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A study to estimate the impacts of emissions trading on profits in aviation

A report for Defra and DfT

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Executive summary

Objectives and relationship to previous studies

The extension of the European Emissions Trading Scheme (ETS) to cover the aviation sector may affect airlines' profits. This paper applies the latest economic theory to construct a model and populate it with market data from the aviation industry. The model estimates the level of free allocation (as opposed to auctioning or buying allowances from the market) that would cause the ETS to have a neutral effect on airlines' profits.

This is an analytical tool which has been developed to help explore some of the implications of aviation joining the ETS and the appropriate level of auctioning of allowances. It focuses on the level of free allocation which would maintain airlines' profits at their pre-ETS level. It is important to note that the Government has no predetermined objective to ensure that the allocation mechanism leads to a profit-neutral outcome. The results are illustrative and are designed to help build an understanding of the possible impact on profits under different assumptions.

This report builds upon earlier work on cost pass-through of allowance costs to ticket prices. This earlier work found that the rate of cost pass-through was likely to be around 100%, although conditions may sometimes occur where it is somewhat lower or very much higher. This report and the earlier work make use of the same model and data sets and the same preparatory investigation of the literature on emissions trading and the aviation sector. The background to the work, an introduction to the model and various ancillary topics are provided in a companion paper, published on the Defra website, detailing the earlier work on cost pass-through. That paper should be read prior to reading this paper.

Much of this report is concerned with the application of an economic model to represent the aviation sector. The economic model used here is founded on sound economic theory of firm behaviour. It is a simple generic and conceptual model and therefore is not able to represent the complexities of the aviation industry or its specific characteristics in detail. However, by inputting several aviation specific parameters, it can be used to provide an indication of the likely orders of magnitude of impact likely to be seen in the aviation industry.

General findings

Airlines' profits may fall when emissions trading is introduced even though prices are likely to rise. Ticket price increases would be likely to be caused by the additional costs of having to buy or hold allowances and result in fewer journeys sold. Revenues may decline for airlines where they face price-sensitive demand (elastic demand), but may increase where they face price-insensitive demand (inelastic demand). The scale of the effect is dependent on the responsiveness of demand to any change in price.

Profits are likely to be eroded relative to the pre-ETS position most quickly in markets in which there are few participating airlines, or where a few airlines supply the great majority of the market. The reduction of profits would be expected to be exacerbated where rival airlines have unequal marginal costs and where the number of fringe, small, high cost operators, is large.

Firms operating in the same market do not all experience the same impact on their profits. The modelling evidence suggests (without being conclusive) that larger airlines may experience more adverse impacts on their profits than smaller airlines. Within the model, larger airlines have higher profit margins. The consequence of emissions trading is that those larger airlines experience greater reductions in profits relative to their smaller peers and as a result, overall sector profits may fall by more than they would have if airlines of all sizes had been affected equally.

Illustrative estimates

Like all models, this model is a simplification of the real life complexity of the aviation industry. The model estimates the level of price changes from two pieces of information: the number of firms and the sensitivity of consumer demand to price changes. The results from this model can be used as a guide or indication of the real life outcome, but should not be interpreted as forecasts. The reality will be more complex and nuanced. As also stated in the report on cost pass-through, this modelling framework does not address the question of whether congested airports are a special case.

This indicative analysis suggests that the range of free allocation required in order to maintain total sector firm profits at their pre-emissions trading level is estimated at between 20% and 40% of emissions (pre-ETS emissions levels) for a wide range of market characteristics. Any additional free allocation above these levels would be likely to raise airline profits above their without-emissions trading level by the value of that additional allocation. Similarly, any shortfall in free allocation below these levels could reduce airline profits from their without-emissions trading level by the value of that shortfall in allocation. These results derive from a model which accounts for pass-through of prices into ticket prices, the responsiveness of demand to price changes, and competition between airlines on individual routes or groups of routes.

A second range, 40% to 70%, is generated from the Cournot analysis used here when **there are no more than two airlines supplying a particular route, and so competition is limited,** and while assuming specific passenger demand characteristics, thought to be more typical of leisure passengers. When the role of alternative routes and destinations is taken into account, there may however only be a few instances where there are no more than two airlines supplying the market.

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1 Introduction

1.1 Introduction

The extension of the European Emissions Trading Scheme (ETS) to cover the aviation sector may affect airlines' profits. This paper applies the latest economic theory to construct a model and populate it with market data from the aviation industry. The model estimates the level of free allocation (as opposed to auctioning or buying allowances from the market) that would cause the ETS to have a neutral effect on airlines' profits.

This is an analytical tool which has been developed to help explore some of the implications of aviation joining the ETS and the appropriate level of auctioning of allowances. It focuses on the level of free allocation which would maintain airlines' profits at their pre-ETS level[1]. It is important to note that the Government has no predetermined objective to ensure that the allocation mechanism leads to a profit-neutral outcome. The results are illustrative and are designed to help build an understanding of the possible impact on profits under different assumptions.

The economic model used is founded on sound economic theory of firm behaviour. It is a simple generic and conceptual model and therefore is not able to represent the complexities of the aviation industry or its specific characteristics in detail. For example, it is not possible to reflect exact price setting behaviour, nor how the results would change at a congested airport where supply constraints bite. However, by inputting several aviation specific parameters, it can be used to provide an indication of the likely orders of magnitude of impact likely to be seen in the aviation industry.

1.2 Structure of the report

The main sections are as follows.

Sections 2 and 3 notes a couple of points of detail on methodology and data relevant to the estimation of the level of profit-neutral free allocation.

