. The following demand-side issues must be examined:

- how, and to what extent, the emissions trading system would affect the ticket price (section 2.2);
- how demand would be affected by changes in the ticket price (section 2.3).

To examine the relationship between allowance price and ticket price, the pricing behaviour in the airline industry must be analysed.

The supply-side effect consists of a change in the service supplied by airlines following the imposition of an emissions trading system. Airlines could improve their energy efficiency and/or make other cost savings. Improvements in energy efficiency encompass both operational and technical measures. Other cost savings might consist of non-fuel cost savings or avoidance by diverting business outside the trading area. Airlines can also buy allowances. Both emission-reduction costs and allowance costs affect the margin on ticket prices directly, to the extent that the costs cannot be passed through in the ticket price. If the costs are passed through in the ticket price, demand will be reduced to some extent, lowering the absolute level of profit, even if the margin remains unchanged.

The extent to which the imposition of an emissions trading system leads to demand- rather than supply-side effects is a matter for empirical analysis.

Both demand- and supply-side effects have an impact on the profit of airlines, and, potentially, of airports. Profits at many airports are effectively controlled by regulators, constraining the prices that airports may charge airlines for the use of their runways. Congested airports in particular are likely to be subject to regulation, since they may be able to extract rents from airlines if capacity is constrained. However, in the base-case model in this paper, congested airports do not suffer a loss of volume, and therefore they would not suffer a loss of revenue due to the imposition of a new emissions trading regime. Uncongested airports may suffer some volume loss in the base-case model, since ticket-price increases reduce passenger demand and therefore demand for air traffic movements. However, this can be regarded as partly accounted for in the model, since the base-case scenario includes a 30% fixed-cost element for airlines, which can be considered as including airport fees.

The profit of airlines under an emissions trading system could be viewed as consisting of the following elements:

- the operating profit (+)—the revenue minus the variable operating costs, mainly fuel and emission-allowance cost, the staff and in-flight services;
- the fixed costs (–)—mainly the aircraft capital, operating and maintenance cost;
- the fixed revenue (+)—the initial allowance allocation under a grandfathering rule.[3]

From this perspective, emissions trading affects profits through all these elements:

- through the operating profit, due to the change in variable costs;
- through the fixed costs, because of investment in energy efficiency;
- through the fixed revenue, because of the initial allowance allocation.

The distribution between these factors depends on a number of issues, including the proportion of fixed and variable costs, the flexibility to change operations and prices, and the allowance price.

The impact on the operating profit is independent of the way in which the allowance has been obtained—ie, it makes no difference to the value of a number of allowances used for a particular flight whether they have been bought or obtained for free in an emission allocation. The value of the allowance is determined by supply and demand in the emissions allowance market, and, when used for a particular flight, it cannot be sold at that price or used for another flight. For this reason, the impact of the cost of an allowance on the flight cost, and possibly on the revenue through a change in the ticket price, should be clearly distinguished from the impact of the revenue from an allowance through the initial allocation.

2.2 Demand-side effects: the change in ticket price

The first step in the analysis of the demand-side effect is to determine how emissions trading results in a change in the ticket price. The change in ticket price following imposition of emissions trading depends on the pricing method. Two pricing methods can be distinguished: marginal cost pricing and demand clearance pricing, and each is analysed below.

2.2.1 Marginal cost pricing under perfect competition

Strictly speaking, marginal cost pricing means that each ticket is priced at the additional cost of carrying the passenger. Once a flight has been scheduled, however, the marginal cost of one passenger is zero. Hence, in the context of airlines, it is more useful to analyse the marginal cost of supplying a particular flight (ie, the cost of operating one additional

[3] Grandfathering involves giving the initial allocation of allowances to the industry free of charge, whereas auctioning requires the industry to pay for the initial allocation.

flight). In that case, the marginal costs are the variable flight costs (ie, fuel, staff, service, handling and slot costs).

Under perfect competition, tickets would be priced at the marginal cost of the flights divided by the expected number of passengers. The introduction of emissions trading increases the cost of operating a flight by the emissions multiplied by the allowance price. Emissions trading would lead to an adjustment in ticket prices, reflecting the value of the allowance prices needed for that flight and a change in the expected number of passengers.

The level of marginal adjustment would depend on the total emissions of a particular flight by a particular aeroplane. An airline might reduce these by improving energy efficiency (see section 2.3), if it can find measures which are cheaper per unit than the cost of the allowances that would be saved. If measures are more expensive, it would be beneficial to pay for allowances for the flight.

Therefore, under marginal cost pricing, the airline has an incentive to reduce emissions to offer the cheapest ticket, and passengers have an incentive to switch to a low-emissions flight. The ticket price would increase and some passengers might prefer to switch their mode of transport or abstain from travel altogether.

There are many obstacles to marginal cost pricing in the airline industry. In general, low-cost airlines are more likely to apply marginal cost pricing than other carriers.

2.2.2 Demand clearance pricing

The assumptions of both competition and demand-driven supply might not be applicable to much of the airline industry. Rather, competition may be restricted by legal agreements or by capacity constraints (particularly limited slot availability at congested airports). Where airport capacity is constrained—and hence, supply is limited—the price is set at the level at which demand is cleared, not at the marginal cost of supply. Demand clearance pricing means that, at congested airports, there are more people willing to fly at a marginal cost-based ticket price than there are seats. Thus, airlines can increase the price until the point at which the number of seats equals the number of passengers willing to pay the higher price.

Demand clearance pricing occurs where the link between the cost of a flight and its price is lost. In this situation, neither the allowance price nor the total compliance price would have any effect on the ticket price, and so there would be no demand reduction at the airports where this form of pricing is used.

There has been a recent debate about the pass-through of costs to ticket prices at congested airports. At the periodic review of BAA charges for 2003–08, concluded in February 2003, the Civil Aviation Authority (CAA) argued that significant monopoly rents were accruing to airlines at its congested airports. Consequently, increasing landing charges would not feed through to increased ticket prices and reduced volumes. However, the Competition Commission, when reviewing the CAA's decision, noted:

> The argument that there are significant rents to airlines at Heathrow sits oddly with the lack of profitability of Heathrow airlines. Almost all are currently making little or no profit.[4]

The Commission argued that it was more plausible to believe that 'competition between airlines is likely to result in some of these potential rents being passed to passengers'.[5]

2.2.3 Congested and uncongested airports

Any assessment of the impact of emissions trading on demand must crucially distinguish between the impact on flights to or from congested airports, and the impact on flights to or from uncongested airports.

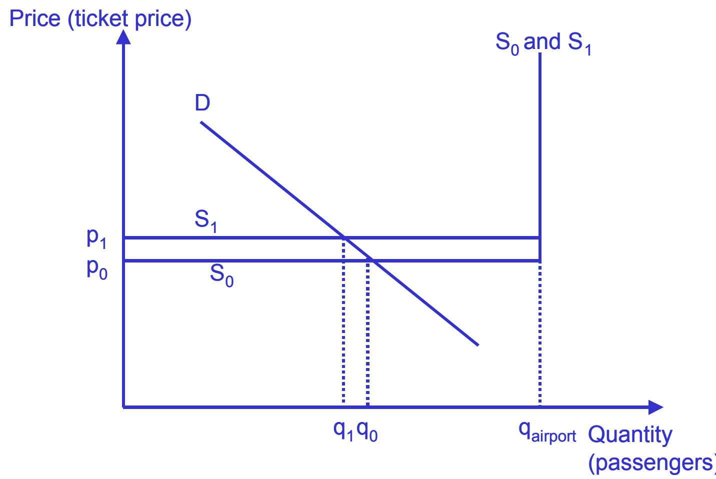
- *Congested airports*—the price of flights to or from congested airports does not reflect the cost of the flight. Hence, compliance costs would have no impact on the ticket price or on demand. However, OXERA also examines a scenario in which costs are passed through in the same manner as at uncongested airports, to highlight the sensitivity of the results to this assumption.

- *Uncongested airports*—unless the ticket is cross-subsidised by revenue from flights to and/or from congested airports, the allowance price would be passed through in the ticket price. This implies that airlines which only or predominantly fly to and from uncongested airports are most likely to increase ticket prices to offset the full (marginal) cost of allowances, and, hence, are most likely to experience volume loss. The airport would suffer revenue loss too.

Figures 2.1 and 2.2 illustrate the stylised interaction of demand and supply of airline seats from uncongested and congested airports respectively.

[4] Competition Commission (2002), 'BAA plc: A Report on the Economic Regulation of the London Airports Companies (Heathrow Airport Ltd, Gatwick Airport Ltd and Stansted Airport Ltd)', February, p. 53.
[5] Ibid, p. 53.

Figure 2.1: Demand and supply at uncongested airports



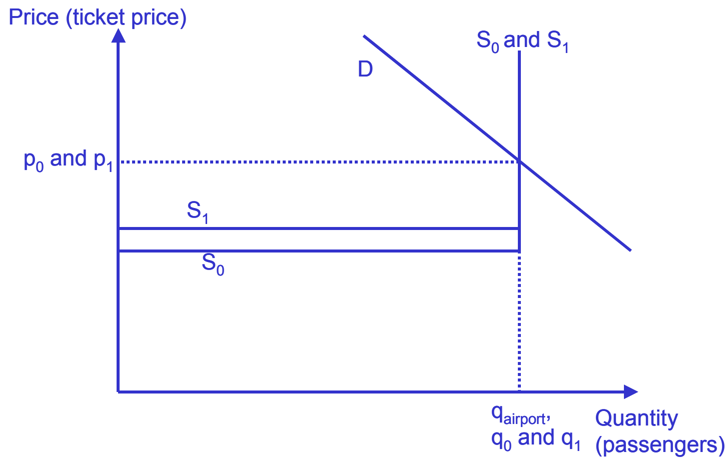
Source: OXERA.

The flight supply curves assume that the only fixed costs that airlines have is their aeroplanes. They also assume that the costs of operating these rise linearly with the number of airline seats offered for sale. At the micro level, there will be some lumpiness in this curve (ie, airline seats come in plane-sized increments), but this is not a significant concern at the macro level at which this analysis is done. These assumptions imply that the marginal cost of offering extra airline seats is the same as the average cost of offering extra airline seats, which in turn implies a horizontal supply curve. The marginal cost pricing model implies that, when an airport is operating below its capacity, and is therefore uncongested, airlines set the price equal to the marginal cost of providing extra airline seats.

The lines S_0 and S_1 represent the industry supply curve of airline seats. S_0 is the supply of airline seats before the imposition of environmental charges and/or requirements to purchase emissions allowances. S_1 shows the case where environmental charges and/or requirements to purchase emissions allowances are imposed. This results in the supply curve shifting up by the per-passenger cost of the emissions allowances/environmental charges.

At the uncongested airport, demand is not sufficient to use all the available capacity, thus the demand curve (D) intersects the horizontal portion of the supply curve. Before the imposition of a tax or emissions trading regime, the supply curve is at S_0, resulting in a price of p_0, and a quantity of q_0. Imposing a tax or emissions trading regime increases the marginal cost of providing airline seats, and therefore shifts the supply curve up to S_1. The result is that the price charged increases by the marginal cost of the tax/allowance trading scheme per seat to p_1. This price rise results in a fall in quantity to q_1, the extent of which depends on the elasticity of demand at uncongested airports (this is examined in section 3.3).

Figure 2.2: Demand and supply at congested airports



Source: OXERA.

At the congested airport, demand is greater than the capacity of the airport (as shown in Figure 2.2). Consequently demand and supply intersect on the vertical portion of the supply curve. The result is that the imposition of a tax/allowance trading scheme has no effect on the price charged by airlines, which remains at p_0, both before and after. Since there is no price change, there is also no change in the quantity, which remains equal to $q_{airport}$ both before and after.

This analysis suggests that, at uncongested airports, airlines will pass through 100% of the increase in marginal costs from the imposition of a tax or emissions trading regime to the ticket prices that they charge passengers. However, at congested airports, this analysis suggests that the airlines will already be pricing at a level to constrain demand to be equal to the available capacity, and so the cost of allowances will only reduce profit margins.

2.3 Supply-side abatement options

Airlines can avoid paying the allowance price by reducing emissions. In this section, incentives for abatement are discussed in the context of the above differentiation between congested and uncongested airports.

In an emissions trading scheme, the incentive for emission reduction is provided by the allowance price. For airlines, the allowance price increases the fuel cost for each unit of fuel consumption. Hence, airlines could save money by implementing measures to improve fuel efficiency, which would cost less per unit of emissions saved than the allowance price.

The incentive given by the allowance price may be no different for flights to and from congested airports than for flights to and from uncongested airports, although the pressure to minimise cost comes in a different form.

- As shown in section 2.2, flights to and from congested airports are priced on the basis of the demand clearance method. As a consequence, the allowance cost makes no difference to the ticket price, or to demand. This implies that the full compliance cost is borne by the airline, thereby reducing its profit margins. Thus, the incentive to minimise compliance costs comes directly from the aim to maximise profit margins by keeping costs down.

- The allowance cost for flights between uncongested airports would be passed through to passengers, in part or in full, in ticket prices, because tickets are more likely to be priced competitively on the basis of marginal costs. Thus, the allowance cost would lead to a higher ticket price and to lower demand. For flights between uncongested airports, it is the revenue loss that drives the cost minimisation by the airline. There may also be a drive to maintain market share by keeping costs, and hence prices, as low as possible.

In both cases, airlines have an incentive to exploit emission-abatement options, which are cheaper than the allowance price. This is irrespective of whether the airline has an allowance shortfall or excess. In the latter case, the airline could still make a gain by reducing emissions and selling the allowances.

A discussion of abatement options from a technological point of view is beyond the scope of this paper.[6] The abatement curve assumed in this paper is discussed below, in section 3.5.

[6] For an overview of abatement options, see Delft, C.E./EDE (2000), 'ESAPE: Economic Screening of Aircraft Preventing Emissions', August. Technological abatement options are also discussed in Delft, C.E. (2002), 'External Costs of Aviation', March, and RCEP (2002), 'The Environmental Effects of Civil Aircraft in Flight: Special Report'. A brief overview of emission-control options is provided in European Commission (1999), 'Communication from the Commission to the Council, the European Parliament, the Economic and Social Committee and the Committee of the Regions, Air Transport and the Environment: Towards Meeting the Challenges of Sustainable Development', COM (1999) 640 final.

3. Modelling Framework

To analyse the impact on airlines of bringing intra-EU flights within an emissions trading regime, an elasticities-based spreadsheet modelling framework was adopted. This takes into account the various effects that such a scheme would have, and compares the outcome with a system of charges for emissions. First, the basic architecture of the model is introduced. The parameters used in the model are then discussed in the subsequent sub-sections.

