Impacts of Competition Enhancing Air Services Agreements: A Network Modelling Approach

Staff Research Paper

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June 1999

The views expressed in this paper are those of the staff involved and do not necessarily reflect those of the Productivity Commission. Appropriate citation in indicated overleaf.

ISBN 0 646 33599 5

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An appropriate citation for this paper is:

Gregan, T. and Johnson, M. 1999, *Impacts of Competition Enhancing Air Services Agreements: A Network Modelling Approach*, Productivity Commission Staff Research Paper, AusInfo, Canberra.

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IMPACTS OF COMPETITION ENHANCING AIR SERVICES AGREEMENTS: A NETWORK MODELLING APPROACH

This research paper supplements appendix F of the Productivity Commission report on International Air Services (PC 1998). It provides the technical details to the model developed in the course of the Commission's inquiry. This paper is directed to a technical audience. Policy details and institutional information are found in the Inquiry report (PC 1998). The objective of the modelling is to support the Inquiry report in addressing a number of its terms of reference, namely:

> (d) assess whether the International Air Services Commission allocation process provides net benefits to Australia, including reference to the value of provisions designed to favour new entrants;
>
> (e) analyse and assess the benefits, costs and overall effects of the international aviation regulatory framework ... for tourism, consumers, air freight and the aviation industry; ... and
>
> (g) assess the options for greater liberalisation.

The paper has five parts. The first part is a review of recent literature regarding the passenger aviation industry and its applicability to the questions addressed by the inquiry. The second part presents the general theory of the airline network problem, the price-setting behavioural model and its numerical solution algorithm. The third part presents the specification of the model for the Australia–Asia air travel market. The fourth part presents the implementation of the Ansett entry simulation. The fifth part examines the impact of altering current Air Services Agreements (ASAs) by creating an open club of countries, in which club member airlines can fly as they wish between each others' countries. An appendix contains a table of base cost data by flight sector, a summary of validation experiments which test the ability of various demand and cost specifications of the model to replicate observed quantities and prices, a discussion of the sensitivity of Ansett results to various demand parameter assumptions and a representative GAMS[1] program used for the base case scenario in the multi-market network model.

There have been three approaches in the literature to test which factors affect airfares. The first two approaches involve econometric methods and the third is spatial modelling.

The first econometric approach tests whether market concentration variables together with demand and cost variables explain airfares better than demand and cost variables alone. This literature includes Brueckner and Spiller (1991), Brueckner, Dyer and Spiller (1992), Dresner and Tretheway (1992), Evans and Kessides (1993), Evans and Kessides (1994), Hurdle, Johnson, Joskow, Werden, and Williams (1989), Industry Commission (1997), Oum, Park and Zhang (1996), Oum, Zhang and Zhang (1993), and Savage, Smith and Street (1994). These studies generally find that the level of market concentration and the presence of hub and airport restrictions lead to higher airfares. However, the application of this approach to proposed policy changes is likely to give misleading results because current aviation agreements are a constraining factor in all time series observations. Estimated statistical relationships for current arrangements are unlikely to apply under alternative arrangements. Therefore this approach is of limited value for this inquiry.

The second approach also uses econometric methods, but focuses on the economies of airline networks. In particular, this literature searches for economies of scale or density or for productivity differences in airline networks. One method explicitly or implicitly constructs a summary output measure for all network outputs, eg revenue passenger kilometres or revenue freight kilometres, and compares it to a summary measure of inputs. Cost function methods nest the comparison of outputs and inputs within an explicit economic framework. Examples of the literature include Caves, Christensen and Tretheway (1984), Kirby (1986), Gillen, Oum and Tretheway (1990), Brueckner and Spiller (1994), Oum and Yu (1995), Oum and Zhang (1997). The findings are mixed, although it is generally accepted that economies of density exist. That is, more passengers carried within the same network of cities leads to lower costs per passenger kilometre. However, the research for the Inquiry aims to explore the economies of airline networks with respect to the markets they serve and the air services agreements that may hinder them. Therefore, representation of a network by a single output variable would be inappropriate.

[1] For more information on the GAMS computer software package see: Brooke, Kendrick and Meeraus (1992); Meeraus (1983); and Bisschop and Meeraus (1982).