Section 4 presents estimates of the profit-neutral level of free allocation and examines

[1] The results from the theoretical modelling framework used here are relative and are therefore not intended to reflect a specific year or any absolute profit level.

their sensitivity to alternative assumptions.

Section 5 briefly summarises the main findings of the report.

Section A1 sets out the formulae for the profit-neutral level of free allocation derived from a Cournot model of the behaviour of firms.

2 Approach

The methodology is set out in the companion report on cost pass-through, entitled *A study to estimate ticket price changes for aviation in the EU ETS*, available on Defra's website. It is suitable for estimating profit changes where permit prices represent a relatively small proportion of firms' overall cost base. It uses a Cournot model.

The Cournot model of quantity-setting firms is the most widely employed model in economics used to analyze imperfectly competitive markets. This is because it generally yields plausible results and is also very tractable to work with.

Like all models, this model is a simplification of the real life complexity of the aviation industry. The model estimates the level of price changes from two pieces of information: the number of firms and the sensitivity of consumer demand to price changes. The results from this model can be used as a guide or indication of the real life outcome, but should not be interpreted as forecasts. The reality will be more complex and nuanced.

In addition to the number of firms in the market and the shape of the demand function, which drive the rate of cost pass-through, as explained in the companion report to this paper, a further parameter drives the level of profit-neutral free allocation. This parameter is the distribution of firms' market shares, measured by an index called the Herfindahl Index, which measures the level of concentration within a market.

In practice firms may be more or less aggressive in their behaviour towards rivals than this modelling framework would suggest. Hence some of the results obtained for markets with large numbers of airlines may also occur when there are fewer, more aggressive airlines.

3 Evidence and data

3.1 Number of firms and market concentration

Table 1 shows the number of airlines operating routes between UK cities and France and the Herfindahl indices for those routes. These routes have been chosen for illustration only. The Herfindahl index is calculated using passenger seat kilometres as the measure of market share. It takes a value between zero and unity, where zero represents a very large number of firms with very small market shares, i.e. perfect competition, and the index rises with increasing concentration, reaching unity for a monopolist. The index falls from 0.96 for the narrowest market definition, Manchester to Nice, to 0.20, when the definition is expanded to the whole of the UK and France. The data were obtained from the CAA and are derived from air traffic control records of all flights to and from UK airports.

Table 1 The effect of the geographical scope of the market on the number of airlines and Herfindahl index, 2006

From	Manchester	Manchester, Liverpool and Birmingham	All UK	All UK
To	Nice	Nice	Nice	France
Number of airlines	1	4	6	13
Herfindahl Index	0.96	0.42	0.39	0.20

Note: airlines with market shares less than 1% are excluded. Source: Vivid Economics calculations based on CAA data

This sample of point-to-point routes shows that there are typically between two and four airlines operating on each route giving a Herfindahl index of between 0.33 and 0.50, as shown in Table 2.

In defining the market in this analysis we have relied upon studies of aviation markets by the European Commission and others, set out in the companion report. For less time sensitive and leisure passengers, some routes may act as substitutes for other routes, but this is less likely to be the case for business passengers. Even within a route, flights at different times of day may not be perfect substitutes and might constitute separate markets. In the long run, routes may also be contested by entry or threatened entry from other airlines.

Table 2 The number of airlines serving city pairs is small, 2006

From	London	Heathrow	London	London	South East England	UK
To	Prague	New York	Washington DC	Glasgow	Jersey	Beijing
Number of airlines	4	4	4	2	3	2
Herfindahl index	0.33	0.35	0.38	0.50	0.47	0.50

Note: airlines with market shares less than 1% are excluded. Source: Vivid Economics calculations based on CAA data

4 Discussion and results

4.1 Theoretical discussion

The outcome of emissions trading with no free allocation of allowances is likely to be a reduction in profits, because of the relationship between pass-through of costs to ticket prices and the subsequent passenger demand. Airlines' profits are likely to fall even though prices are likely to rise. The scale of the change in profits is influenced by several factors which are discussed below.

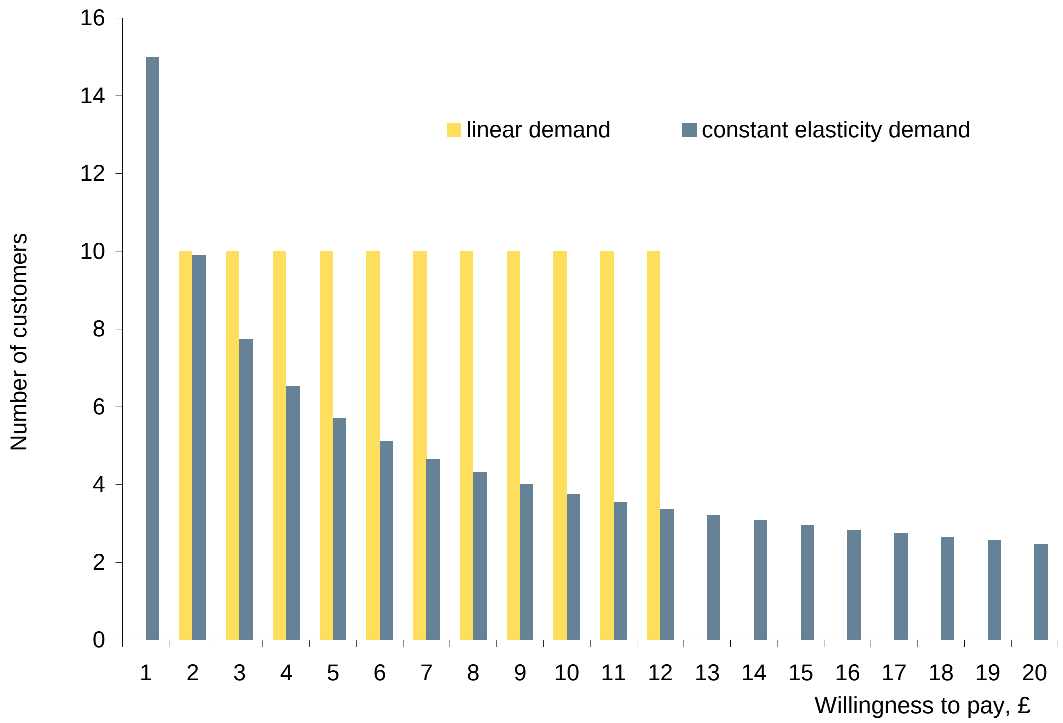
The consequence of ticket price increases is generally that fewer journeys are sold. It is likely that the airlines will experience lower profits when fewer journeys are sold and they may respond in various ways by trimming or re-allocating capacity and by changing the balance of prices across passenger groups.