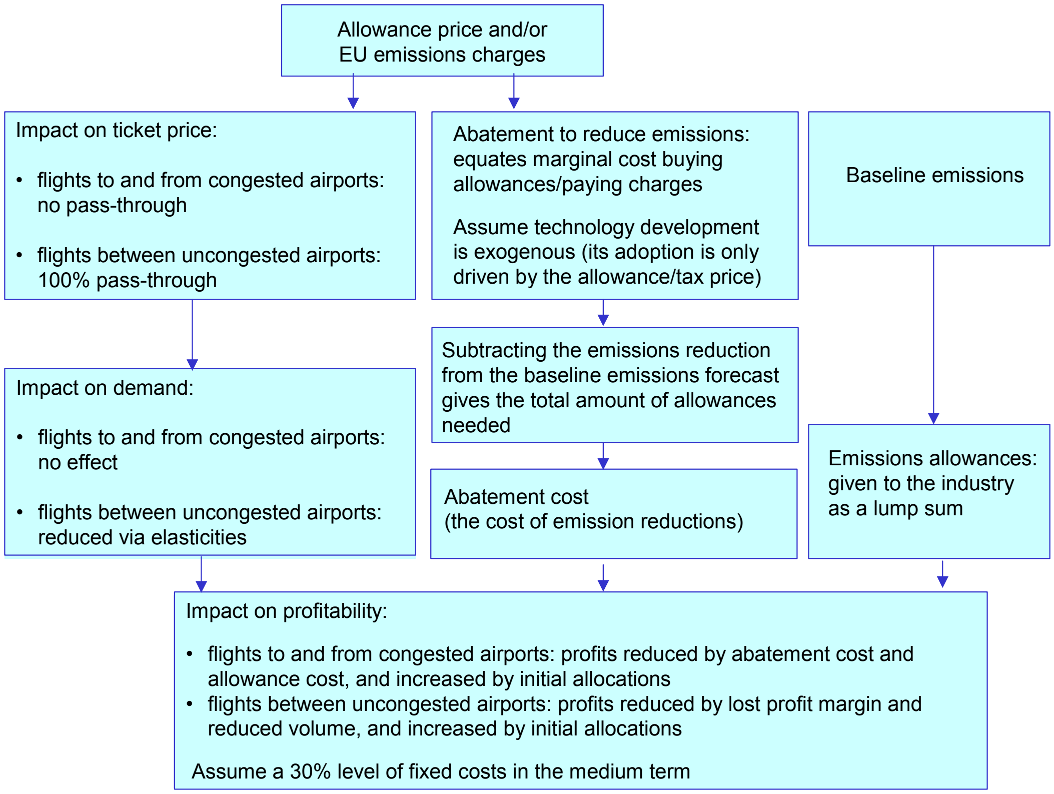
3.1 Model outline

The basic outline of the model is illustrated in Figure 3.1. It is a static, rather than a dynamic, model, which means that it does not explicitly take into account the path of emissions leading up to the 2008–12 period. As the outline shows, the emissions charges and allowance price are the main inputs into the model and drive most of the interactions that subsequently take place. These are set exogenously from the model—therefore, any outputs from the model do not feed back and change the allowance price or level of the emissions charge. It is assumed that the airline industry consists of a number of price-takers and does not influence the emission allowance price by changing its demand for, or supply of, allowances. A more extensive modelling exercise, including the main emissions-producing industries, would be required in order to model the industry's ability to influence prices.

The level of the emissions charge or allowance price affects airline costs, which consequently feeds through to ticket prices at uncongested airports, and reduces the margin being earned at congested airports. The increased prices at uncongested airports reduce passenger demand, and consequently reduce the profit earned by airlines at these airports. The magnitude of this impact is partly determined by the proportion of airlines' costs that are considered fixed. If all costs are fixed, the airlines cannot reduce costs in the face of reduced demand, resulting in a relatively large loss of profits. If all costs are variable, the airlines can reduce costs in proportion to the fall in demand, keeping their profit margin constant, but losing some absolute level of profit due to the reduction in the scale of the operation.

The allowance price or emissions charge also gives the airlines an incentive to abate their emissions. This is dealt with using an abatement curve based on data from Delft.[7] The abatement curve equates the marginal cost of abatement with the marginal cost of purchasing allowances or paying taxes to determine the level of abatement that the industry adopts, and how much this costs. The industry will abate to the point at which the marginal cost of abatement equals the allowance price/emissions charge per unit of emissions. Beyond that point, airlines will purchase more allowances/pay more charges rather than engage in more abatement.

Figure 3.1: Model structure



The baseline emissions forecasts used are those of the European statistical agency, Eurostat.[8] Eurostat uses forecasts from Eurocontrol of the likely level of aircraft movements during the study period and combines this with fuel consumption and emissions statistics to create its emissions forecasts.[9] These exogenous emissions forecasts are combined with the scenarios, which provide the quantity of allowances that the industry will be given within a trading regime to cover its allowed emissions.

The final output of the model is an estimate of the reduction in profits of the airlines. These reductions will primarily consist of the abatement cost and the cost of the net acquisition of allowances at congested airports. In addition, they will be due to a reduced quantity of passengers at uncongested airports—and at congested airports if costs are (partly) passed through. These costs will be offset against the value of the allowances given to the industry.

[7] Delft, C.E. (2002), 'Economic Incentives to Mitigate Greenhouse Emissions', July, commissioned by the European Commission, DG TREN.
[8] Eurostat (2003), 'Calculation of Indicators of Environmental Pressure Caused by Transport', May.
[9] Eurocontrol (2003), 'Forecast of Annual Number of IFR Flights (2003–2010)', STATFOR, **1**, section 3.4, February.

3.2 Congested and uncongested airports

As the model outline and the framework above make clear, a key feature of the model is the distinction drawn between congested and uncongested airports because of the difference in cost pass-through to the ticket price at these airports. Table 3.1 outlines the assumptions used in the modelling.

Table 3.1: Assumptions on cost pass-through at congested and uncongested airports

Airport class	Pass-through from costs to ticket price
Uncongested	100%
Congested	0%

Source: OXERA assumptions.

In order to examine the case in which OXERA's assumptions do not hold, and airlines pass through some of the cost increases into ticket prices, another scenario is developed in which airlines operating at congested airports pass through 100% of the increase in costs to ticket prices.

The difference in cost pass-through to the ticket price at congested and uncongested airports is an important factor in the analysis of the financial impact of emissions trading. Therefore, an estimate of the proportion of intra-EU demand that passes through congested airports is required. The evidence on this is divided, however. On the one hand, Eurocontrol argues in its medium-term forecast that only Heathrow Airport can be considered to be a congested airport in the 2008–12 scenario.[10] On the other hand, if the EU's slot coordination rules[11] are used to define which airports within the EU are congested, virtually all major airports are already congested, with more likely to become so by the 2008–12 period.

The situation becomes even less clear when projecting forward to 2050. One plausible argument is that there will only be a small increase in the provision of airport capacity over that period, perhaps due to complaints from local residents. This could result in an extremely high proportion of demand passing through congested airports. A second plausible argument is that, over such a long timeframe, supply will be substantially more elastic than over short periods, and hence it is plausible that only a small proportion of demand will pass through congested airports.

In the base-case scenario, a figure of 25% of demand passing through congested airports is used. This figure reflects that, although a proportion of air travel demand in Europe passes through congested airports, far from all of it does, particularly since the low-cost

[10] Eurocontrol (2003), 'Forecast of Annual Number of IFR Flights (2003–2010)', STATFOR, **1**, section 3.4, February.
[11] A congested airport needs to coordinate the allocation of its slots; therefore an airport that is classed by the EU as 'Fully Coordinated' is arguably a congested airport.

carriers (eg, Ryanair) have begun operating primarily from secondary and tertiary airports.

Table 3.2: Proportion of congested airports

Scenario	Proportion of congested airports
Base case	25%
Sensitivity analyses	15% and 35%

Source: OXERA assumptions.

3.3 Price elasticity of demand

In order to determine the impact on demand, and consequent reduction in flights, caused by an increase in price at uncongested airports, it is necessary to determine a value for the price elasticity of demand (PED).[12] The literature concerning transport demand offers a wide range of estimates for this value. Brons et al.[13] use meta-analysis of 37 studies carried out across the world. The aggregation of so many estimates allows the use of frequency analysis to select the mode of the distribution, which enables the selection of an elasticity estimate that is robust and broadly representative of air transport demand in Europe.

Table 3.3 presents three coefficients taken from this study. The first, representing business travel, uses estimates based on business-class travellers. The second and third figures, representing leisure travellers, and leisure travellers with a greater absolute PED, respectively, use estimates based on travellers not in business class. As shown in the table, there were two peaks in the distribution of non-business class travellers.

Table 3.3: Modal elasticity estimates from 37 studies

Demand type	Elasticity
Business	–0.8
Leisure—less elastic	–1.4
Leisure—more elastic	–1.6

Source: Brons et al. (2002), op. cit., Figures 3(a) and 3(b).

Table 3.3 shows that business-class travellers respond less to an increase in price than leisure travellers. The interpretation offered by the authors is that business travellers may attach a higher value to time than leisure travellers, and often do not pay for the flight themselves.

[12] The PED describes the sensitivity of demand to price increases. For example, if price were to rise by 1% and the PED were equal to –0.5, the quantity demanded would fall by 0.5%.
[13] Brons, M., Pels, E., Nijkamp, P., and Rietveld, P. (2002), 'Price Elasticities of Demand for Passenger Air Travel: A Meta-analysis', *Journal of Air Transport Management*, **8**, 165–75.

The Brons et al. analysis suggests that European demand is not significantly different from average world demand, as their European dummy was insignificant. The interpretation of this is that using a cross-section of estimates of elasticties from around the world should not have a significant effect on the estimate of the elasticity.

It is arguable that uncongested airports tend to cater to a more leisure-based market than congested airports. Thus, OXERA's modelling in this paper assumes that uncongested airports have a price elasticity of demand equal to –1.5. In the case where congested airports do pass through cost increases to consumers via higher prices, OXERA has assumed an elasticity of –0.8 to represent the higher proportion of business demand at these airports.[14] However, there is anecdotal evidence that suggests that a growing amount of business traffic is flowing through less congested airports (eg, Luton Airport), although this is not necessarily as inelastic as business travellers flying from congested airports (eg, Heathrow Airport).

The analysis in Brons et al. also suggests that passenger demand has become less elastic over time. This may be explained by incomes rising faster than the price of flights, implying that the cost of a flight becomes less significant as a proportion of income over time. Their estimates suggest that the absolute value has been falling by around 0.009 to 0.011 per annum since the 1970s.[15] If this straight-line trend is extrapolated forward to 2050, it implies an absolute reduction in the value of the price elasticity for business travel from –0.8 to –0.38, and for leisure travel from –1.5 to –0.98.[16] This assumption is compared with the elasticities used in the 2008–12 modelling to check the sensitivity of the results.

3.4 Emissions trading and taxation

Tradeable emissions allowances and taxes share many similarities, but differ in important respects. The marginal incentive on the airlines to abate emissions is the same under both systems. This means that, if an allowance trading scheme and taxation regime charged the same per unit of emissions, they would elicit the same abatement and reduction in emissions from the industry. The main differences between a tax and a trading scheme are:

- allowances are tradeable, allowing one firm or industry to purchase allowances from another;
- allowance trading sometimes comes with an initial allocation (a free allowance), which reduces the financial impact on the industry.

[14] This elasticity may not conflict with the notion of airlines at congested airports accruing rents, since they do not independently set the volume of traffic—this is set externally by the airport.
[15] Brons et al. (2002), op. cit., Table 3.
[16] These represent a change of 0.423 and 0.517 by 2050, respectively.

The remainder of this section describes the framework within which emissions trading and taxation are assumed to operate, and the levels at which each system is likely to impose a levy on emissions.

3.4.1 The framework of emissions trading and taxation

Two scenarios are presented regarding the balance between emissions trading and taxation.

Scenario B1 Airlines requires 1 allowance for each 1 tonne of CO_2 emitted, with an EU emissions charge used to address airline's residual climate change impact (the total impact being assumed to be either 2.5 times or 3 times that due to CO_2 alone).

Scenario B2 Airlines requires either 2.5 or 3 allowances for each 1 tonne of CO_2 emitted and there is no EU emissions charge.

In addition to these, a third scenario is modelled, which can be considered to be the counterfactual of no emissions trading.

Scenario B3 Airlines do not participate in an emissions trading regime. Instead it is subject to an EU emissions charge that is equal to 2.5 times or 3 times the impact due to CO_2 emissions alone.

In the modelling, it is assumed that the emissions trading and taxation are applied at the same point in time—ie, they are effective throughout the period 2008–2012. This assumption is made so that the impact of the policy instruments can be viewed in isolation, without having the impact of different introduction dates complicating the results.

Two key assumptions for this part of the modelling are that:

- aviation is brought within the mandatory, open, cap-and-trade, EU emissions trading system, within the wider context of the Kyoto Protocol; and
- only flights within the EU are brought within the EU ETS.

It is assumed that, within the allowance trading regime, individual airlines, and the airline industry as a whole, are price-takers. That is to say that they are not large enough to affect the price of the allowances being traded in the market. This allows the allowance price to be set exogenously from the model. It also implies that the amount of allowances that the airline industry demands has no effect on the price of those allowances, so they remain constant within each scenario. Thus, each allowance purchased costs the same.

Similarly, the EU emissions charge is assumed to be levied at the same rate on every unit of emissions. It is not assumed to change as the absolute level of emissions changes.

Three scenarios regarding the quantity of emissions allowances that would be provided are used.

Scenario A1 A 25% reduction in emissions by 2008–12 against a 1990 baseline, plus 40%, equal to a growth of 5% on 1990 emissions.

Scenario A2 An 8% reduction in emissions by 2008–12 against a 1990 baseline;

Scenario A3 A 60% reduction in emissions by 2050 against a 1990 baseline.

3.4.2 The allowance price and the level of taxation

The key distinction between allowance trading and taxation is that the price of an allowance is set by the market forces of demand and supply, while the level of taxation is likely to be set with reference to the estimated external damage costs caused. Each area is examined below.

The allowance price

Since the EU emissions trading market does not yet exist, it is difficult to determine what the equilibrium price is likely to be. However, there is evidence from brokers regarding the current offer and bid prices. These are in the range of €5–€7/tCO_2. Estimates from energy market models forecast higher prices, of €15–€30/tCO_2.

Factors underlying the European emission allowance price include:

- underlying growth in emissions versus the cap;
- abatement options within the trading sectors;
- abatement options from outside the trading sectors through project-based mechanisms.

The third factor is particularly important from the perspective of opening up the EU ETS to emission reductions from installations and countries outside of the scheme. The amendment to the Greenhouse Gas Emissions Trading Directive setting out the rules for such links is due to be proposed by the European Commission. If implemented, these project-based credits are expected to drive the allowance price down. Evidence from the Dutch Emission Reduction Unit Tenders (ERUPT) shows that many projects are available at a price of €3–€5/tCO_2 in central and eastern Europe.[17] Credits from overseas are priced higher because of higher transaction and project implementation costs.

In January 2003, Hultman and Kammen, of the University of California at Berkeley, presented a paper at the International Conference on Natural Assets summarising model estimates for, and recent experience with, CO_2 allowance prices.[18] A selection of the results is shown in Table 3.4.

[17] ERUPT is an instrument used by the Dutch government to purchase CO_2 reductions through investments in Central and Eastern Europe. See www.senter.nl for more details.

[18] Hultman, N.E., and Kammen, D.M. (2003), 'Equitable Carbon Revenue Distribution Under an International Emissions Trading Regime', paper prepared for the International Conference on Natural Assets, Philippines, January.

Table 3.4: Estimates of the price of CO_2 emissions allowances (€ per tonne)

Estimate type	Low	Medium	High
Modelling	3–10	4–17	25–31
Recent experience	0.5–1.7	2–4.6	5.1–10.3

Note: These figures were originally quoted in US$, and have been converted at a rate of $1 = €0.9 for the lower figure in each pair (the approximate rate in May 2003), and $1 = €1.1 for the higher figure in each pair (the approximate rate in May 2002).
Source: Hultman and Kammen (2003), p. 8.

The modelling estimates modelled carbon trading on a global scale, including US participation. Therefore, these prices 'most likely represent an upper limit on the prices likely in an ex-U.S. carbon market'.[19] The 'recent experience' includes trading that has taken place in the UK and the Netherlands. The market has tended to be 'disjoint, illiquid, and opaque',[20] so these estimates should be treated with some caution. Overall, the modelling estimates suggest slightly higher allowance prices than the recent experience.

Table 3.5 shows the assumptions used in the modelling for the allowance price. These are based on the estimates given in Table 3.4. The allowance price is assumed to be the per-unit price, which means that if the total damage costs of CO_2 are assumed to be 3 times those caused by CO_2 alone, in the full trading scenario (scenario B2) three permits are required for every 1 tonne of CO_2 to be emitted—the effective price to airlines of emitting 1 tonne of CO_2 in this scenario would be 3 times the figures shown in Table 3.5.

Table 3.5: Assumptions used in the modelling—CO_2 allowance price

	Low	Medium	High
Allowance price (€/tCO_2e)	5	10	20

Source: OXERA assumptions.

The model takes the allowance price as an exogenous input. Therefore, demand and supply of allowances within the model do not affect the price of those allowances. It is more realistic to model the allowance price as endogenous, but this would require detailed estimates of the likely demand from other industries that would be involved in the allowance trading scheme. This assumption also means that the number of allowances granted to the airline industry does not affect the price of those allowances.