The third approach in the literature is spatial modelling. Examples include Berechman and de Wit (1996), Gillen, Harris and Oum (1997), Hendricks, Piccione and Tan (1995), Lederer (1993), Nero (1996), Zhang (1996), and Brueckner and Spiller (1994). In this approach, airfares and airline networks are embedded in a model that explicitly accounts for the demand for air travel, the costs and operation of airline networks and the strategic interactions of airlines. The costs of resource misallocation arising from restrictions placed on a network's development and operation by multilateral agreements can then be estimated.

The conceptual framework embodied in the model developed in this study draws heavily on three articles. The demand specification draws on Gillen, Harris and Oum (1997) (GHO), who estimate the gains from liberalisation of air travel between Canada and Japan and between Canada and Germany. Their model employs a constant elasticity of substitution (CES) demand specification which assumes airlines offer services that are imperfect substitutes and customers care about price and non-price attributes (eg frequency of service).

The specification of market behaviour draws on Lederer (1993), who shows the existence of a (unique) non-cooperative equilibrium in a model which can be adapted to this study. His demand specification differs from GHO but assumes as GHO does that airlines compete in price and non-price attributes of service.[2]

Hendricks, Piccoine and Tan (1995) is useful in specifying the airlines' networks for two reasons. First, it demonstrates that hub and spoke networks can be profit-maximising network designs under the cost and demand conditions that characterise airline networks. Second, it disentangles the network passenger flows from passenger demand within an imperfectly competitive framework.

Theoretical framework

The theoretical framework is formulated in a general way which can be modified to suit any aviation market. Its application to the Australia–Asia market is discussed in the next section. Although generally stated, the model describes aviation markets at a point in time. As such it is a short-run model. Conditions for airline entry or exit are not discussed. In addition, asset decisions

2 Lederer (1993) assumes that consumers minimise the total cost of travel where non-price attributes are given in money equivalents. By implication, a single consumer treats airlines services as perfect substitutes subject to a quality mark up expressed as a dollar value. The CES specification used by the Commission can be construed as an approximate aggregation of heterogeneous consumers in a national market.

(aircraft, terminals or overheads) are not made with reference to market conditions over the life of the assets. The theoretical model is specified in three parts. These are demand for air services, airline networks, and price-setting airline behaviour.

The following notational convention will be used. The set of airlines is *A*. The generic element of *A* is denoted by *ac*. To identify the origins and destinations of passengers, the subscripts *o*-*d* will be used, respectively. To identify the origin and destination of a flight between two cities (a flight sector), the subscripts *i*-*j* will be used, respectively.

Demand for air services

The demand follows a nested decision process based on a CES demand system for air travel that is separable from other goods and services. That is, there is an aggregate demand for travel from origin *o* to destination *d* which is disaggregated to airlines according to their relative prices as influenced by the CES demand parameters.[3]

To construct the demand system, the following are defined. *MS(ac,o,d)* is a set of three dimensions, airlines, origins and destinations that defines the markets and the airlines that serve them. The sets $MS(ac/o,d)$ and $MS(o,d/ac)$ are, respectively, the set of airlines that serve an *o*-*d* market and the set of *o*-*d* markets that airline *ac* serves. *qd(ac,o,d)* is the quantity demanded for travel on airline *ac* from origin *o* to destination *d*. *totfreq(ac,o,d)* is the total frequency of travel offered by airline *ac* from origin *o* to destination *d*.[4] *qdadj(ac,o,d)* is the quality adjusted quantity demanded of *o*-*d* travel on airline *ac*. *p(ac,o,d)* is the price of travel on airline *ac*. *padj(ac,o,d)* is the quality-adjusted price of travel on airline *ac* from origin *o* to destination *d*. *qagg(o,d)* is the aggregate (quality adjusted) quantity of travel demanded from origin *o* to destination *d*. Finally, $\alpha(ac,o,d)$, $\beta(o,d)$, $\sigma(o,d)$, $\eta(o,d)$, and *AGG(o,d)* are parameters of the demand system in the *o*-*d* market.