In this situation, the rate at which sector profits fall depends upon the rate at which revenue rises or falls as prices rise, i.e. the shape of the demand function (the relationship between volume of air travel and ticket prices). It also depends upon the number of airlines and their market shares. Profits are most quickly eroded in markets in which a few airlines supply the great majority of the market.

In the discussion which follows there are two profiles of customer demand used in the economic model. In the first, a few customers are willing to pay large amounts for their tickets and increasing numbers are prepared to pay small amounts. This corresponds to a demand curve with constant elasticity. In the second, there is a uniform distribution of willingness to pay among customers. This corresponds to a linear demand curve. Both are shown in Figure 1.

The true profile of customer preferences is not known and has not been explored in this study. It may vary between routes and in customer patronage between airlines. It seems possible that the constant elasticity demand curve could be a fairer representation of business passengers than linear demand, because there are some business passengers who are prepared to pay very high prices for travel. The corollary is that the linear demand curve could be a fairer representation of leisure passengers (which account for the majority of the market) because there is a much lower proportion of leisure passengers who are willing to pay high prices to travel. The profile of willingness to pay will be reflected in the profile of ticket prices sold in the aviation industry and thus it may be possible to estimate it from ticket price data.

Figure 1 Profile of customers showing number of customers willing to pay exactly a given amount for a ticket, illustrative figures



Source: Vivid Economics

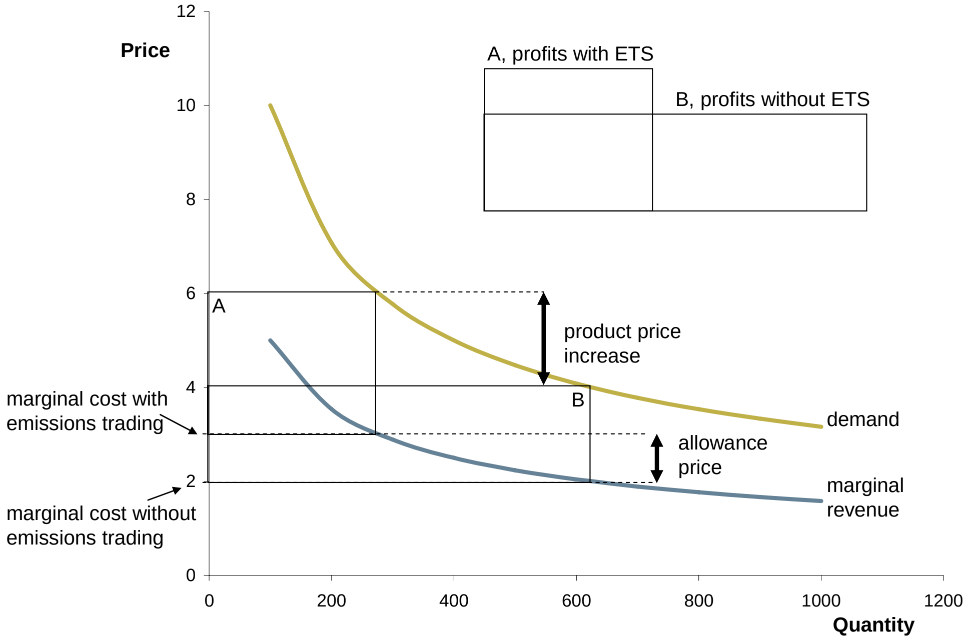
4.1.1 The simple case of monopoly

The following is a theoretical exploration of possible effects. It is not claimed here to be an accurate reflection of what would happen in aviation, but is indicative of possible outcomes.

Let us begin by examining the extreme case of a monopolist—a market served by one airline. Aviation markets rarely have a monopoly structure, but the example is simple to draw and indicates the results that are obtained when there are several airlines competing. The reduction in profits as a consequence of emissions trading is shown in Figures 2 and 3 for a monopolist. Figure 2 illustrates the outcome for a constant elasticity of demand function.