Level of taxation

There have been many estimates for the external damage costs of CO_2 emissions; a selection of these is outlined in Table 3.6, which shows that there remains considerable uncertainty about the damage caused by the emission of CO_2 into the atmosphere.

[19] Ibid, p. 7.
[20] Ibid, p. 8.

Table 3.6: Estimates of the shadow price of CO_2 emissions (€ per tonne)

Source	Low	Medium	High
Defra and HM Treasury (2002)[1, 2]	13.4–15.3	26.7–30.5	53.5–61.0
Delft (2002*a*)	2–8	14–37	47–104
Delft (2002*b*) (assumptions)	10	30	50
Pearce et al. (1999)[1]	18–20	–	62–70
Pearce (2003)[1, 3]	1.4–1.8	–	9.6–11.7

Notes: [1] This study quotes values for the social cost of carbon, rather than the social cost of CO_2. A conversion factor of 3.67 is used to adjust these figures into cost per tonne of CO_2. [2] These figures were originally quoted in £ sterling, and have been converted to € using a higher and a lower rate, hence the range for these figures. The larger figure uses £1 = €1.6 (the approximate rate in May 2002); the lower figure uses £1 = €1.4 (the approximate rate in May 2003). [3] These figures were originally quoted in US $, and have been converted at a rate of $1 = €0.9 for the lower figure (the approximate rate in May 2003) and $1 = €1.1 for the higher figure (the approximate rate in May 2002).
Sources: Defra and HM Treasury (2002), 'Estimating the Social Cost of Carbon', January. Delft, C.E. (2002a), 'External Costs of Aviation', March. Delft, C.E. (2002*b*), 'Economic Incentives to Mitigate Greenhouse Gas Emissions from Air Transport in Europe', July. Pearce, D.W. et al. (1999), 'Life Cycle Research Programme for Waste Management: Damage Cost Estimation for Impact Assessment', Economics for the Environment Consultancy, London. Pearce, D.W. (2003) 'The Social Cost of Carbon and its Policy Implications', *Oxford Review of Economic Policy*, Autumn.

In a recent working paper from the University of Hamburg, Tol examines 88 estimates of the cost of CO_2 emissions, and is perhaps the largest and most recent study of its kind. Tol concludes that if 'we take all studies without discriminating between them, the best guess for the marginal costs of carbon dioxide emissions is $5/tC', which equates to around €1.4 per 1 tonne of CO_2 emitted.[21] The paper highlights that estimates vary considerably, with some studies producing estimates in the hundreds of euros, while others produce estimates close to zero. However, Tol believes that:

> One can therefore safely say that, for all practical purposes, climate change impacts may be very uncertain but is unlikely that the marginal costs of carbon dioxide emissions exceed $50/tC [around €14 per 1 tonne of CO_2] and are likely to be substantially smaller than that.

The total climate change impact is considered to be either 2.5 or 3 times that of the impact caused by CO_2 alone. Thus, under scenario B1, the EU emissions charge can be considered to be equal to 1.5 times and 2 times the value of the estimated damage done by CO_2 alone. Under scenario B3, the EU emissions charge can be considered to be equal to 2.5 times and 3 times the value of the estimated damage caused by CO_2 alone. The assumptions in terms of price per CO_2 equivalent are outlined in Table 3.7.

[21] Tol, R.S.J (2003), 'The Marginal Costs of Carbon Dioxide Emissions: An Assessment of the Uncertainties', University of Hamburg, Working Paper FNU-19, section 6.

Table 3.7: Assumptions used in modelling—EU emissions charge

	Low	Medium	High
Charge (€/tCO_2e)	5	10	20

Note: These figures are based on the assumptions that the damage caused by the emission on one unit of carbon is equal to €5, €20, and €50 for the low, medium and high scenarios respectively.
Source: OXERA assumptions.

The figures in Table 3.7 are low compared with several of the estimates shown in Table 3.6, however evidence from recent work such as Tol (2003) suggests these estimates may be too high. A Defra seminar held on July 7th 2003 also suggested that the higher values may be less plausible than previously thought.[22]

3.5 Abatement cost curve

The abatement schedule describes the quantity of emissions that will be abated at a particular marginal cost. As the marginal cost rises, he quantity of emissions that will be abated also rises. Within the model, the allowance price, which is set exogenously, acts as the marginal price of not abating, since this is the price that the airline must pay in order to emit a unit of emissions. The industry will abate emissions up to the point at which the marginal cost of abatement equals the marginal price of emissions. Beyond that point the industry will prefer to purchase allowances or pay charges, as this is cheaper than further abatement.

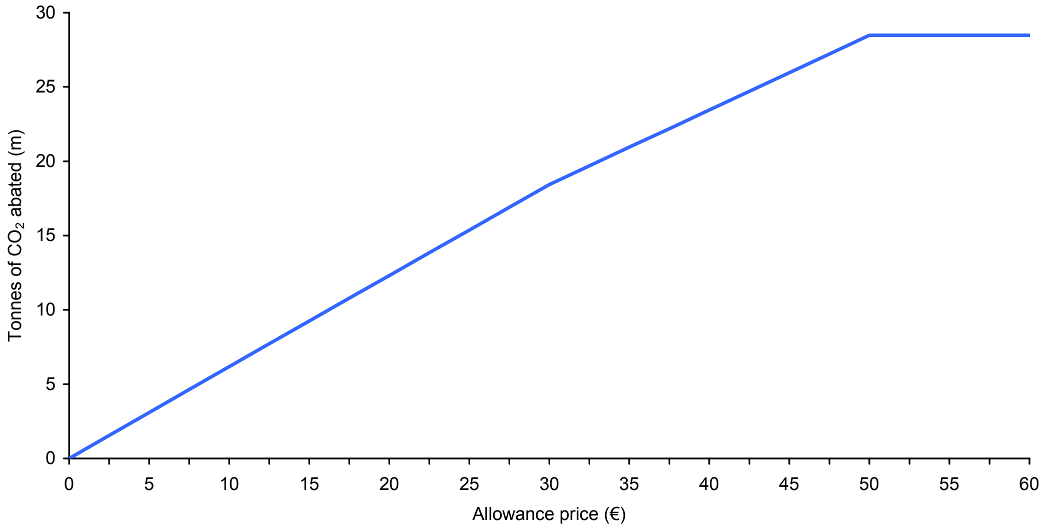
The abatement schedule used in the model is derived from information contained in Delft (2002).[23] This report considered several technologies which are currently available to the airline industry, and some that are in development. These include:

- fixing wingtip devices, which reduce drag by reducing wingtip vortices;
- covering planes with riblets, which improve the laminar flow characteristics consequently reducing drag;
- re-routing of aircraft to reduce fuel consumption;
- re-organising network operations (eg, changing flight frequency); and,
- accelerated renewal of the aircraft fleet.

The abatement schedule is presented in Figure 3.2. The X axis shows the allowance price (€/tCO_2); and the Y axis the CO_2 emission reduction expected at the given allowance price.

[22] Defra (2003), 'An International Seminar on the Social Cost of Carbon', July 7th.
[23] Delft, C.E. (2002), 'Economic Incentives to Mitigate Greenhouse Gas Emissions from Air Transport in Europe', July.

Figure 3.2: Abatement schedule



Source: Delft, C.E. (2002), 'Economic Incentives to Mitigate Greenhouse Gas Emissions from Air Transport in Europe', July, and OXERA calculations.

3.6 Emissions forecasts and allowance allocation

Eurostat's emissions forecasts for the EU have been used to form the baseline level of emissions that are expected under each of the scenarios.[24] The Eurostat data indicates that CO_2 emissions in 1990 were around 145Mt per annum, and are expected to rise to around 245Mt by 2010. These forecasts do not cover the 2050 scenario, however, so they have been extrapolated forward for the modelling in this paper. The assumptions used for doing this are detailed below.

Under an emissions trading scheme, the airlines receives a lump-sum transfer of emissions allowances from the trading authority each year. Table 3.8 shows the levels of emissions allowances that are granted under the scenarios A1 and A2, and the assumed baseline emissions for 2010.

[24] Eurostat (2003), 'Calculation of Indicators of Environmental Pressure Caused by Transport', May.

Table 3.8: Emissions and emissions allowances

	2010 emissions (Mt per annum)	Growth from 1990 levels (%)
Baseline emissions	245	69
Allowances allocated under scenario A1[1]	152	5
Allowances allocated under scenario A2[2]	133	–8

Notes: [1] A 25% reduction in emissions against 40% growth from 1990 levels. [2] An 8% reduction in emissions against 1990 levels.
Sources: Eurostat (2003), 'Calculation of Indicators of Environmental Pressure Caused by Transport', May, and OXERA calculations.

In the partial trading and partial taxation scenario (B1), a single allowance is provided for the initial emissions allocations set out in Table 3.8. In the full trading scenario (B2), the initial allocation of allowances is assumed to be equal to 2.5 or 3 times the figures shown in Table 3.8. This assumption is made because it is arguable that the initial allocation should allow the airlines to emit the number of tonnes of CO_2 specified without incurring further charges or having to purchase further allowances. If, in the full trading scenario, the initial allocation is simply equal to the figures shown in Table 3.8 (and hence, the same number as in the partial trading and partial taxation scenario), this scenario will produce the same financial impact as the partial trading and partial taxation scenario, because OXERA has assumed that the allowance price and emissions charge prices are equal.

An estimate of the baseline emissions from intra-EU aviation in 2050 has been achieved by extrapolating the trend in emissions from the Eurostat forecasts forward to 2050 using an annual growth rate of 2.67%, the average of the last ten years, and applying a 0.5% fuel efficiency saving per annum. The result of this, together with the emissions cap for scenario A3, is shown in Table 3.9.

Table 3.9: Emissions and emissions allowances

	2050 emissions (Mt per annum)	Growth from 1990 levels (%)
Baseline emissions	567	291
Emissions allowable under scenario A3[1]	133	–60

Notes: [1] A 60% reduction in emissions against a 1990 baseline by 2050.
Sources: Extrapolated from Eurostat (2003), 'Calculation of Indicators of Environmental Pressure Caused by Transport', May, and OXERA calculations.

Allowances can be given to an industry in two ways. First, they can be grandfathered to those companies that currently emit these pollutants at no cost. Alternatively, allowances can be auctioned. If the allowances are auctioned then it is likely that the auction price will be equal to the price on the secondary trading market. The auction is unlikely to result in a price greater than the market price, since participants in the auction can purchase allowances in the secondary market instead. The auction is unlikely to achieve a price lower than the allowance price in the secondary market because it would be profitable for companies to arbitrage between the two markets if such a wedge existed.

4. Emissions Trading Relative to Alternatives: 2008–12 Scenarios

The results from the modelling are presented in the sub-sections below. The tables and figures in this section illustrate the estimated *annual* financial impact on the airlines caused by the introduction of EU emissions charges and/or an allowance trading scheme, in 2003 euros. The figures shown represent costs to the industry (therefore, negative figures represent gains to the industry).

A summary of the scenario references is shown below to aid navigation of the results.

Table 4.1: Summary of scenario numbers

Scenario	Scenario type	Description
A1	Emissions allowance	A 25% reduction in emissions by 2008–10 against a 1990 baseline plus 40%, equal to a growth of 5% on 1990 emissions
A2	Emissions allowance	An 8% reduction in emissions by 2008–10 against a 1990 baseline
B1	Trading and taxation	Airlines requires 1 allowance for each 1 tonne of CO_2 emitted, with an EU emissions charge used to address airline's residual climate change impact (the total impact being assumed to be either 2.5 times or 3 times that due to CO_2 alone)
B2	Trading and taxation	Airlines requires either 2.5 or 3 allowances for each 1 tonne of CO_2 emitted and there is no EU emissions charge
B3	Trading and taxation	Airlines do not participate in an emissions trading regime. Instead it is subject to an EU emissions charge that is equal to 2.5 times or 3 times the impact due to CO_2 emissions alone

4.1 Financial impact

This section presents four tables (4.2 to 4.5) showing the total financial impact on the airlines under the baseline assumptions in scenarios A1 and A2 with the total damage caused by emissions of CO_2 equal to 2.5 and 3 times the damage caused by CO_2 alone. The baseline assumptions used in the tables are that airlines have 30% fixed costs; that 25% of demand passes through congested airports; that there is no pass-through to fares at congested airports; and that the total cost of emitting 1 tonne of CO_2 (the sum of EU emissions charges and allowance prices) is equal to €30 in the 3-times damage case, and €25 in the 2.5-times damage case.

Four figures (4.1 to 4.4) show the sensitivity of the results to changes in the allowance price and level of the EU emissions charge. They show:

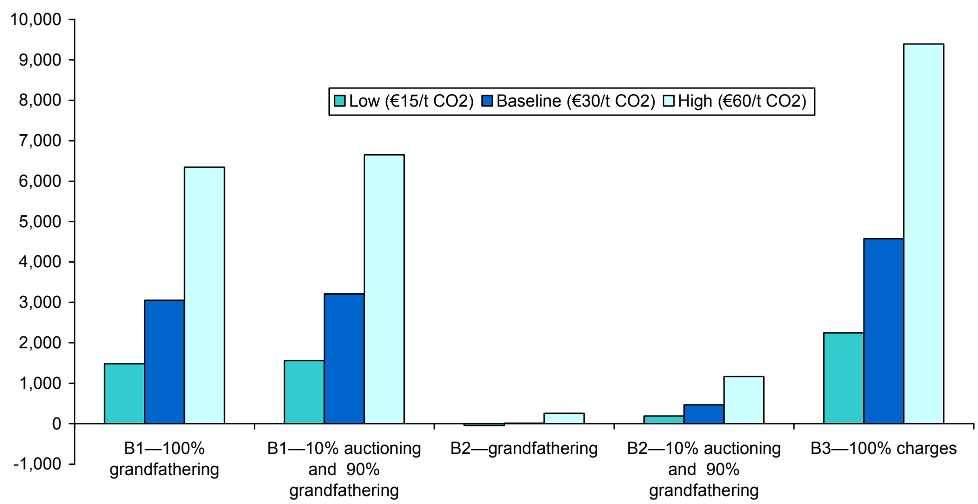
- *a low scenario*—the total cost of emitting 1 tonne of CO_2 equals €15 for 3 times the damage, and €12.5 for 2.5 times the damage;
- *the baseline scenario*—the total cost of emitting 1 tonne of CO_2 is equal to €30 in the 3-times damage case, and €25 in the 2.5-times damage case; and
- *a high scenario*—the total cost of emitting 1 tonne of CO_2 equals €60 for 3 times the damage, and €50 for 2.5 times the damage.

Table 4.2: Baseline impact in scenario A1 assuming that total damage is 3 times that due to CO_2 alone (€m per annum)

	Partial trading and partial taxation		Full trading		Full taxation
Scenario	**B1**[1]	**B1**[1]	**B2**[2]	**B2**[2]	**B3**[3]
Allowance arrangement	Grandfathering	10% auctioning and 90% grandfathering	Grandfathering	10% auctioning and 90% grandfathering	None: 100% charges
Congested airports	1,778	1,778	1,778	1,778	1,778
Uncongested airports	2,682	2,682	2,682	2,682	2,682
Abatement	119	119	119	119	119
Allowances	–1,523	–1,370	–4,568	–4,111	0
Overall impact	**3,056**	**3,208**	**11**	**468**	**4,579**

Notes: Assumes 30% fixed costs, 25% of demand passing through congested airports, no pass-through to fares at congested airports. [1] €10 allowance price, €20 emissions charge per tonne of CO_2 emissions; [2] €30 allowance price per tonne of CO_2 emissions; [3] €30 emissions charge per tonne of CO_2 emissions.
Source: OXERA modelling.