The following system of demand equations defines the demand system for every pair of passenger origins and destinations.

$$qdadj(ac,o,d) = totfreq(ac,o,d)^{\beta(o,d)}\, qd(ac,o,d),\ \forall(ac,o,d) \in MS(ac,o,d); \qquad (1)$$

$$padj(ac,o,d) = totfreq(ac,o,d)^{-\beta(o,d)}\, p(ac,o,d),\ \forall(ac,o,d) \in MS(ac,o,d); \qquad (2)$$

3 An explanation of nested CES functions can be found in Armington (1969,1970).

4 Its connection to the frequency of service across flight sectors is defined later.

$$pagg(o,d) = \left(\sum_{MS(ac|o,d)} \alpha(ac,o,d)\, padj(ac,o,d)^{1-\sigma(o,d)} \right)^{1/(1-\sigma(o,d))}; \qquad (3)$$

$$qagg(o,d) = AGG(o,d)\, pagg(o,d)^{\eta(o,d)};\ and \qquad (4)$$

$$qdadj(ac,o,d) = \alpha(ac,o,d) \left(\frac{padj(ac,o,d)}{pagg(o,d)} \right)^{-\sigma(o,d)} qagg(o,d), \quad \forall (ac,o,d) \in MS(ac,o,d); \qquad (5)$$

Flight quality in this specification depends only on the frequency of *o-d* service offered by the airline. Thus equation (1) defines quality adjusted quantity of travel on airline *ac* as a function of the raw quantity demanded on airline *ac* and the total frequency of service on airline *ac*. $\beta(o,d)$ is positive so that an increase in flight frequency improves the quality of a trip on the airline.

Similarly, equation (2) relates the quality adjusted price for travel on an airline to the frequency of travel on the airline and the price of travel. Because $\beta(o,d)$ is positive, the equation implies that an increase in flight frequency reduces the quality adjusted price of a trip to the consumer for a given airfare.

Equation (3) defines the aggregate price of travel from origin *o* to destination *d* as a function of the quality adjusted prices of trips on airlines. The $\alpha(ac,o,d)$ are weights which sum to one. $\sigma(o,d)$ is the constant elasticity of substitution parameter. By assumption, airlines offer substitute services and $\sigma(o,d)$ is greater than one. Services are more substitutable as the value of σ is increased.

Equation (4) relates the aggregate demand for air travel to the aggregate price. $\eta(o,d)$ is negative and is the own price elasticity of aggregate demand. *AGG(o,d)* is a scaling coefficient.

Equation (5) completes the system linking the consumers' quality adjusted demand for travel on airline *ac* to its own quality adjusted price, the aggregate price of travel, and the aggregate demand for air travel. It is derived by differentiating the nested CES expenditure function with respect to *padj(ac,o,d)*.[5]

Finally, the welfare measure for the consumption of air travel is defined by consumer surplus. The consumer surplus associated with *pagg(o,d)* is

$$CS(o,d; pagg(o,d)) = \frac{AGG(o,d)}{(\eta(o,d)+1)} \left(1000^{\eta(o,d)+1} - pagg(o,d)^{\eta(o,d)+1} \right). \qquad (6)$$

5 The expenditure function is *pagg(o,d)* × *qagg(o,d)* (see Woodland (1982) p. 376).

where 1000 is a 'large' price.[6] The GAMS code in the appendix contains equations (1) to (6).

Airline networks

The description of airline networks is presented in three parts. The first part describes the limitations placed on flight networks by physical feasibility or by international air service agreements. The second part describes how airlines can allocate seats in their flight network so that passengers depart from their origin and arrive at their destination. The third part describes the costs of the airline network.

Flight sectors and networks

An airline's network is composed of its feasible flight sectors. The *i-j* flight sector is a non-stop flight from origin *i* to destination *j*. The set of aircraft types is denoted *AT*, *at* is a generic element of that set. Two sets jointly determine feasibility.[7] The first set *nogo(i,j,at)* is physical feasibility of the flight sectors and specifies the flight sectors that are outside an aircraft type's range. The second set *sectr(ac,i,j)* is the set of flight sectors permitted by ASAs. For example, Singapore Airlines must fly through Singapore on the way from Australia to Japan. It also reflects observed flight patterns. For example, Alitalia flew through Bangkok on its way to Europe. Liberalisation of ASAs increases the elements of *sectr(ac,i,j)*. Thus, define the feasible set of flight sectors for airline *ac* as *FEAS(ac,i,j,at)* such that *(ac,i,j,at)* is an element of *FEAS(ac,i,j,at)* if and only if *(i,j,at)* is not in *nogo(i,j,at)* and *(ac,i,j)* is in *sectr(ac,i,j)*.