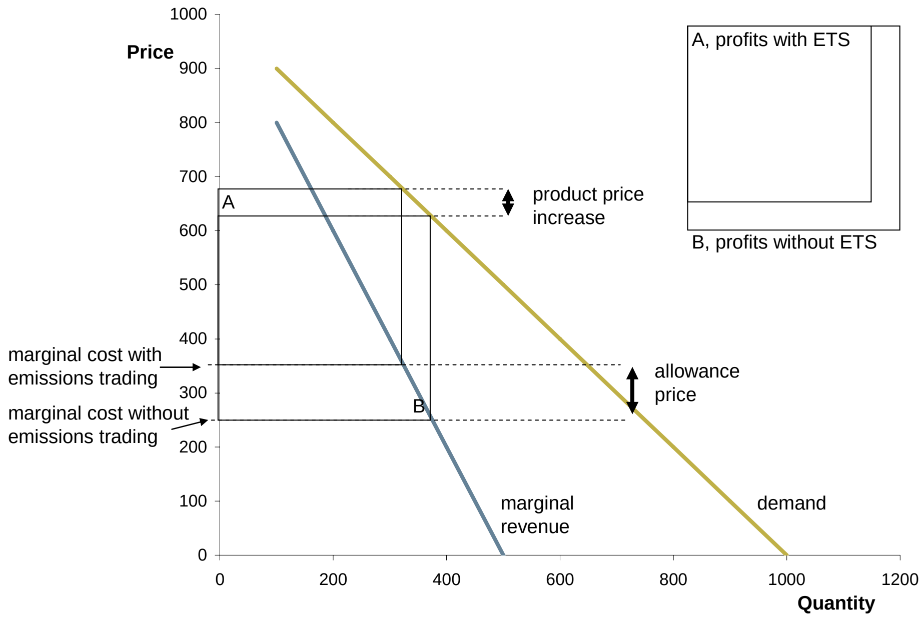
Initially, the marginal cost is 2 and the price is 4. With emissions trading and a cost of allowances of 1, the total marginal cost is 3 and the price is 6. The rate of cost pass-through is 200%. The price-cost mark-up has risen from 2 to 3, but the volume of sales has fallen. Overall, profits have fallen. Area A represents profits with emissions trading and Area B is profits without emissions trading. Area B is larger than Area A, showing that profits fall when emissions trading is introduced. Note that profits fall even though cost pass-through is greater than 100%. Figure 3 presents the analogous picture for a linear demand function. In this case, profits fall, as before, but cost pass-through is less than 100%.

Figure 2 The effect of emissions trading on profits of a monopolist, constant elasticity demand function



Source: Vivid Economics

Figure 3 The effect of emissions trading on profits of a monopolist, linear demand function



Source: Vivid Economics

The cases outlined above indicate that output falls faster than prices, resulting in falling revenues and lower profits. It is exacerbated by the increase in marginal costs, which also erodes profits.

In most aviation markets, the situation is more complex because there are several firms operating in the market. Let us explore this more complex, real life situation in which pricing strategies differ between airlines and are more complex than in some other markets, and in which a single airline may operate a variety of types of service.

The aviation sector has relatively few airlines operating each route. These firms may find themselves in one of two unwelcome circumstances. Either they raise prices by more than the cost increase, in which case they suffer the loss of a large volume of sales, as in Figure 2. Or, in alternative demand conditions, they raise prices by less than the cost increase, foregoing some price-cost mark-up and hence profitability, as in Figure 3. The net result in each case is a fall in profits even though the firms are taking the optimal action to maximise the profits available to them. This behaviour makes sense for firms which have market power. When firms with market power change their prices, their pricing decisions affect their volume of sales, therefore they have to consider the effect on their total revenue of a change in prices. In other words, the suppliers are constrained by the demand-side response.

This is a different outcome from a market where there are many small firms. In this situation, firms offer prices with reference to costs only and without regard to revenue. The firms calculate the price at which they can recover the costs of producing an additional unit of output. If they face a cost increase, they pass it through to prices, and they do not have surplus profits at risk. In a perfectly competitive world, firms cannot hold prices above cost because they are immediately undercut by rivals offering a product that is priced at cost.

This is not to say that firms with market power are making excessive profits, although that is also possible. Indeed they may need to make higher profits on operating activities in order to meet the cost of financing large capital investments. The economists' notion of a perfectly competitive world of many small firms does not allow those firms to recover fixed costs or large capital outlays associated with production. When an airline establishes a service on a route, it has to make a capital and other contractual commitments in marketing and vehicle contracts. It needs to have some market power in order to recover these sunk costs.

4.1.2 The case of oligopoly and a constant elasticity demand function

The model employed in this study does not assume that all airlines have identical market shares and costs, but rather uses the *observed* distribution of market shares for illustrative routes, which implies that airlines have different costs. This relationship between profit margin and market share, or equivalently (when there is one prevailing price) market share and marginal cost, is a theoretical and well-established result obtained from the Cournot model. It is not an assumption of the model but is instead a result obtained from it. It can be understood by considering the last unit of output that a low-cost firm can sell profitably, i.e. the marginally profitable flight. For a firm with even slightly higher unit costs, this flight is not profitable and hence will not be offered. There is no way that a higher cost firm could have a higher market share.

Emissions trading is likely to cause shifts in relative costs between airlines and thus their market shares, and these shifts in market shares can have a considerable effect on the profit-neutral level of free allocation. Airlines with smaller market shares win market share from their larger rivals. Hence some airlines benefit at the expense of others.

In order to understand how these effects come about within the Cournot modelling framework used in this report, first consider some simple examples. Here are three examples, each involving two airlines.

Suppose that before the trading scheme is introduced the data reveal that Airline A has a market share of 2/3 = 67% while Firm B has a market share of 1/3 = 33%. In the Cournot framework, Firm A will, in equilibrium, have an (operating) profit margin that is twice that of Firm B. This is a standard result from the economic theory. It is often borne out in practice.