Figure 4.1: Total financial impact with different allowance prices and EU charge levels in scenario A1 assuming that total damage is 3 times that due to CO_2 alone (€m per annum)



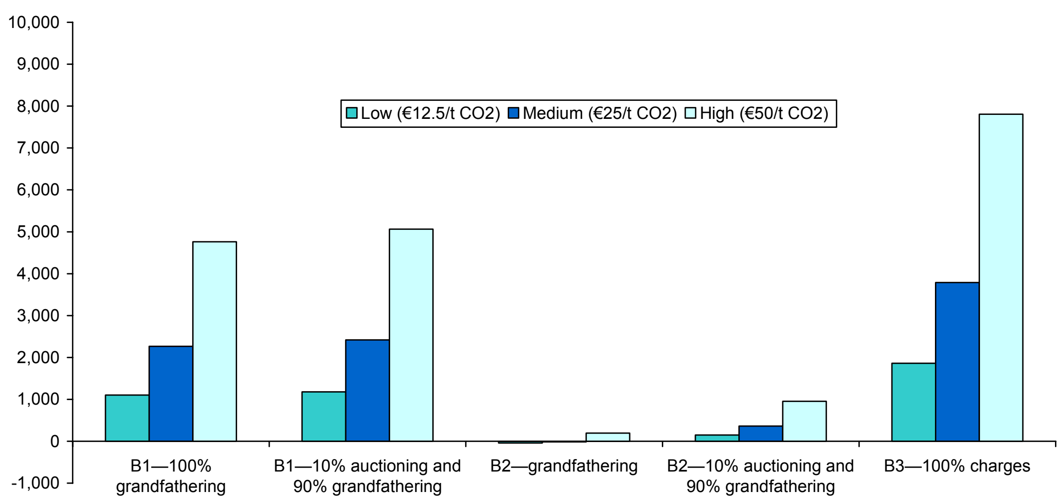
Note: Figures in parentheses refer to the marginal price (sum of allowances and charges) paid to emit 1 tonne of CO_2.
Source: OXERA modelling.

Table 4.3: Baseline impact in scenario A1 assuming that total damage is 2.5 times that due to CO_2 alone (€m per annum)

	Partial trading and partial taxation		Full trading		Full taxation
Scenario	**B1**[1]	**B1**[1]	**B2**[2]	**B2**[2]	**B3**[3]
Allowance arrangement	Grandfathering	10% auctioning and 90% grandfathering	Grandfathering	10% auctioning and 90% grandfathering	None: 100% charges
Congested airports	1,490	1,490	1,490	1,490	1,490
Uncongested airports	2,218	2,218	2,218	2,218	2,218
Abatement	83	83	83	83	83
Allowances	–1,523	–1,370	–3,806	–3,426	0
Overall impact	2,268	2,420	–16	365	3,790

Notes: Assumes 30% fixed costs, 25% of demand passing through congested airports, and no pass-through to fares at congested airports. [1] €10 allowance price, €15 emissions charge per tonne of CO_2 emissions. [2] €25 allowance price per tonne of CO_2 emissions. [3] €25 emissions charge per tonne of CO_2 emissions.
Source: OXERA modelling.

Figure 4.2: Total financial impact with different allowance prices and EU charge levels in scenario A1 assuming that total damage is 2.5 times that due to CO_2 alone (€m per annum)



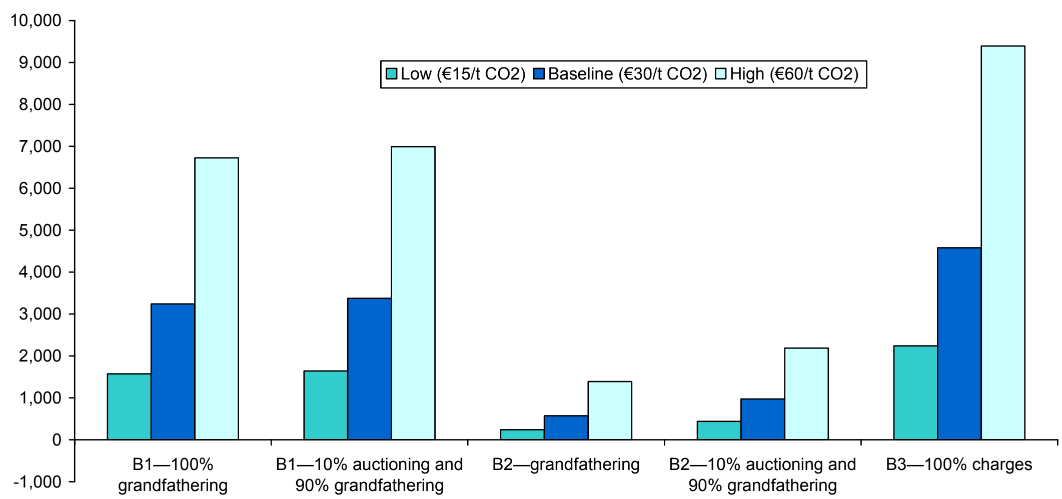
Note: Figures in parentheses refer to the marginal price (sum of allowances and charges) paid to emit 1 tonne of CO_2.
Source: OXERA modelling.

Table 4.4: Baseline impact in scenario A2 assuming that total damage is 3 times that due to CO_2 alone (€m per annum)

	Partial trading and partial taxation		Full trading		Full taxation
Scenario	**B1**[1]	**B1**[1]	**B2**[2]	**B2**[2]	**B3**[3]
Allowance arrangement	Grandfathering	10% auctioning and 90% grandfathering	Grandfathering	10% auctioning and 90% grandfathering	None: 100% charges
Congested airports	1,778	1,778	1,778	1,778	1,778
Uncongested airports	2,682	2,682	2,682	2,682	2,682
Abatement	119	119	119	119	119
Allowances	–1,334	–1,201	–4,002	–3,602	0
Overall impact	3,245	3,378	577	977	4,579

Notes: Assumes 30% fixed costs, 25% of demand passing through congested airports, no pass-through to fares at congested airports. [1] €10 allowance price, €20 emissions charge per tonne of CO_2 emissions. [2] €30 allowance price per tonne of CO_2 emissions. [3] €30 emissions charge per tonne of CO_2 emissions.
Source: OXERA modelling.

Figure 4.3: Total financial impact with different allowance prices and EU charge levels in scenario A2 assuming that total damage is 3 times that due to CO_2 alone (€m per annum)



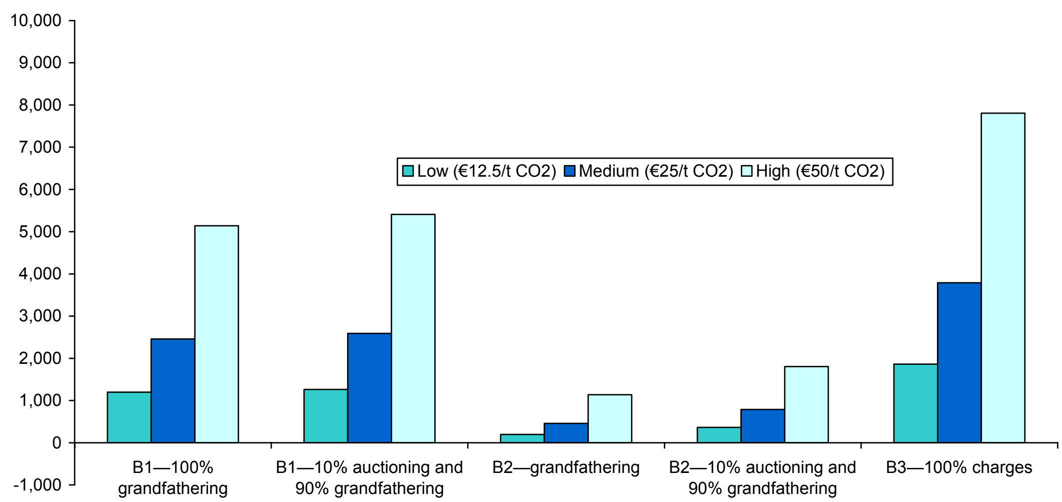
Note: Figures in parentheses refer to the marginal price (sum of allowances and charges) paid to emit a tonne of CO_2.
Source: OXERA modelling.

Table 4.5: Baseline impact in scenario A2 assuming that total damage is 2.5 times that due to CO_2 alone (€m per annum)

	Partial trading and partial taxation		Full trading		Full taxation
Scenario	**B1**[1]	**B1**[1]	**B2**[2]	**B2**[2]	**B3**[3]
Allowance arrangement	Grandfathering	10% auctioning and 90% grandfathering	Grandfathering	10% auctioning and 90% grandfathering	None: 100% charges
Congested airports	1,490	1,490	1,490	1,490	1,490
Uncongested airports	2,218	2,218	2,218	2,218	2,218
Abatement	83	83	83	83	83
Allowances	–1,334	–1,201	–3,335	–3,002	0
Overall impact	2,456	2,590	455	789	3,790

Notes: Assumes 30% fixed costs, 25% of demand passing through congested airports, and no pass-through to fares at congested airports. [1] €10 allowance price, €15 emissions charge per tonne of CO_2 emissions. [2] €25 allowance price per tonne of CO_2 emissions. [3] €25 emissions charge per tonne of CO_2 emissions.
Source: OXERA modelling.

Figure 4.4: Total financial impact with different allowance prices and EU charge levels in scenario A2 assuming that total damage is 2.5 times that due to CO_2 alone (€m per annum)



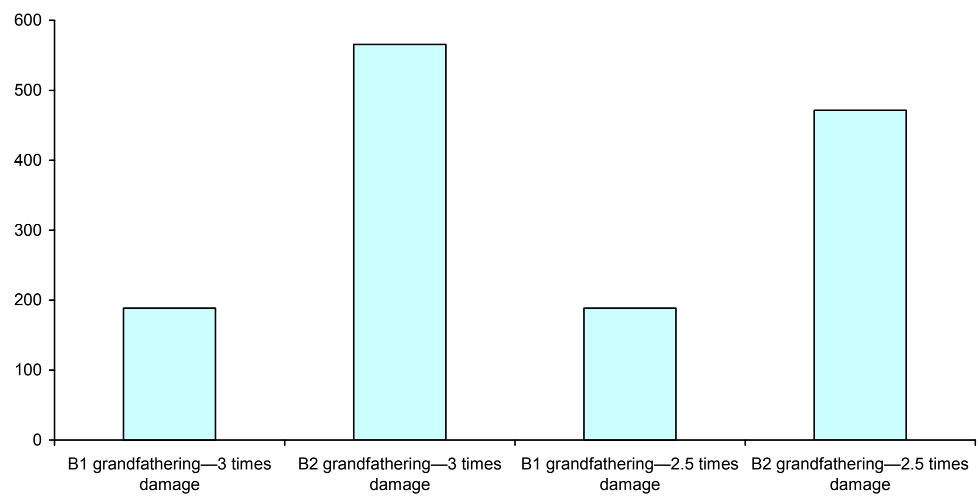
Note: Figures in parentheses refer to the marginal price (sum of allowances and charges) paid to emit 1 tonne of CO_2.
Source: OXERA modelling.

The impact at congested and uncongested airports, and the costs due to abatement, do not vary within each table (4.2 to 4.5). This is because all of the variables that affect these results are the same under each of the trading and taxation scenarios (B1, B2, and B3). These scenarios assume that the price of allowances and the level for the tax are the same. Substituting between these, therefore, has no effect on the marginal incentives faced by the industry, and the actions taken with regard to changing ticket prices and abatement will remain the same. Consequently, the total financial impact only differs between the scenarios within each table due to the changing value of the allowances granted to the industry—the more allowances, the smaller the total impact. This result means that scenarios that include allowances have a significantly smaller financial impact on the industry than those that do not. Scenario B2 with 100% allowance trading and full grandfathering of allowances has the smallest financial impact on the airlines, while scenario B3 with 100% EU charges has the largest financial impact.

The total financial impact on the industry is greater when the damage caused by CO_2 is assumed to be 3 times that done by CO_2 emissions alone, than when the damage is assumed to be 2.5 times that done by CO_2 alone.

The total impact on the industry varies considerably as the allowance price and the value of the emissions charge are changed. However, as long as the allowance price and EU emissions charge are kept equal to one another, changing the level of these does not alter the relative impact of the B scenarios on the industry—scenario B2 with grandfathering always has the smallest impact, and B3 always has the largest impact.

Figure 4.5: The difference in financial impact on the industry between scenarios A1 and A2 (€m per annum)



Source: OXERA modelling.

Figure 4.5 shows the difference in financial impact between scenarios A1 and A2—scenario A1 has a smaller impact because it provides a larger initial allocation. There is no difference between the full EU emissions charging scenarios under A1 or A2 since the impacts do not depend on the size of the initial allocation.

Table 4.6 provides a summary of the impacts of changing a selection of the other assumptions made in the modelling.

Table 4.6: Impact of changing the assumptions

Variable	Relationship with total financial impact on the industry	Comment
Proportion of congested airports	Positive: as this rises, the impact rises	The greater the proportion of uncongested airports, the more of the charge that can passed through to consumers via higher prices, and the less that is taken away from the supernormal profits generated at congested airports
Proportion of costs that are fixed	Positive: as this rises, the impact rises	The proportion of fixed costs affects the extent to which airlines can offset the impact of charges
Whether airlines can pass through costs at congested airports	Yes: reduced impact	Passing costs through to consumers reduces the impact on the industry
The quantity of allowances given freely	Negative: as the quantity rises, the impact falls	Allowances are a lump -sum transfer to the industry, which offsets the costs of acquiring allowances or spending on abatement strategies
The proportion of allowances that are auctioned	Positive: as this rises, the impact rises	The more allowances that have to be purchased at auction, the lower the value of the lump-sum transfer of the allowances to the industry
Price elasticities of demand	Positive: as this rises, the impact rises	A more elastic demand response to increases in price means that passing costs through to consumers has a greater impact on profitability than a less elastic demand
Allowance price and EU emissions charge	Positive: as this rises, the impact rises	A higher charge per unit of emissions increases the charges that must be paid at congested airports and the profit loss incurred at uncongested airports
Baseline emissions	Positive: as this rises, the impact rises	If technical progress is slower than predicted by Eurostat, more allowances will be required. If progress is faster then fewer allowances will be required

Source: OXERA analysis.

Table 4.7 quantifies some of these sensitivities. It shows the impact on the A1 base-case scenario, assuming that total damage caused by CO_2 emissions equals 3 times that caused by CO_2 alone, and a allowance price/EU charge price of €30 per tonne.

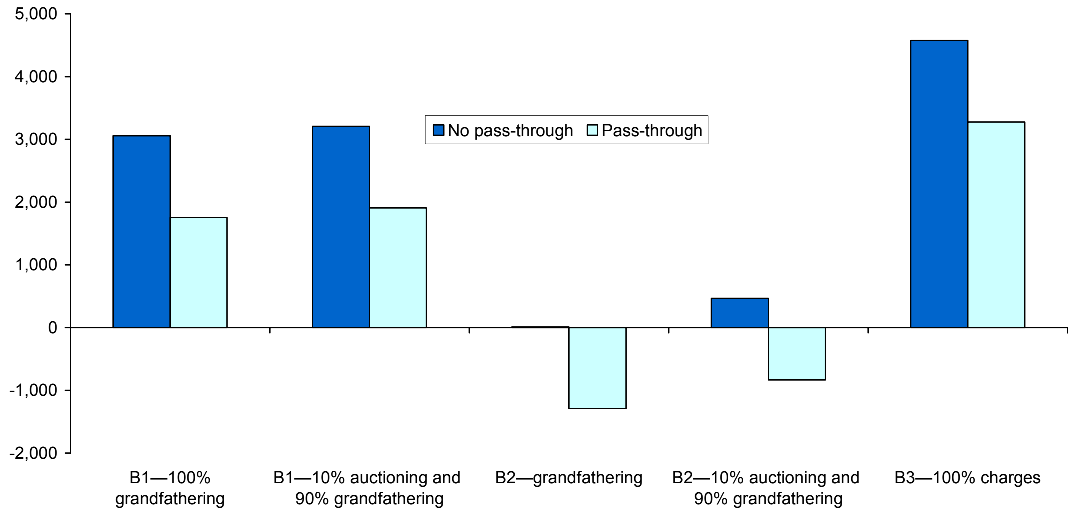
Table 4.7: Sensitivity analyses of the total financial impact on the basis of scenario A1 with 3 times damage cost (€m per annum)

Variable	Baseline assumption	Lower assumption	Change in overall financial impact—lower assumption[1]	Higher assumption	Change in overall financial impact—higher assumption
Proportion of congested airports (%)	25	15	–354	35	354
Proportion of costs that are fixed (%)	30	20	–837	40	837
Whether airlines can pass through costs at congested airports	No	Yes	–1,301	n/a	n/a
The proportion of allowances that are auctioned (%)	0	n/a	n/a	10	457
Price elasticities of demand (uncongested airports))	1.5	1.0	–894	2.0	894
Profit margin (%)	2.1	1.1	–57	3.1	56
Baseline emissions (m tonnes/annum)	245	220	–193	270	193

Notes: [1] A negative number indicates that the industry is better off than under the baseline scenario. Results are based on the A1 scenario with total damage caused by CO_2 equal to 3 times that caused by CO_2 alone. The allowance price/EU emissions charge was set equal to €30 per tonne of CO_2 emitted.
Source: OXERA modelling.