Further suppose that low-cost Firm A has a profit margin of £2 per unit, while high-cost Firm B has a profit margin of £1. Now an emissions trading scheme is introduced that increases each firm's marginal cost by, say, £1. Consider three scenarios for the rate of cost pass-through onto the market price.

— Suppose that the rate of cost pass-through is positive, but very small (say 1%). This means that Firm A's profit margin falls from £2 to just over £1. However, the profit margin of the less efficient Firm B falls from £1 to essentially zero. This implies that, with this low rate of cost pass-through, Firm A's profit margin is now much higher than Firm B. Firm B will have lost almost all its market share to Firm A.

— Suppose now that the rate of cost pass-through is 100%. This implies that both Firm A and Firm B's profit margins are unchanged. In the Cournot framework employed, this means that the market shares are also unchanged at 2/3 = 67% and 1/3 = 33% respectively.

— Finally, suppose that the rate of cost pass-through is 1,000% (for the sake of argument). This means that Firm A's profit margin now is £11, while Firm B's is £10. In the Cournot framework, this implies that Firm A's market share will have fallen from 2/3 = 67% to 11/21 = 52%. Conversely, the smaller, high-cost firm's market share has risen from 1/3 = 33% to 10/21 = 48%. Firm B's profit must also have risen since its profit margins are (much) higher and it has also gained market share.

Note that gross profit margins fall unless 100% or more of costs are passed on.

Table 3 Changes in market share caused by changes in profit margins, when

cost pass-through is greater than 100%

	Initial scenario	Scenario 1	Scenario 2	Scenario 3
Rate of cost pass-through		1%	100%	1,000%
Firm A profit margin	2	1	2	11
Firm B profit margin	1	0	1	10
Firm A market share	2/3 = 67%	1/1 = 100%	2/3 = 67%	11/21 = 52%
Firm B market share	1/3 = 33%	0/1 = 0%	1/3 = 33%	10/21 = 48%

Source: Vivid Economics

The smaller firms manage to capture a larger share of the market and some production switches from the larger, lower-cost firms to the smaller, higher-cost firms. As a result, the average cost of production rises and sector profits fall.

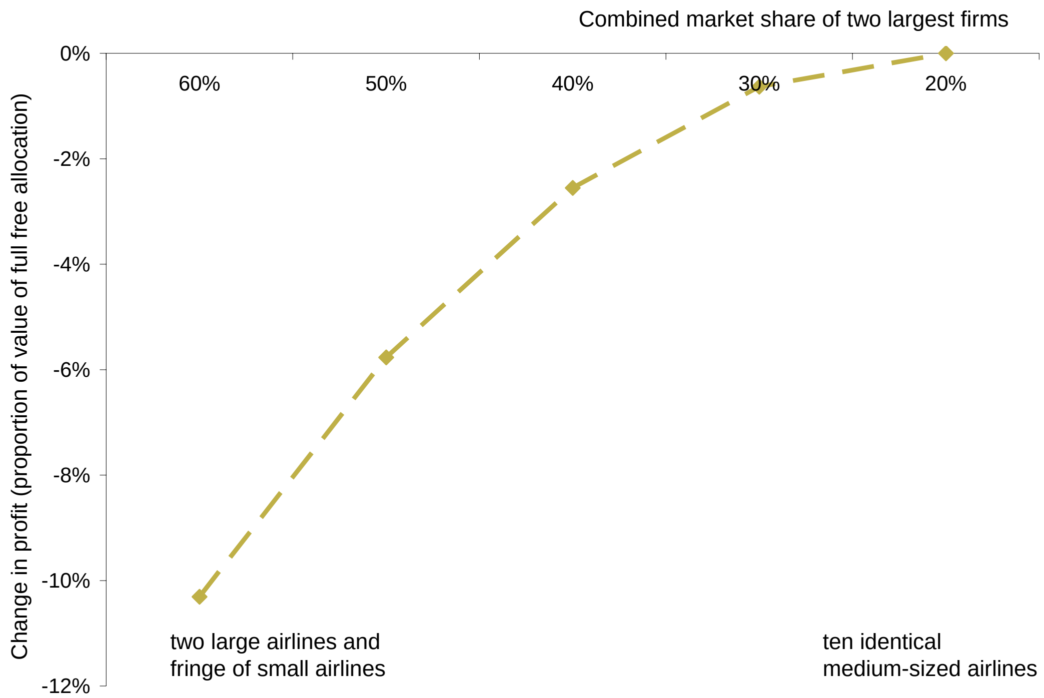
In summary so far, for a constant elasticity demand function, there are several effects:

- Although costs have risen, this is offset to the extent that firms benefit from product price rises as a result of passing through a proportion of the allowance price;
- firms lose out from a lower volume of sales as a consequence of lower consumer demand, which follows on from product price rises;
- small firms, whose market shares increase, benefit from higher volumes of sales by taking customers from their rivals;
- large firms, whose market shares fall, lose out from lower volumes of sales by ceding customers to rivals;
- the average cost of production rises as customers switch from larger to smaller, higher-cost firms.

In Figure 4, some of these effects are summarised using constant-elasticity demand curves. Figure 4 shows the effect of **customer switching** on profits for an imaginary oligopoly of 10 firms, in which there are two large airlines and eight identical small airlines. The vertical axis measures profit lost due to customer switching in proportion to the cost of emissions with no free allocation. The horizontal axis depicts the combined market share of two large airlines. At the right hand side of the chart, when the combined market share of the two large airlines is 20%, all ten airlines in the market have the same market share. At the left hand side of the chart, when the combined market share of the two large airlines is 60%, the disparity in market shares between the large and small airlines is the largest.