As Table 4.7 shows, the assumption about whether airlines can pass through costs at congested airports has a significant impact on the results—if they can pass through costs then the financial impact on the industry is reduced considerably. Perhaps the least sensitive assumption is the assumed profit margin for the airlines.

Figure 4.6: Comparing scenario A1 with no pass-through to passengers' ticket prices at congested airports with scenario A1 with pass-through to passenger ticket prices at congested airports (€m per annum)



Source: OXERA modelling.

Figure 4.6 shows that, were the cost increases caused by the imposition of allowance trading or EU emissions charges to be passed through to passenger ticket prices at congested airports, the total financial impact on the industry would be considerably reduced. In scenario B2 the industry actually makes a significant net gain. This occurs because the airlines can pass through most of the impact to customers and reduce the size of their operations, but they receive the lump-sum transfer of allowances.

Tables 4.8 and 4.9 adopt HM Treasury's current guideline value for the cost of carbon, which is £70tC, uprated at £1t/C per annum in real terms from 2000.[25] This equates to approximately €30 per tonne of CO_2 emissions.[26] These scenarios have been run in order to provide a comparison as close as possible to the UK government estimates for the damage caused by airline emissions.

[25] Defra and HM Treasury (2002), 'Estimating the Social Cost of Carbon Emissions', January.
[26] A conversion factor of 3.67 converts from t/C emissions to t/CO_2 emissions, and a £1 = €1.5 exchange rate is used.

Table 4.8: Impact in scenario A1 adopting HM Treasury cost of carbon, and assuming that total damage is 3 times that due to CO_2 alone (€m per annum)

	Partial trading and partial taxation		Full trading		Full taxation
Scenario	**B1**[1]	**B1**[1]	**B2**[2]	**B2**[2]	**B3**[3]
Allowance arrangement	Grandfathering	10% auctioning and 90% grandfathering	Grandfathering	10% auctioning and 90% grandfathering	None: 100% charges
Congested airports	5,236	5,236	5,236	5,236	5,236
Uncongested airports	8,780	8,780	8,780	8,780	8,780
Abatement	293	293	293	293	293
Allowances	–9,135	–8,222	–13,703	–12,332	0
Overall impact	5,173	6,087	606	1,976	14,308

Notes: Assumes 30% fixed costs, 25% of demand passing through congested airports, and no pass-through to fares at congested airports. [1] €30 allowance price, €60 emissions charge per tonne of CO_2 emissions. [2] €90 allowance price per tonne of CO_2 emissions. [3] €90 emissions charge per tonne of CO_2 emissions.
Source: OXERA modelling.

Table 4.9: Impact in scenario A2 adopting HM Treasury cost of carbon, and assuming that total damage is 3 times that due to CO_2 alone (€m per annum)

	Partial trading and partial taxation		Full trading		Full taxation
Scenario	**B1**[1]	**B1**[1]	**B2**[2]	**B2**[2]	**B3**[3]
Allowance arrangement	Grandfathering	10% auctioning and 90% grandfathering	Grandfathering	10% auctioning and 90% grandfathering	None: 100% charges
Congested airports	5,236	5,236	5,236	5,236	5,236
Uncongested airports	8,780	8,780	8,780	8,780	8,780
Abatement	293	293	293	293	293
Allowances	–4,002	–3,602	–12,006	–10,805	0
Overall impact	10,306	10,707	2,302	3,503	14,308

Notes: Assumes 30% fixed costs, 25% of demand passing through congested airports, with costs passed through to fares at congested airports. [1] €30 allowance price, €60 emissions charge per tonne of CO_2 emissions. [2] €90 allowance price per tonne of CO_2 emissions. [3] €90 emissions charge per tonne of CO_2 emissions.
Source: OXERA modelling.

Tables 4.8 and 4.9 show that increasing the price of allowances and EU charges to those suggested by the government's recent work significantly increases the financial impact on the industry when compared against the baseline scenario.

4.2 Impact on fares and passenger demand

This section outlines the impact on fares and passenger demand under the different scenarios. The impact does not vary between scenarios B1, B2 and B3, as long as the total price paid per tonne of CO_2 emitted remains constant. Neither do the results vary between scenarios A1 and A2, since the level of allowances given to the industry does not feed through into ticket prices. Throughout the modelling, it has been assumed that air traffic movements change in proportion to the number of passengers and vice versa, implying a fixed load factor.

Table 4.10 illustrates the impact when it is assumed that airlines at congested airports do not pass through cost increases to their ticket prices. The fares variable represents the average fare paid (the average revenue per passenger journey) and the passenger variable represents the impact on passenger volumes (the total number of equivalent passenger journeys).

Table 4.10: Impact in scenarios A1 and A2 assuming that congested airports do not pass through costs (% change)

Location	Variable	Total damage is 3 times that caused by CO_2 emissions alone[1]	Total damage is 2.5 times that caused by CO_2 emissions alone[2]
Uncongested airports	Fares	5.02	4.18
Congested airports	Fares	0.00	0.00
Aggregate	Fares	3.77	3.14
Uncongested airports	Passengers	–7.53	–6.28
Congested airports	Passengers	0.00	0.00
Aggregate	Passengers	–5.65	–4.71

Notes: Assumes 30% fixed costs, 25% of demand passing through congested airports, and no pass-through to fares at congested airports. Results are the same for charges and allowances. [1] Total cost per unit of CO_2 emitted is €30. [2] Total cost per unit of CO_2 emitted is €25.
Source: OXERA modelling.

Table 4.11 illustrates the impact when it is assumed that airlines at congested airports pass through cost increases to their ticket prices. This table shows that the aggregate impact on ticket prices and passenger volumes is larger in this scenario. This allows them to pass through some of the costs to the consumer, reducing the impact on the industry.

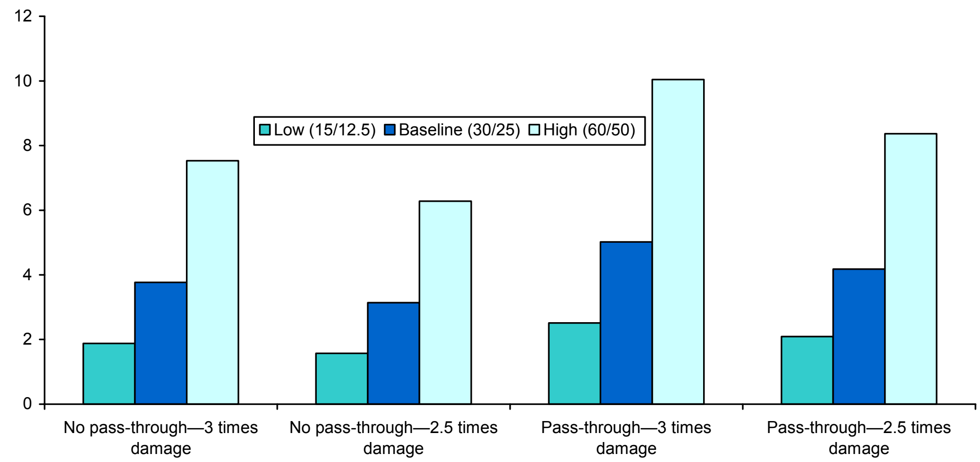
Table 4.11: Impact in scenario A1 and A2 assuming that congested airports pass through costs (% change)

Location	Variable	Total damage is 3 times that caused by CO_2 emissions alone[1]	Total damage is 2.5 times that caused by CO_2 emissions alone[2]
Uncongested airports	Fares	5.02	4.18
Congested airports	Fares	5.02	4.18
Aggregate	Fares	5.02	4.18
Uncongested airports	Passengers	–7.53	–6.28
Congested airports	Passengers	–4.02	–3.35
Aggregate	Passengers	–6.65	–5.54

Notes: Assumes 30% fixed costs, 25% of demand passing through congested airports, and no pass-through to fares at congested airports. Results are the same for charges and allowances. [1] Total cost per unit of CO_2 emitted is €30. [2] Total cost per unit of CO_2 emitted is €25.
Source: OXERA modelling.

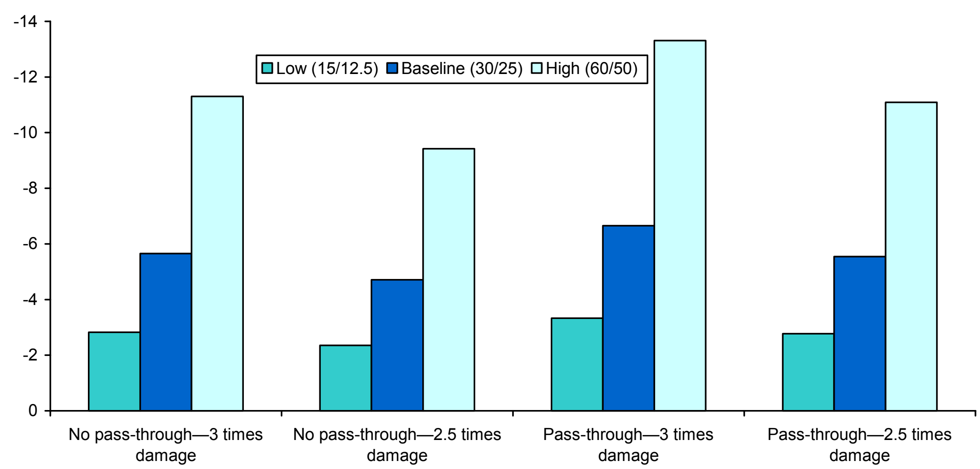
Figures 4.7 and 4.8 show the sensitivity of the fares and passenger-volume results respectively to changes in the allowance price and/or EU emissions charge.

Figure 4.7: Impact on fares in scenarios A1 and A2 with different allowance prices and EU charges (% change)



Notes: Figures in parentheses refer to the marginal price (sum of allowances and charges) paid to emit 1 tonne of CO_2.
Source: OXERA modelling.

Figure 4.8: Impact on passenger volume in scenarios A1 and A2 with different allowance prices and EU charges (% change)



Note: Figures in parentheses refer to the marginal price (sum of allowances and charges) paid to emit 1 tonne of CO_2.
Source: OXERA modelling.

4.3 Environmental impact

The total environmental impact of each of the different regimes under the baseline scenarios is shown in Tables 4.12 and 4.13. These tables show how the total forecast level of emissions varies between each of the scenarios in comparison against the baseline value for 2010.

Table 4.12: Baseline emissions impact in scenario A1 assuming that total damage is 3 times that due to CO_2 alone (Mt of CO_2 per annum)

Scenario	Baseline	Partial trading and partial taxation B1[1]	Full trading B2[2]	Full taxation B3[3]
Reductions	n/a	–45	–93	–21
Demand	n/a	–13	–13	–13
Supply	n/a	–8	–8	–8
Other industry	n/a	–24	–72	0
Overall emissions	**245**	**200**	**152**	**224**
% reduction of baseline	n/a	18.3%	37.9%	8.5%

Notes: Assumes 30% fixed costs, 25% of demand passing through congested airports, and no pass-through to fares at congested airports. [1] €10 allowance price, €20 emissions charge per tonne of CO_2 emissions; [2] €30 allowance price per tonne of CO_2 emissions; [3] €30 emissions charge per tonne of CO_2 emissions.
Source: OXERA modelling.

Table 4.13: Baseline emissions impact in scenario A2 assuming that total damage is 3 times that due to CO_2 alone (Mt of CO_2 per annum)

Scenario	Baseline	Partial trading and partial taxation B1[1]	Full trading B2[2]	Full taxation B3[3]
Reductions	n/a	–51	–112	–21
Demand	n/a	–13	–13	–13
Supply	n/a	–8	–8	–8
Other industry	n/a	–30	–91	0
Overall emissions	**245**	**194**	**133**	**224**
% reduction of baseline	n/a	20.9%	45.6%	8.5%

Notes: Assumes 30% fixed costs, 25% of demand passing through congested airports, no pass-through to fares at congested airports. [1] €10 allowance price, €20 emissions charge per tonne of CO_2 emissions; [2] €30 allowance price per tonne of CO_2 emissions; [3] €30 emissions charge per tonne of CO_2 emissions.
Source: OXERA modelling.

The total reduction in emissions is split into three categories. The demand effect is the reduction in emissions caused by fewer flights from uncongested airports where the costs of trading/taxation have been passed through to passengers resulting in a reduction in demand. The supply effect reflects the adoption of abatement technologies by airlines in response to the trading and tax schemes. Finally, the other industry effect is the emissions reductions purchased by the airline sector from other industrial emitters. It is only this third factor that varies between the scenarios—the demand and supply effects are the same whether or not emissions trading is adopted, assuming that the permit price and the tax are equal. Unlike the first two factors, the other industry reductions do not lower airline emissions. Instead, they are an offsetting reduction in emissions from another industry.

4.4 Issues to consider when interpreting the 2008–12 results

As the modelling results show, the levels of the EU charges and allowance price significantly alter the financial impact on the airlines. At present, there is a considerable margin of uncertainty surrounding most estimates of both of these, and, consequently, there is a considerable margin of error surrounding the estimates of the financial implications for the airlines. As these estimates become clearer, so too will the likely impact on the industry.

The abatement curve used in the modelling may not capture all possible emission-reducing strategies that airlines could adopt were allowance trading introduced or charges levied. For example, it does not examine the possibility of reductions in engine idling at airports, a practice which can burn considerable quantities of fuel. The abatement curve includes only technologies that are currently available, or are under development and may become available in time for this scenario.

Also, the abatement curve is not endogenous. This means that the imposition of levies on emissions has no effect on the abatement curve. Ideally, this curve would be endogenous. However, this is likely to prove less of a problem for the 2008–12 results than for the 2050 results, since technology will have less time in which to advance, making the existing abatement curve a closer approximation.

5. Emissions Trading Relative to Alternatives: 2050 Scenario

The results from the 2050 modelling are presented in the sub-sections below. The tables and figures in this section illustrate the estimated *annual* financial impact in 2050 on airlines caused by the introduction of EU emissions charges and/or an allowance trading scheme, in 2003 euros. The figures represent costs to the industry (therefore, negative figures represent gains to the industry).

A summary of the scenario references is shown below to aid navigation of the results.

Table 5.1: Summary of scenario numbers

Scenario	Scenario type	Description
A3	Emissions allowance	A 60% reduction in emissions by 2050 against a 1990 baseline
B1	Trading and taxation	Airlines requires 1 allowance for each 1 tonne of CO_2 emitted, with an EU emissions charge used to address airline's residual climate change impact (the total impact being assumed to be either 2.5 times or 3 times that due to CO_2 alone)
B2	Trading and taxation	Airlines requires either 2.5 or 3 allowances for each 1 tonne of CO_2 emitted and there is no EU emissions charge
B3	Trading and taxation	Airlines do not participate in an emissions trading regime. Instead, it is subject to an EU emissions charge that is equal to 2.5 times or 3 times the impact due to CO_2 emissions alone

Source: Project terms of reference.