The chart shows how a greater variance in airline size within the industry (moving from right to left) creates larger profit reductions due to switching. It reveals that airlines suffer a greater reduction in profits upon the introduction of emissions trading when they have non-identical market shares than if they all have the same market share. The greater the disparity of market shares, the greater the impact on profits. As noted earlier, this is because the Cournot model assumes that smaller firms have higher costs and hence lower profit margins. If these higher-cost firms achieve a higher market share, the aggregate level of profits will be depressed.

Figure 4 Change in sector profit when emissions trading is introduced



Source: Vivid Economics

Although the effect of market share switching on profits is important, it is smaller than both the change in the industry aggregate volume of sales and the effect of product price increases.

These results are most likely to be observed among aviation services where the customer mix is relatively heterogeneous, such as business or mixed business and leisure flights, because this mix is likely to give rise to demand that is similar to constant elasticity demand. The alternative case, homogenous customers, may be seen in leisure only and charter services. It is noteworthy that the majority of airline passengers are leisure passengers.

4.1.3 The case of oligopoly and a linear demand function

So far, the illustrations have involved rates of cost pass-through of greater than 100% associated with a constant elasticity demand function. Although this is possible in some airline markets, it may not be representative of the industry as a whole, as different segments of the market demonstrate different demand characteristics. Demand could also demonstrate linear demand characteristics where cost pass-through is below 100%. There is little or no evidence on the precise nature of demand for aviation services so both have been considered here. In the situation of linear demand, profit margins decrease and large, low-cost firms' profit margins increase relative to small firms' profit margins such that the large firms gain market share at the small firms' expense. Under a linear demand function, in contrast to the charts above, customer switching to some extent offsets the negative impact of emissions trading on profits. A higher number of small firms produces an enhanced offsetting impact on sector profits and similarly a higher market share for the large companies enhances the offsetting impact.

In summary, for a linear demand function,

- Again, although costs rise, this would be offset to the extent that firms benefit from product price rises as a result of passing through a proportion of the allowance price;
- firms lose out from a lower volume of sales as a consequence of lower consumer demand, which follows on from product price rises;
- large firms, whose market shares increase, benefit from higher volumes of sales by taking customers from their rivals;
- small firms, whose market shares fall, lose out from lower volumes of sales by ceding customers to rivals;
- the average cost of production falls as customers switch from smaller to larger firms, because larger firms have lower marginal costs in the Cournot framework.

These results are most likely to be observed among aviation services where the customer mix is relatively homogenous, such as leisure only services, because this mix is likely to give rise to demand that is similar to linear demand.

These distributional effects resulting from changes in the rate of cost pass-through have implications for the profit-neutral free allocation of emissions allowances.

4.2 Illustrative estimates

The results based on market data for a sample of routes are shown in Table 4 and Figure 5 below. The rates of impact on profits with no free allocation range from 10% to 70% of emissions costs (where emissions costs are the firm's pre-ETS emissions levels valued at the market price of allowances[2]). The range of results under linear demand is 10% to 70%, but under constant elasticity demand it is (with a single exception) 10% to 45%. As discussed earlier, linear demand may correspond to leisure passengers and constant elasticity demand to business passengers, but there is little evidence to confirm this.

In the leisure market segment, the route North-West of England to Nice is selected as illustrative of a typical leisure market. In the business market segment, the point-to-point Heathrow-New York route is used as an example. In the freight market, time-sensitive freight is represented by Heathrow to New York and non-time-sensitive freight by a Europe-wide market definition.

The overall variation in impact on profits is much more dependent on the choice between demand functions representing leisure or business customer markets than between elasticity assumptions within the latter group of demand functions (though lower elasticities tend to generate smaller impacts on profits). On some routes, such as UK to Beijing, this divergence in results is large. On other routes, such as London to Prague, it is small. When there is a large number of firms the linear demand function produces a smaller allocation than the constant elasticity demand function, and where there is a small number of firms, the relative size of allocations is reversed.

The theoretical model used here suggests that for markets where the firms are around four in number, the impact on profits with no free allocation is between 20%

[2] As noted earlier, the results from the modelling framework are relative only and therefore do not refer to any specific year or absolute profit levels.

and 40% of the cost of allowances and is fairly insensitive to the choice of demand function and elasticity. Many of the more popular routes are supplied by around four airlines. Hence airlines are likely to experience a reduction in profit equal to between 20% and 40% of the cost of their emissions for many of their leisure and business passenger services, if they receive no free allocation. Where allowances are distributed for free, the impact on profits would of course be lower.

For routes served by fewer airlines, the choice of demand function becomes significant. On routes where there are only one or two airlines serving leisure passengers, the modelling used here suggests that the impact on profits is higher, at around 40% to 70% of the value of total emissions (pre-ETS emissions levels).

In conclusion, there are two ranges for the impact on profits with no free allocation. The illustrative cases indicate that a range 20% to 40% of the cost of allowances would be the estimated impact on profits for a wide range of market characteristics where the customer base is business or leisure. This range is derived from both the constant elasticity demand results and the linear demand results involving three or more airlines. This would cover the majority of air services by volume of passenger kilometres and revenue. The illustrative cases also suggest that a range of 40% to 70% is appropriate for services where the customer base is leisure if at the same time there are fewer than three airlines. This is derived from the linear demand results for the Glasgow and Beijing routes. As explained above, these rates are likely to vary across routes and airlines and if allowances are allocated for free, the impact on profits would be lower. The results are indicative and may not be experienced by every airline in the industry.

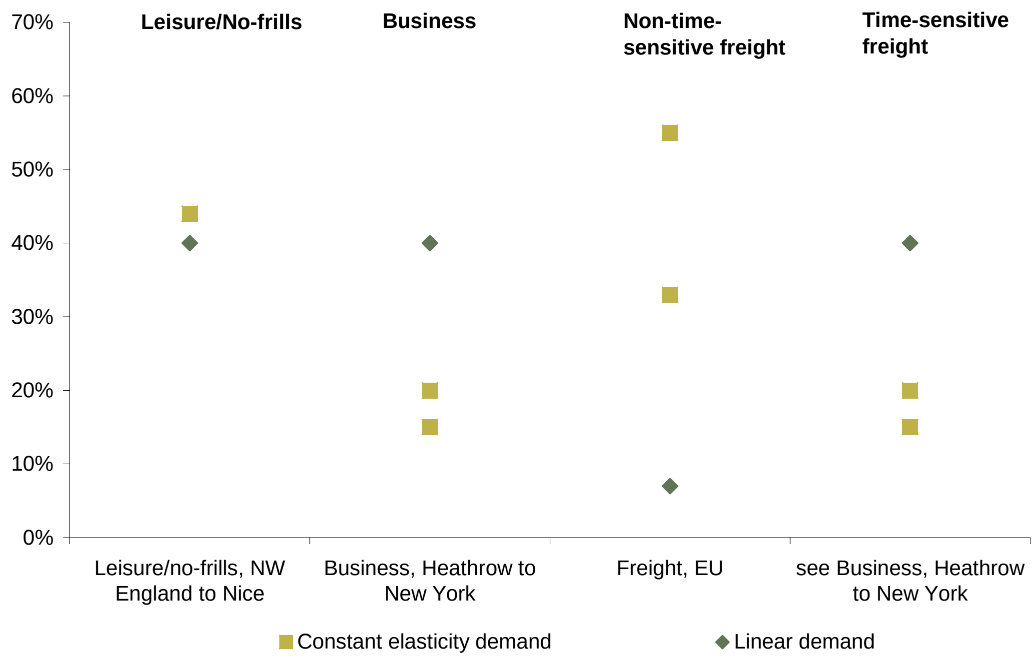
Where there are a large number of airlines serving the market, for example, the time-sensitive freight market, the illustrative results are given as any EU origin to any EU destination. These results, 7% for linear demand and 33–55% for constant elasticity demand, are particularly sensitive to the shape of the demand curve and it is not clear which offers the best representation of actual market conditions.

Table 4 Impact on profits with no free allocation under different market definitions and demand assumptions, expressed as proportion of the cost of pre-ETS emissions levels

From	North West England	London	Heathrow	London	London	South East England	UK	Any EU (Non-time sensitive freight)
To	Nice	Prague	New York	Washington DC	Glasgow	Jersey	Beijing	Any EU
Number of firms	4	4	4	4	2	3	2	26
Linear demand	40%	40%	40%	40%	67%	50%	67%	7%
Price elasticity	1.2–1.3	0.7–1.3	0.6–0.7	0.7	1.1–1.3	0.7–1.3	1.1–1.3	0.5–1.5
Constant elasticity demand	44–44%	15–26%	15–20%	31%	8–18%	37–43%	9–20%	33–55%

Note: the data for any EU to any EU is taken from a database of all flight records from and to EU destinations. No range is stated for London to Washington DC as the model's conditions are not satisfied for elasticities less than 0.7. This is also the reason for the short ranges, for some of the other routes. Source: Vivid Economics

Figure 5 Impact on profits with no free allocation for a sample of markets, expressed as proportion of the cost of pre-ETS emissions levels



Source: Vivid Economics

It is not clear how the results would change if the airlines were not profit-maximising. If airlines do not profit-maximise but instead pursue sales revenue or market share maximisation, they may not find their profits affected in the same way as profit-maximising firms would have done. The effect of these alternative strategies is to make firms set lower prices to attract higher sales. The result, a smaller price increase, is the same result that would have occurred if profit-maximising firms had been facing more rivals. It is not certain what effect this would have on the change in profits from trading.

5 Conclusions

Firms' profits are likely to fall even though prices rise, if the ETS were introduced with no free allocation. The consequence of ticket price increases is fewer journeys sold. With fewer journeys sold, volumes decline and so do profits for the average firm.

Firms operating in the same market do not all experience the same impact on their profits. For airlines with a mixed customer base, the larger airlines are predicted to experience greater impacts on their profits than smaller airlines because the price rises may help smaller airlines increase their market share.

The effect on profits is also influenced by the profile of firms within the sector. The relative size of firms and their number both affect the extent to which profits are diminished by emissions trading. In the Cournot framework, the impact on profits is greatest in markets in which there are few participating airlines, or where a few airlines supply the great majority of the market.

The impact on sector profits with no free allocation is estimated here at between 20% and 40% of the cost of emissions (pre-ETS emissions levels) for a wide range of market characteristics, including those most likely to be found in aviation markets. **A second range, 40% to 70%,** is generated when **there are fewer than three airlines supplying a particular route** and while assuming characteristics more typical of leisure only services.

In summary, this indicative analysis suggests that a reduction in profits equal to 20–40% of the cost of emissions (pre-ETS emissions levels) would occur in the absence of any free allocation under a wide range of circumstances with two exceptions. The first exception is in the non-time-sensitive freight market insofar as it has the characteristics of linear demand, in which case the profit forgone would be smaller. The second exception is where there are routes served by one or two airlines where the patronage has the characteristics of linear demand, where the profit forgone would be larger. The latter case is the only case in which a higher level of free allocation, 40–70%, would lead to a profit neutral-outcome. In all other circumstances this higher level of free allocation would lead to higher profits than would occur without emissions trading.