5.1 Financial impact

Tables 5.2 and 5.3 illustrate the total financial impact on airlines under the baseline assumptions in scenario A3 with the total damage caused by emissions of CO_2 equal to 2.5 and 3 times the damage caused by CO_2 alone. The baseline assumptions used in the tables are that airlines have 30% fixed costs; that 25% of demand passes through congested airports; that there is no pass-through to fares at congested airports; that the total cost of emitting 1 tonne of CO_2 (the sum of EU emissions charges and allowance prices) is equal to €30 in the 3-times damage case, and €25 in the 2.5-times damage case; that fuel efficiency rises at 0.5% per annum; that the intra-EU airline industry grows by 3.6% in real terms per annum until 2020, and then by 2.5% ; and that the elasticities are reduced over time to –0.98 at uncongested airports.

Figures 5.1 and 5.2 show the sensitivity of the results to changes in the allowance price and the level of the EU emissions charge. They show:

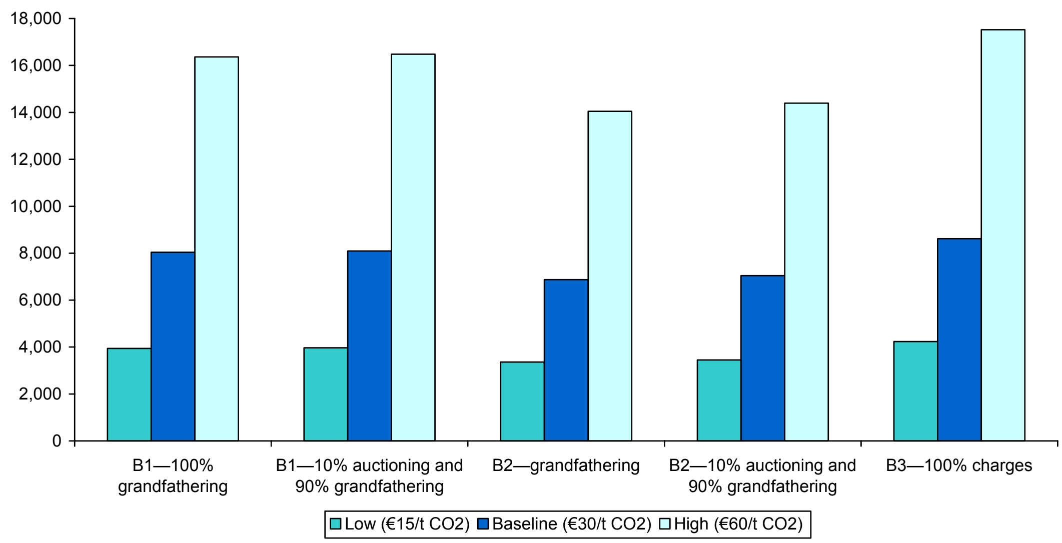
- *a low scenario*—the total cost of emitting 1 tonne of CO_2 equals €15 for 3 times the damage, and €12.5 for 2.5 times the damage;
- *the baseline scenario*—the total cost of emitting 1 tonne of CO_2 is equal to €30 in the 3-times damage case, and €25 in the 2.5-times damage case; and,
- *a high scenario*—the total cost of emitting 1 tonne of CO_2 equals €60 for 3 times the damage, and €50 for 2.5 times the damage.

Table 5.2: Baseline impact in 2050 in scenario A3 assuming that total damage is 3 times that due to CO_2 alone (€m per annum)

	Partial trading and partial taxation		Full trading		Full taxation
Scenario	**B1[1]**	**B1[1]**	**B2[2]**	**B2[2]**	**B3[3]**
Allowance arrangement	Grandfathering	10% auctioning and 90% grandfathering	Grandfathering	10% auctioning and 90% grandfathering	None: 100% charges
Congested airports	4,115	4,115	4,115	4,115	4,115
Uncongested airports	4,224	4,224	4,224	4,224	4,224
Abatement	2,76	2,76	2,76	2,76	2,76
Allowances	–580	–522	–1740	–1566	0
Overall impact	**8,035**	**8,093**	**6,875**	**7,049**	**8,615**

Notes: Assumes 30% fixed costs, 25% of demand passing through congested airports, no pass-through to fares at congested airports. [1] €10 allowance price, €20 emissions charge per tonne of CO_2 emissions. [2] €30 allowance price per tonne of CO_2 emissions. [3] €30 emissions charge per tonne of CO_2 emissions.
Source: OXERA modelling.

Figure 5.1: Total financial impact with different allowance prices and EU charge levels in scenario A3 assuming that total damage is 3 times that due to CO_2 alone (€m per annum)



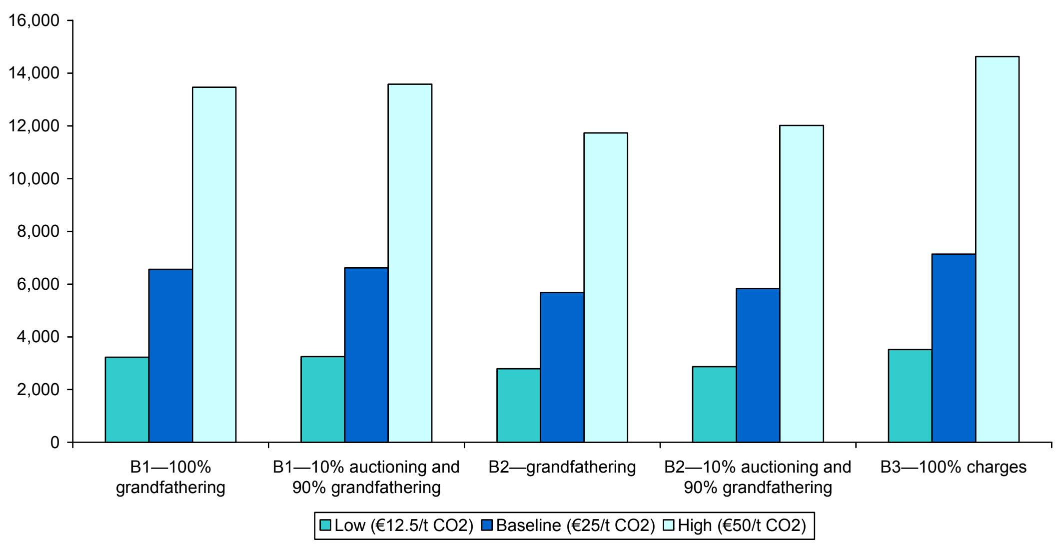
Note: Figures in parentheses refer to the marginal price (sum of allowances and charges) paid to emit a tonne of CO_2.
Source: OXERA modelling.

Table 5.3: Baseline impact in 2050 in scenario A3 assuming that total damage is 2.5 times that due to CO_2 alone (€m per annum)

	Partial trading and partial taxation		Full trading		Full taxation
Scenario	**B1[1]**	**B1[1]**	**B2[2]**	**B2[2]**	**B3[3]**
Allowance arrangement	Grandfathering	10% auctioning and 90% grandfathering	Grandfathering	10% auctioning and 90% grandfathering	None: 100% charges
Congested airports	3,449	3,449	3,449	3,449	3,449
Uncongested airports	3,497	3,497	3,497	3,497	3,497
Abatement	192	1,92	1,92	1,92	1,92
Allowances	–580	–522	–1,450	–1,305	0
Overall impact	6,558	6,616	**5,688**	**5,833**	**7,138**

Notes: Assumes 30% fixed costs, 25% of demand passing through congested airports, and no pass-through to fares at congested airports. [1] €10 allowance price, €15 emissions charge per tonne of CO_2 emissions. [2] €25 allowance price per tonne of CO_2 emissions. [3] €25 emissions charge per tonne of CO_2 emissions. *Source*: OXERA modelling.

Figure 5.2: Total financial impact with different allowance prices and EU charge levels in scenario A3 assuming that total damage is 2.5 times that due to CO_2 alone (€m per annum)

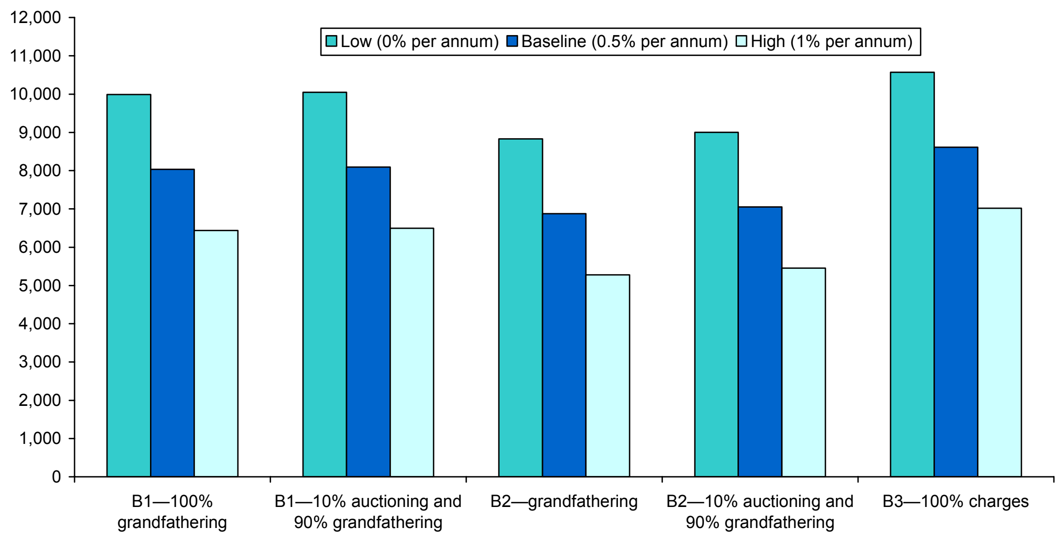


Note: Figures in parentheses refer to the marginal price (sum of allowances and charges) paid to emit 1 tonne of CO_2.
Source: OXERA modelling.

As in the 2008–12 scenarios, the impact at congested airports, uncongested airports, and the costs due to abatement do not vary within each table (5.2 and 5.3). This is because all the variables that affect these results are the same under each of the trading and taxation scenarios (B1, B2, and B3). Therefore, the total financial impact only differs between the scenarios within each table due to the changing value of the allowances granted to the industry—the more allowances, the smaller the total impact. As before, this result indicates that scenarios that include allowances have a less significant financial impact on the industry than those that do not. However, the difference is less pronounced than before because the level of the initial allocation is smaller, and the expected level of emissions is larger.

Figure 5.3 illustrates the sensitivity of the results to changes in the assumption about fuel efficiency. The baseline is a 0.5% improvement per annum. This figure shows the sensitivity of the A3 scenario with total damage equal to 3 times that caused by CO_2 to a 0% improvement and a 1% improvement. It shows that the assumptions about fuel savings are extremely important, since changing them even by a small amount has a large financial consequence for the industry.

Figure 5.3: Sensitivity of results in scenario A3 assuming that total damage is 3 times that due to CO_2 alone to changes in the fuel efficiency assumption



Note: Figures in parentheses refer to the annual rate of fuel efficiency improvement.
Source: OXERA modelling.

Table 5.4 shows various quantified sensitivities of the results to changes in the assumptions.

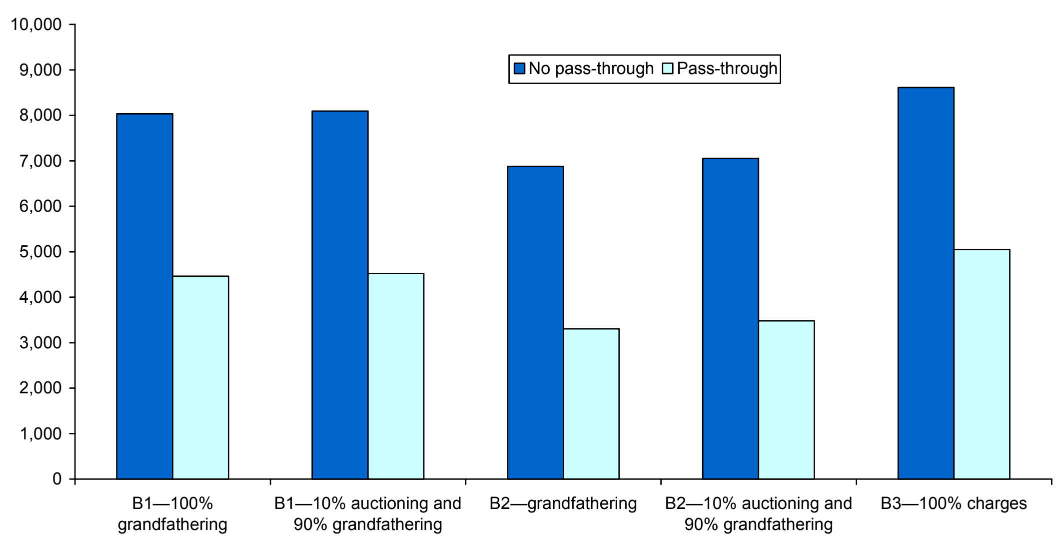
Table 5.4: Sensitivity analyses of the financial impact based on the A3 and B1 scenario (€ per annum)

Variable	Baseline assumption	Lower assumption	Change in overall financial impact—lower assumption	Higher assumption	Change in overall financial impact—higher assumption
Proportion of congested airports (%)	25	15	–1,083	35	1,083
Proportion of costs that are fixed (%)	30	20	–1,318	40	1,318
Whether airlines can pass through costs at congested airports	No	Yes	–3,570	n/a	
The proportion of allowances that are auctioned	0	n/a		10	174
Price elasticities of demand (uncongested airports)	1.0	0.5	–2,069	1.5	2,241
Profit margin (%)	2.1	1.1	–46	3.1	44

Notes: Results are based on the A1 scenario with total damage caused by CO_2 equal to 3 times that caused by CO_2 alone. The allowance price/EU emissions charge was set equal to €30 per tonne of CO_2 emitted.
Source: OXERA modelling.

As Table 5.4 highlights, if airlines can pass through costs at congested airports, the results are altered by around €3.5 billion per annum. Figure 5.4 illustrates the impact in the various scenarios.

Figure 5.4: Comparing scenario A3 (no pass-through to passenger ticket prices at congested airports) with scenario A3 (pass-through to passenger ticket prices at congested airports) (€m per annum)

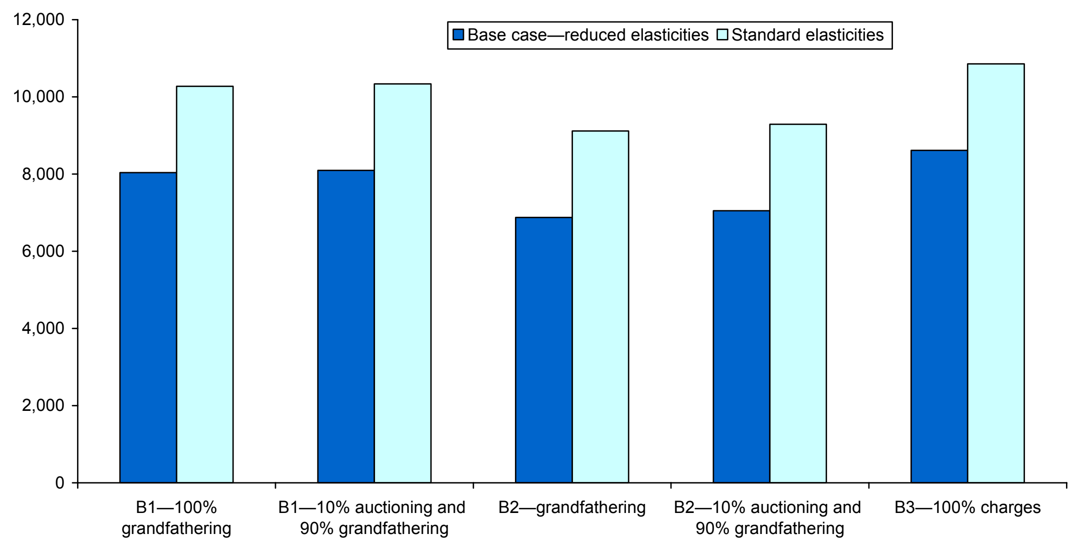


Source: OXERA modelling.

Figure 5.4 shows that, were the cost increases caused by the imposition of allowance trading or EU emissions charges to be passed through to passenger ticket prices at congested airports, the total financial impact on the industry would be reduced considerably.