It should be remembered that the modelling framework used here relies on simplified theoretical underpinnings and is therefore not able to capture the real complexities of the aviation industry. In reality, the nature of competition, price setting behaviour and other factors would be more sophisticated than any model can capture so the illustrative results here should be interpreted against that background.

A1 Cournot model

This appendix provides a technical explanation of some of the features of the model used in this paper.

Herfindahl index

The use of the Herfindahl index in the Cournot modelling undertaken here is reflective of the analysis undertaken by competition authorities for assessing market concentration and market dominance. However, in competition cases, the Herfindahl index is just one of many indicators and it is often recognized that the index provides only a partial picture of competitive dynamics within an industry. Such caveats do not apply within the confines of the model used here because the use of the Herfindahl index is *directly* shown by the Cournot model to be the relevant variable. A firm-level analysis of profit-neutral free allocation depends on the market share (σ_i) of the firm. Thus, it should not be surprising that the industry-level analysis reflects the overall distribution of market shares, which is fully captured in the Herfindahl index (*H*) according to the equation below.

$$H = \sum_{i=1}^{N} (\sigma_i)^2$$

Profit-neutral free allocation

The theoretical framework developed by Hepburn, Quah and Ritz (2006) determines profit-neutral free allocation in a Cournot oligopoly setting with linear production costs and profit-maximizing firms. The framework employs a linearization technique that makes it possible to disregard any unnecessary assumptions on the shape of the demand curve or firm symmetry. The linearization technique is a useful simplification that is likely to provide a better representation of the profit-neutral free allocation level where permit prices are a smaller proportion of the firm's overall cost base.

Intuitively, the proportion of free allocation needed to ensure profit-neutrality for an industry as a whole, or a particular market segment thereof, reflects the *operating* profit lost per unit of industry output.

Profit-neutral free allocation at the industry level satisfies:

$$G = \frac{2-(2-NH)E}{N+1-E} \gtreqless 0$$

G thus depends on the number of firms (N), the demand curvature parameter, E, as well as the Herfindahl index of concentration.

It is possible for *G* to be *negative*, which occurs when the industry's operating profits increase as a result of emissions trading. In contrast, it is also possible for *G* to be greater than 100% with sufficiently high levels of industry asymmetry, specifically when E>1 (fulfilled for all elasticities on all constant elasticity demand curves) and H>2/(N+1) (there is a high concentration of market shares). The demand curvature condition ensures that cost pass-through is greater than 100%, so that all firms' absolute profit margins increase with the introduction of the ETS. Small firms, with lower absolute profit margins, benefit relatively more and therefore gain market share from large firms. If one or two large firms have a very high market share, then the industry intuitively has 'more to lose'; the scale of their losses exceeds the gains to the small firms and requires a profit-neutral free allocation of greater than 100%.

When the number of symmetric firms grows large, thus approaching perfect competition, *G* tends towards zero; that is, no allowances have to be grandfathered to ensure profit-neutrality. The reason for this is that in a perfectly competitive industry, firms are making zero economic profits before the introduction of the emissions trading, and indeed after its introduction. Therefore no free allocation is necessary to preserve profits.

The relationship between elasticity and *G* was shown to vary depending on the number of firms and the Herfindahl index. *G* falls as elasticity increases when H>2/(N+1), the same condition of industry asymmetry required for profit-neutral allocation to exceed 100%. The intuition is also similar; lower elasticity (higher demand curvature) implies higher cost pass-through, which increases absolute operating profit margins. Since small firms then gain a greater market share from larger firms, the losses to the larger firms are larger than the gains to small firms and the profit-neutral free allocation level must be higher to compensate the large firms.

The elasticity approach

Due to the paucity of data, it is necessary to transform the preceding equation to reflect demand elasticity rather than demand curvature. Under the assumption of constant elasticity demand, the demand curvature parameter can be expressed as

$E=1+1/\eta>1$, where $\eta=|P/P'(Q)Q|$ is the price elasticity of demand. Then the formula for profit-neutral free allocation can be rewritten as:

$$G = \frac{2-(2-NH)(1+\frac{1}{\eta})}{(\frac{N-1}{\eta})} \gtreqless 0$$

For many products, it is possible to obtain estimates of the price elasticity of demand, which can be used in this formula together with the number of firms and the Herfindahl index. This approach leaves open both the possibility that profit-neutral free allocation is negative and that it exceeds 100%.

It is necessary to test that the following (very weak) conditions are satisfied for each market segment and each firm in each market segment respectively:

- cost pass-through is positive and there is a unique equilibrium to the model, $N+1-E>0$;
- the second-order condition for profit-maximisation is satisfied, $2-\sigma_i E>0$ for each firm;
- the level of marginal costs implied by a firm's market share is non-negative, $\sigma_i<\eta$ for each firm;
- the equilibrium is locally stable, such that a small 'shock' to the industry still leads to convergence to the unique equilibrium, $N+1-N\sigma_i E>0$ for each firm;
- firms compete in symmetric strategic substitutes, such that under delegation a firm prefers to be an 'aggressive leader', rather than a follower, $N-E>0$.

References

Hepburn, C., Quah, J. and Ritz, R. (2006), *Emissions trading and profit-neutral grandfathering*, Discussion paper 295, Department of Economics, Oxford University

Other references may be found in the companion report to this paper.