Table 5.4 also highlights that the choice of elasticities can have a significant impact on the results. Figure 5.5 compares the results of the base case (reduced elasticities) with the results obtained when using the same elasticities as in the 2008–12 modelling. It illustrates that the increase in elasticities has a considerable financial impact on the industry—of more than €2 billion per annum in all the scenarios illustrated.

Figure 5.5: Comparing reduced elasticities and standard elasticities in the A3 scenario with 3-times damage costs (€m per annum)

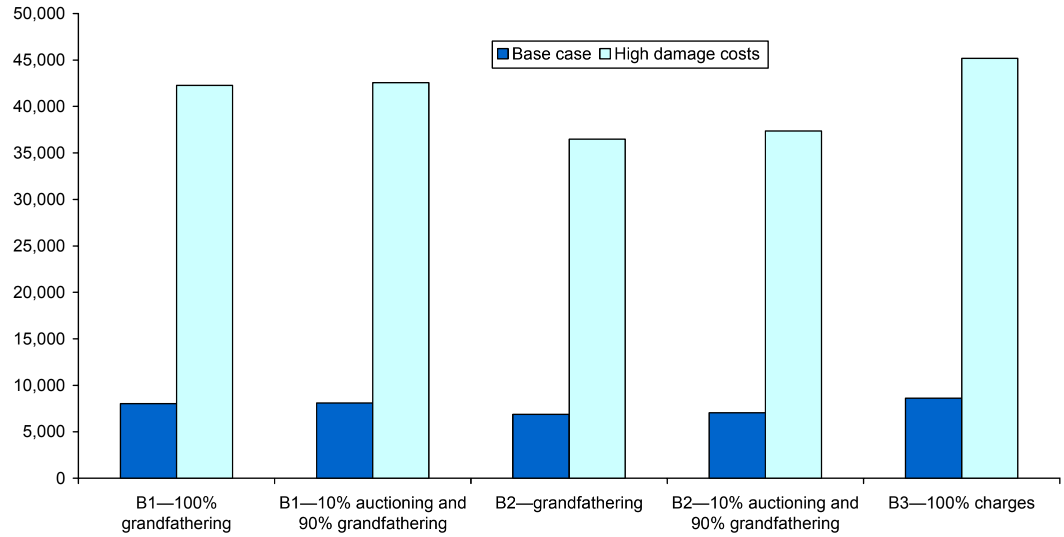


Source: OXERA modelling.

Section 3.4.2 described the evidence available that informed the choice of allowance prices and emissions charges. However, the range of evidence for expected future prices is wide, and there is a risk that the assumptions in the main forecasts are too optimistic. Consequently, a scenario has been run adopting the government's central case of £70t/C, uprated by £1t/C per annum in real terms, giving a cost of carbon of £120t/C for the 2050 scenario.[27] Converting to euros and to CO_2, this equates to around €50t/CO_2 (or €150t/CO_2 at 3-times damage).[28] Figure 5.6 shows the financial impact of running such a scenario compared against the base-case scenario.

[27] Defra and HM Treasury (2002), 'Estimating the Social Cost of Carbon Emissions', January.
[28] A conversion factor of 3.67 converts from t/C emissions to t/CO_2 emissions, and a £1 = €1.5 exchange rate is used.

Figure 5.6: Comparing the base case with Defra's central case damage costs scenario in the A3 scenario with 3-times damage costs (€m per annum)



Notes: Both scenarios assume 30% fixed costs, 25% of demand passing through congested airports, and no pass-through to fares at congested airports. The base case assumes total combined charges/allowances equal to €30 per tonne of CO_2 equivalent. 'High damage costs' assumes €150 per tonne of CO_2 equivalent.
Source: OXERA modelling.

As Figure 5.6 shows, adopting the government's current central case for the damage cost associated with carbon emissions results in a very large financial impact on the airline industry compared against the base-case scenario.

5.2 Impact on fares and passenger demand

This section outlines the impact on fares and passenger demand under the different scenarios. The impact does not vary between scenario B1, B2 and B3, provided the total price paid per tonne of CO_2 emitted remains constant. Throughout the modelling it has been assumed that air traffic movements change in proportion to the number of passengers and vice versa, implying a fixed load factor.

Table 5.5 illustrates the impact when it is assumed that airlines at congested airports do not pass through cost increases to their ticket prices. The fares variable represents the average fare paid (the average revenue per passenger journey) and the passenger variable represents the impact on passenger volumes (the total number of equivalent passenger journeys).

Table 5.5: Impact in scenario A3 assuming that congested airports do not pass through costs (% change)

Location	Variable	Total damage is 3 times that caused by CO_2 emissions alone[1]	Total damage is 2.5 times that caused by CO_2 emissions alone[2]
Uncongested airports	Fares	4.11	3.42
Congested airports	Fares	0.00	0.00
Aggregate	Fares	3.08	2.57
Uncongested airports	Passengers	–4.03	–3.36
Congested airports	Passengers	0.00	0.00
Aggregate	Passengers	–3.02	–2.52

Notes: Assumes 30% fixed costs, 25% of demand passing through congested airports, and no pass-through to fares at congested airports. Results are the same for charges and allowances. [1] Total cost per unit of CO_2 emitted is €30. [2] Total cost per unit of CO_2 emitted is €25.
Source: OXERA modelling.

Table 5.6 illustrates the impact when it is assumed that airlines at congested airports pass through cost increases to their ticket prices. This table shows that the aggregate impact on ticket prices and passenger volumes is larger in this scenario. This allows airlines to pass through some of the costs to the consumer, reducing the impact on the industry.

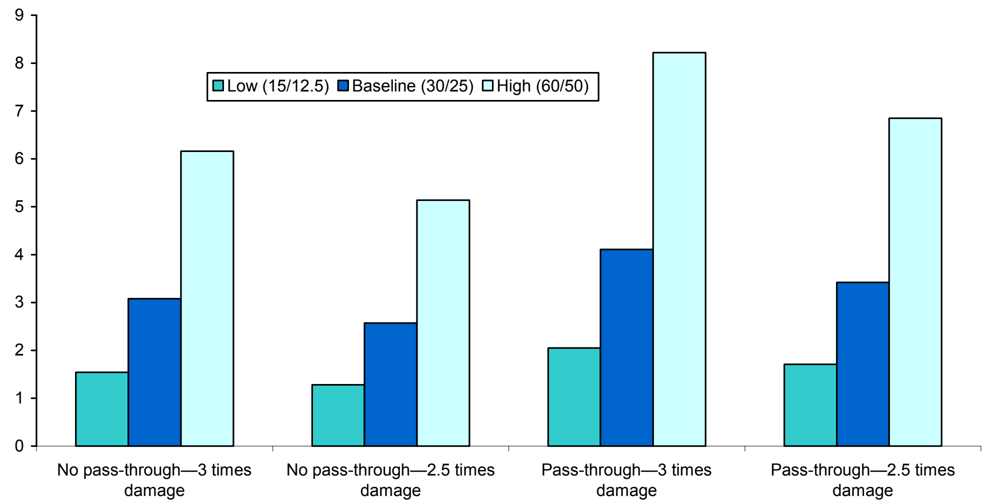
Table 5.6: Impact in scenario A3 assuming that congested airports pass through costs (% change)

Location	Variable	Total damage is 3 times that caused by CO_2 emissions alone[1]	Total damage is 2.5 times that caused by CO_2 emissions alone[2]
Uncongested airports	Fares	4.11	3.42
Congested airports	Fares	4.11	3.42
Aggregate	Fares	4.11	3.42
Uncongested airports	Passengers	–4.03	–3.36
Congested airports	Passengers	–1.56	–1.30
Aggregate	Passengers	–3.41	–2.84

Notes: Assumes 30% fixed costs, 25% of demand passing through congested airports, with 100% pass-through of cost increases to fares at congested airports. Results are the same for charges and allowances. [1] Total cost per unit of CO_2 emitted is €30. [2] Total cost per unit of CO_2 emitted is €25.
Source: OXERA modelling.

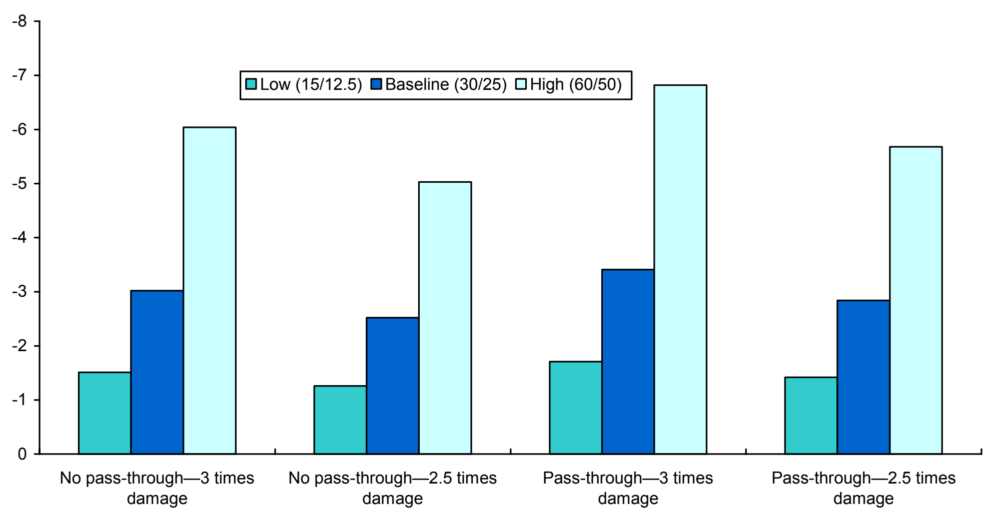
Figures 5.7 and 5.8 illustrate the sensitivity of the fares results to changes in the level of the allowance price and EU charges.

Figure 5.7: Impact on fares in scenario A3 with different allowance prices and EU charges (% change)



Notes: Figures in parentheses refer to the marginal price (sum of allowances and charges) paid to emit 1 tonne of CO_2.
Source: OXERA modelling.

Figure 5.8: Impact on passenger volume in scenario A3 with different allowance prices and EU charges (% change)



Notes: Figures in parentheses refer to the marginal price (sum of allowances and charges) paid to emit 1 tonne of CO_2.
Source: OXERA modelling.

5.3 Environmental impact

The total environmental impact of each of the various regimes under the baseline scenarios is shown in Table 5.7. This table demonstrates how the total forecast levels of emissions vary between each of the scenarios in comparison with the baseline value for

2050. The baseline is an extrapolated forecast from the Eurostat forecasts for 2010, assuming a 0.5% per annum improvement in fuel efficiency.

Table 5.7: Baseline emissions impact in scenario A3 assuming that total damage is 3 times that due to CO_2 alone (Mt of CO_2 per annum)

Scenario	Baseline	Partial trading and partial taxation B1[1]	Full trading B2[2]	Full taxation B3[3]
Reductions	n/a	–193	–509	–34
Demand	n/a	–17	–17	–17
Supply	n/a	–18	–18	–18
Other industry	n/a	–158	–475	0
Overall emissions	**567**	374	58	533
% reduction of baseline	n/a	34.0%	89.8%	6.1%

Notes: Assumes 30% fixed costs, 25% of demand passing through congested airports, and no pass-through to fares at congested airports. [1] €10 allowance price, €20 emissions charge per tonne of CO_2 emissions; [2] €30 allowance price per tonne of CO_2 emissions; [3] €30 emissions charge per tonne of CO_2 emissions. Figures may not sum correctly due to rounding.
Source: OXERA modelling.

The total reduction in emissions is split into three categories. The demand effect is the reduction in emissions caused by fewer flights from uncongested airports where the costs of trading/taxation have been passed through to passengers, resulting in a reduction in demand. The supply effect reflects the adoption of abatement technologies by airlines in response to the trading and tax schemes. Finally, the other industry effect is the emissions reductions that are purchased by airlines from other industrial emitters. It is only this third factor that varies between the scenarios—the demand and supply effects are the same whether or not emissions trading is adopted, assuming that the permit price and the tax are equal. Unlike the first two factors, the other industry reductions are not a reduction in airline emissions; rather, they are an offsetting reduction in emissions from another industry.

Table 5.7 shows that most of the emissions reductions achieved under the full and partial trading are achieved by airlines purchasing very large amounts of offsetting allowances from other industries. Purchasing such large amounts may change the market price for allowances, invalidating the assumption used in the modelling that the airlines are price-takers in this market.

5.4 Issues to consider when interpreting the 2050 results

Straight-line extrapolated forecasts of emissions, such as those used in the modelling presented in this paper, do not take a range of factors into account. For example, the determinants of the demand for air travel could change significantly over that period, altering the trend rate of growth.

A second issue is that the abatement curve used in the analysis is exogenous, and therefore assumes that the allowance price has no effect on the development of new technologies, or on the price of existing technologies. An example of this type of reaction was seen in the 1970s after the oil price shocks; car manufacturers increased the amount of research and development funds available to projects that aimed to increase the fuel efficiency of cars.

Ideally, the abatement curve would be endogenous to the model so that these factors are taken into account. However, this is very difficult since it requires strong assumptions to be made about the reductions in costs that may be achieved with existing technology, and what the likelihood is of future technologies being developed, and at what price. Also, in the long run, the shape of the abatement curve will depend on the size of the EU airline market relative to the global market—ie, how important emissions charges will be in encouraging technological development of more efficient airlines.

Another issue concerns the proportion of the airline industry that is operating from congested airports, as it may change significantly over such a long period, during which both demand and supply are also likely to change significantly. The supply of airport capacity, while highly inelastic in the short run, is likely to become much more elastic in the long run, as governments and private companies respond to changes in the demand for airport capacity. However, resistance to airport development may also increase. The Terminal Five inquiry at Heathrow took many years to complete, and further planning inquiries may also be lengthy, reducing the response of supply.

In addition, in the period to 2050, alternative modes of transport may develop in response to the increased cost of flying. For example, high-speed rail may link many European cities, offering similar total journey times when compared with air travel. Also, alternatives to travel may develop, such as greater use of electronic communications (such as videoconferencing).

The potential expansion of the EU will have an effect on this scenario. If this is considerable, its airline sector will naturally grow.

If slots become a tradeable commodity, the key distinction that this paper draws between congested and uncongested airports will cease to be valid, as this is based on the notion that airlines accrue rents on these scarce, and generally non-tradeable, commodities. Once slots are tradeable, these supernormal profits can be expected to be captured by the owner of the slots. Several parties claim to have property rights to these slots. If they were to be given to airlines, supernormal profits at congested airports are still likely to occur, and the scenario will be similar to that analysed in this paper. If the property rights are deemed to belong to the airports or governments, the supernormal profits will be removed from the airlines and the scenario will change significantly.

5.5 Steps for Inclusion in the EU scheme

Inclusion of airline emissions in the EU ETS during the period 2008–12 would require, first, an amendment to the Greenhouse Gas Emissions Trading Directive, which would involve a proposal by the European Commission, readings in the European Parliament, Council discussion, and, if necessary, a conciliation procedure. Article 30 of the Directive specifies that:

> the Commission may make a proposal to the European Parliament and the Council by 31 December 2004 to amend Annex I to include other activities and emissions of other greenhouse gases listed in Annex II.[29]

The first opportunity to include airline emissions in the EU ETS expires on December 31st 2004, assuming that the Directive is not delayed.

In the amendment, not only the activity itself, but also the terms and conditions under which the activity is integrated, are to be included. The question is whether activities to be included could be subject to different terms from the incumbents. In the case of airlines, the question is how similar the installations are to industrial installations already in the scheme, not only in terms of the global-warming potential of the emissions, but also in relation to the wider regulatory framework. The EU ETS includes an amendment to the 1996 Integrated Pollution Prevention and Control Directive (IPPC) with respect to the control of CO_2 emissions; however, for other pollutants and externalities, the requirements of the IPPC Directive remain valid. Aviation has been regulated differently—aspects of transport regulation have been applied to aviation as well (eg, technology standards relating to safety and noise). The other central feature of transport regulation—car and fuel duties—has not been applied to aviation. From this perspective, emissions from aviation could be modelled not only on the regime for industrial installations, but also on the model for other modes of transport.

Once an amendment is made, intra-EU aviation would need to be included in the National Allocation Plans that are drafted for the 2008–12 period. The Greenhouse Gas Emissions Trading Directive specifies that these plans should be submitted to the Commission by March 31st 2007 at the latest. The Commission then has three months to accept or reject the National Allocation Plan. The airline sector will have to negotiate its target, together with the industrial sectors in the trading scheme, the largest of which is the energy sector.

The views of the Commission regarding economic instruments and aviation have been made public:

> stronger use of emission trading as an instrument for furthering environmental improvements could also be established at regional (Community) or at national level. In that case it would be necessary to set a cap on emissions and to set rules for trading emissions under such a cap. This approach would imply that growth industries such as air transport may purchase emission rights from declining industries or from industries where new technologies already available pave the way for cost-effective reductions of emissions. This mechanism may contribute to both the acceleration of structural change and environmental improvement. However, it is worth noting that from the point-of-view of the aviation industry the effects of such a system would not necessarily be significantly different from the imposition of environmental levies. In both cases, environmental

[29] Council of the European Union (2003), 'Common Position adopted by the Council on 18 March 2003 with a View to the Adoption of Directive of the European Parliament and of the Council Establishing a Scheme for Greenhouse Gas Emission Allowances Trading within the Community and Amending Council Directive 96/61/EC', 15792/1/02, March.

> improvement would in essence be brought about by rendering more expensive emissions from air operations.[30]

The reference to environmental levies is important because, in the same paper, the Commission dismisses a fuel tax on intra-EU flights, stating that 'it would not strike the delicate balance between environmental, economic and internal market requirements.' The Communication seems to suggest that the trading of emission rights on a community scale could cost as much as a tax. As the analysis above shows, rights trading costing as much as the tax depends on a number of restrictive conditions (eg, all emissions being auctioned).

It is unclear at this stage whether Member States are keen to include intra-EU aviation in the EU ETS. There is certainly a drive for redressing the balance created by the absence of taxation of aviation fuels. The choice appears to be between Member States levying taxes on a coordinated basis, as is done for other transport sources, and inclusion in an emissions trading scheme, on an equal basis with industrial installations. A possible compromise would be to allow inclusion, but to specify an initial allocation, which would involve a higher percentage of auctioning, to achieve a more level playing field between different modes of transport.

5.6 Environmental credibility

The political considerations focus primarily on balancing the environmental-damage cost created by aviation with economic considerations. This paper has shown the financial impact of various environmental options. In this section, the particular environmental benefit from emissions trading is discussed.

The environmental benefit from emissions trading is determined by the sum of the emission allocations, and not by an allocation to a particular industry. The reason is that trading might result in a distribution of emissions, whereby one sector emits more than originally expected and another sector less. Inclusion of airline emissions in the EU ETS would increase the total cap by the airline's initial allocation. Two proposals for this are discussed in this paper: –25% from projected emissions (A1), and –8% from 1990 emissions (A2).

This is not to say that emissions would not exceed these initial allocations. A central argument in this analysis is that there is no (or only a reduced) demand response for flights from a congested airport, which means that the only reduction would come from abatement on the supply side. In the short term, with limited affordable options for emission reductions, this might mean that emissions from airlines are not reduced

[30] European Commission (1999), 'Communication from the Commission to the Council, the European Parliament, the Economic and Social Committee and The Committee of the Regions, Air Transport and the Environment: Towards Meeting the Challenges of Sustainable Development', COM (1999) 640 final, para 36.

significantly. However, it does mean that emissions could be reduced elsewhere through trade in allowances.

In the case of a tax, without a behavioural effect, the only emission reduction would be through the abatements from the aviation industry itself. Therefore, if the allowance price equals the tax rate, and the aviation industry is a net importer of allowances under the trading scheme, a (partial) tax would lead to fewer emission reductions overall than inclusion of airline emissions in the EU ETS.

The impact on airline's emissions is further influenced by the proportion of fixed costs in short- and medium-haul flights. Although emissions per passenger-km are higher for short-haul flights (and, therefore, short-haul is hit harder by the allowance price or the emissions charge), the proportion of fuel costs of total costs is lower. Hence, it might be that medium-haul flights are hit harder in relative terms, leading to switching from medium- to short-haul. Long-haul flights are assumed to be unaffected, although there might be some change from short- and medium-haul flights to EU destinations to medium- and long-haul flights to destinations outside the EU. Both switches in flight patterns could lead to emissions from airlines being reduced less significantly than expected.

5.7 Widening the scope of the EU ETS

Widening the scope of the scheme by linking it to other international schemes and inclusion of international flights would strengthen its environmental credibility, if the emission caps in the other trading systems are set on an equivalent basis. Presumably, the Kyoto targets would be taken as a basis for such links.

The inclusion of flights between the EU and non-EU destinations in an emissions trading scheme is predicated on the existence of a global trading scheme, at least including the major destinations. Bilateral deals (eg, between Canada and the EU) involving the inclusion of travel between those two destinations could lead to a competitive disadvantage, unless the airlines were accommodated with a generous allowance allocation and the costs were not passed through in the ticket price.

In all likelihood, inclusion of international travel would need to wait until agreement is reached in the United Nations Framework Convention on Climate Change or another international body, such as the International Civil Aviation Organization.

6. Conclusion

Following the analysis in this paper, it is possible to conclude the following for the period 2008–12.

- The modelling suggests that the overall financial impact on the airline industry of a emissions taxation regime (scenario B3) would be around €4.6 billion per annum in the 2008–12 period if total damage costs were 3 times those caused by CO_2 alone, giving an effective charge of €30/t CO_2. Analysis by CE Delft has indicated that a €30/t CO_2 emissions charge would generate €3.3 billion per annum in revenues.[31] However, these estimates are not directly compatible; the OXERA estimate is of the impact on the profitability of the industry, while CE Delft is an estimate of revenue generated by a charge.

  The impact would be reduced if allowance trading were adopted. If partial taxation and partial allowance trading (scenario B1) were adopted, the financial impact would be around €3 billion per annum. If full allowance trading were adopted (scenario B2), and three allowances were granted to the industry for every tonne of emissions, the financial impact would be reduced to below €500m per annum.

  If airlines were to pass through the cost increases at congested airports, the financial impact would be reduced, to around €3.2 billion per annum under a full taxation regime, and around €1.8 billion per annum under a partial taxation and partial allowance trading regime. This would result in gains to the industry of around €1 billion per annum if full allowance trading were adopted with three permits per tonne of emissions awarded to the airlines.

  These results are sensitive to the assumptions made during the modelling, which include the proportion of airports considered to be congested (25%); the proportion of costs that are fixed (30%); price elasticities of demand at uncongested airports (–1.5); and airlines' profit margin (2.1%).

- Full emissions trading (scenario B2) would have a smaller overall financial impact on the industry than partial emissions trading combined with an EU emissions charge (scenario B1) if the charges and allowance prices were set equal. This occurs because there is no free allocation provided to the industry in B1 scenario. In some cases, the size of the initial allocation could be large enough to imply that the introduction of the emissions trading scheme would have an overall positive financial impact on the industry. In other cases the impact in scenario B2 would be up to around 20% as large as that in scenario B1.

[31] CE Delft (2002), 'Economic Incentives to Mitigate Greenhouse Gas Emissions from Air Transport in Europe', commissioned by the European Commission, July.

- Partial emissions trading combined with an EU emissions charge (scenario B1) would have a significantly larger financial impact than full emissions trading (scenario B2), but a smaller impact than a situation with full EU emissions charges (scenario B3). Partial emissions trading would have around 65–75% of the financial impact of full EU emissions charges.

- The larger initial allocation in scenario A1 (a 5% increase on 1990 emissions levels) would mean that the financial impact under either of the emissions trading scenarios (partial or full) would be smaller than under scenario A2 (an 8% reduction from 1990 levels), which would provide a reduced quantity of initial allocation. The financial impact of the full EU emissions charges (scenario B3) would be the same under both scenario A1 and A2, since the initial allocation would not affect the EU emissions charge.

- The results suggest that any level of emissions trading would have a less significant financial impact than full taxation at the *same* price/charge level. However, the results also suggest that partial emissions trading at a *high price* might have a greater financial impact on the industry than EU emissions charges at a *low level*.

- The sensitivity analysis highlighted that changing several of the assumptions would have a significant bearing on the financial impact on the industry. Doubling the level of the allowance price and the EU emissions charge would approximately double the financial impact under all the scenarios. Halving it would approximately halve the financial impact. If airports could pass through the cost increases to passengers, this could reduce the financial impact by around 30% under the EU emissions charges scenario (B3), around 40% under the partial emissions trading scenario (B1), and could result in a significant profit to the industry under full emissions trading (B2).

- The environmental impact of the taxation and trading scenarios would be the same in terms of reductions in actual emissions from airlines—the baseline scenario would result in around a 9% reduction. This compares with a 6% reduction in emissions estimated by the CE Delft study for the taxation option. The difference may be caused by the greater demand impact assumed by the OXERA model.

  The trading scenarios allow net emissions to be reduced by purchasing reductions in emissions from other industrial sectors. In the partial trading scenario, this would result in an 18% reduction, and, in the full trading scenario, a 38% reduction against the baseline.

Following the analysis of the 2050 case, it is possible to conclude with the following remarks.

- The results suggest that emissions trading and/or taxation would have a significantly greater financial impact in the 2050 scenario than in the 2008–12 scenarios. This would be driven by the increased emissions caused by the growth of the airline industry, together with a smaller initial allocation due to a stricter target. The full taxation scenario (scenario B3) suggests that the impact would be around €8.5 billion per annum under the baseline assumptions. If partial emissions trading (scenario B1), together with partial taxation, were adopted, this would be reduced to around €8 billion per annum, and to around €7 billion per annum if full emissions trading were adopted (scenario B2) and three allowances per tonne of emissions were allocated.

If airlines were to pass through the cost increases at congested airports, the financial impact would be reduced, by around €3.5 billion per annum under the three scenarios outlined above.

- Full emissions trading (scenario B2) would have a slightly smaller financial impact on the industry than partial emissions trading with an EU emissions charge (scenario B1) if the allowance price and EU emissions charge are set equal. Scenario B2 would have around a 13% smaller impact than scenario B1. The difference in financial impact between these two scenarios would be smaller than in the 2008–12 scenarios. This is partly because the initial allocations would be less important in the 2050 scenario, making up around 25% of the expected baseline level of emissions in 2050 compared with 62% under scenario A1 and 54% under scenario A2 in the 2008–12 period.

- Partial emissions trading combined with an EU emissions charge (scenario B1) would have a slightly less significant impact than a situation with full EU emissions charges (scenario B3). Partial emissions trading would have around 92% of the financial impact of full EU emissions charges. This difference would be smaller than that of the 2008–12 scenarios owing to the smaller size of the initial allocations.

- While the results suggest that any level of emissions trading would be better than full taxation at the same price/charge level, the difference would not be as significant as in the 2008–12 scenarios. The results also suggest that partial emissions trading at a *high price* might have a considerably greater financial impact on the industry than EU emissions charges at a *low level*. The difference would be likely to be larger than in the 2008–12 scenarios because the initial allocations are smaller in the 2050 scenario.

- The sensitivity analysis indicates that doubling the allowance price and EU emissions charge levels would approximately double the financial impact on the industry. Halving it would approximately halve the financial impact. Varying the level of assumed fuel efficiency gains between 0% and 1% per annum would have a very significant effect, adding to or reducing the financial impact by around 20%. This implies that the results are sensitive to the level of technological development during the period under examination. The price elasticities of demand would have a significant impact on the results when varied; adjusting the 2008–12 scenario elasticities would increase the total financial impact by around 30–40%. Allowing airlines at congested airports to pass through costs to consumers would significantly reduce the financial impact on the industry by passing some of the costs on to consumers. Allowing pass-through at congested airports would almost halve the financial impact in the baseline scenario.

- The environmental impact of the taxation and trading scenarios would be the same in terms of reductions in actual emissions from airlines—the baseline scenario would result in a reduction of around 6%. However, the trading scenarios would allow net emissions to be reduced by purchasing reductions in emissions from other industrial sectors. This means that the partial trading scenario would result in a 34% reduction, and the full trading scenario would lead to a 90% reduction against the baseline. However, the purchases of allowances from other industries may be so large in these scenarios that the assumption that airlines are price-takers in the allowance market may be invalidated.

Appendix 1: Key Assumptions

	Baseline assumption	
	2008–12	2050
Variable		
Proportion of congested airports (%)	25	25
Proportion of costs that are fixed (%)	30	30
Whether airlines can pass through costs at congested airports	No	No
The proportion of allowances that are auctioned (%)	0	0
Price elasticities of demand (congested)	–0.8	–0.38
Price elasticities of demand (uncongested)	–1.5	–1.0
Profit margin (%)	2.1	2.1
Emissions (Mt per annum)	245	567
Size of the EU airline sector (turnover, € billion/annum)	144	428
Fuel efficiency per annum	n/a	0.5

Appendix 2: Terms of Reference

Reviewing existing studies and literature, the contractor should consider:

- the financial impact on the aviation industry of bringing intra-EU flights within an environmentally effective, credible system of EU emissions trading, in comparison with the policy alternatives (e.g. APD, EU emissions charge)
- the impact of emissions trading on demand (passengers / annum)
- the institutional / legal / political steps necessary to bring aviation within the mandatory, open, cap & trade, EU emissions trading system

This should include an analysis of how the cost of mitigating a "tonne of CO_2 equivalent" rises with a more stringent cap, and the likely impact on airline ticket prices.

Given the key assumptions which follow, the following scenarios should be considered:

- For the emissions cap:
  - (A1) 25% emissions reduction against projected growth by 2008-12 (i.e. approximately +40% absolute emissions growth against a 1990 baseline)
  - (A2) 8% absolute emissions reduction by 2008-12 against a 1990 baseline, in context of the EU burden sharing agreement under the Kyoto Protocol
  - (A3) 60% absolute emissions reduction across the EU by 2050 against a 1990 baseline, in context of UK Government's vision as set out by the Prime Minister and in the Energy White Paper

- As regards the CO2 only v total climate change impact debate:
  - (B1) that aviation needs only 1 permit for each tonne of CO_2 emitted, with an EU aviation emissions charge used to address aviation's residual climate change impact (total impact may be assumed to be a) 3 times, and b) 2.5 times that due to CO_2 emissions alone)
  - (B2) that there is a focus on total climate change impact, with aviation needing a) 3 permits and b) 2.5 permits for each tonne of CO_2 emitted, and with no EU aviation emissions charge

  In scenario (B1), the contractor should also provide a view on how the two policy instruments would probably be implemented (e.g. would they be introduced at the same time or in sequence?).

In context of looking ahead to 2050, the contractor should also provide a view on:

- When the EU scheme might be expanded into a wider international emissions trading system (e.g. linking with Canada)
- When the EU scheme might be extended to include flights to/from the EU as well as flights within the EU
- When it might be possible to shift from a "CO_2 only" / "CO_2 multiplier" approach for aviation to a trading system which includes all aviation emissions

Key assumptions

For the purposes of this work, the contractor should assume:

- that aviation is brought within the mandatory, open, cap & trade, EU emissions trading system, within the wider context of the Kyoto Protocol
- that only flights within the EU are brought within the EU emissions trading system
- that international aviation emissions are allocated to countries (given their legal status as "parties to the UNFCCC"), on the basis that 50% of aircraft emissions are allocated to the country of departure and 50% to the country of destination
- that aviation would be treated equitably with other sectors in terms of permit distribution (auctioning v grandfathering), and with permit distribution taking place at EU member state level
- that aviation would be treated equitably with other sectors in terms of access to permits provided by the other Kyoto flexibility mechanisms (i.e. Joint Implementation and the Clean Development Mechanism)
- that, in terms of monitoring and verification, there should be no need for an aviation specific Emissions Trading Authority and the additional administrative costs this implies, as a single emissions trading authority could act for all sectors
- that there should be consistency, as far as practicable, with the emissions trading rules being developed under the UNFCCC process, and definitions and calculation methodologies should be consistent with the IPCC Good Practice Guidelines