Subsequent notation utilises the following subsets of *FEAS(ac,i,j,at)*. The set $FEAS(i,j,at \,/\, ac)$ is the set of *i-j* flight sectors that airline *ac* is permitted to fly (*sectr(ac,i,j)*) and can fly using aircraft type *at* ($(i,j,at) \not\in nogo(i,j,at)$). The set $FEAS(j,at \,/\, ac,i)$ is the set of destinations *j* and aircraft type *at* airline *ac* is permitted and able to fly to from origin *i*. The set $FEAS(i,at \,/\, ac,j)$ is the set of

6 Consumer surplus is the area under the demand curve. 1000 is chosen for integration because there is an infinite area under the demand curve. However, the modelling work is only interested in changes in consumer surplus. As long as equilibrium prices are less than $1 000 000 (units are in $1 000 in the model) the integral is defined, equilibrium prices can be found and the measures of the change in consumers surplus can be estimated.

7 An alternative method of defining airlines' flight networks is to specify a general ability to fly anywhere and then to constrain airlines' flight networks through explicit equations in the model. Sets were chosen to keep the model's dimensions manageable.

origin *i* from which airline *ac* is permitted to fly to destination *j* and can fly with aircraft type *at*.

The frequencies of service on airline *ac*'s network on an *i-j* sector with aircraft type *at* is denoted *freq(ac,i,j,at)*. *freq(ac,i,j,at)* is non-negative but is positive only if *(ac,i,j,at)* is in *FEAS(ac,i,j,at)*.

Aviation agreements also constrain the number of flights that airlines can fly and, as noted above, the flight routes that airlines may take. The former constraints are imposed on origin-destination pairs and are therefore defined later.

Seat allocation

By assumption, trips are defined as return trips. *qs(ac,o,d)* denotes the number of travellers on airline *ac* that begin their flight from origin *o* on their way to destination *d*. The total number of passengers *pass(ac,o,d)* carried by airline *ac* from origin *o* to destination *d* includes travellers going away and travellers returning. Namely,

$$pass(ac,o,d) = qs(ac,o,d) + qs(ac,d,o), \forall (ac,o,d) \in MS(ac,o,d). \quad (7)$$

An airline moves *o-d* passengers by allocating them seats on its flight network. Let *seats(ac,o,d,i,j,at)* be the number of seats allocated to *o-d* passengers on flight sector *i-j*, flown on aircraft type *at*. To ensure that every passenger leaves from *o* and arrives at *d*, the following equations restrict seat allocation choices over all feasible flight sectors and for all markets in which airline *ac* is represented:

$$seats(ac,o,d,i,j,at) \geq 0; \quad (8)$$

$$seats(ac,o,d,i,o,at) = 0; \quad (9)$$

$$seats(ac,o,d,d,j,at) = 0; \quad (10)$$

$$pass(ac,o,d) = \sum_{(at,j)\in FEAS(j,at|ac,o)} seats(ac,o,d,o,j,at), \forall (ac,o,d) \in MS(ac,o,d); \quad (11)$$

$$pass(ac,o,d) = \sum_{(at,j)\in FEAS(d,at|ac,j)} seats(ac,o,d,j,d,at), \forall (ac,o,d) \in MS(ac,o,d); \quad (12)$$

$$\sum_{(at,j)\in FEAS(j,at|ac,i)} seats(ac,o,d,j,i,at) = \sum_{(at,j)\in FEAS(j,at|ac,i)} seats(ac,o,d,i,j,at), \quad \text{for all } (ac,o,d) \in MS(ac,o,d) \quad (13)$$

Equation (8) says that, *seats(ac,o,d,i,j,at)* is non-negative. Equations (9) and (10) ensure that passengers do not 'loop' through their origin or destination, respectively.[8] Equation (11) says that airlines must allocate every *o-d* passenger a seat on a flight on an aircraft out of origin *o*. Equation (12) says that airlines must allocate every *o-d* passenger a seat on an aircraft to arrive at the destination *d*. Equation (13) says that *o-d* passengers that arrive at an intermediate stop-*i* must also depart from intermediate stop-*i*.

Three final restrictions ensure that the airline has sufficient capacity to fly its passengers and that it makes return flights with every aircraft:

$$Q(ac,i,j,at) = \sum_{(o,d)\in MS(o,d|ac)} seats(ac,o,d,i,j,at); \tag{14}$$

$$Q(ac,i,j,at) = freq(ac,i,j,at)Qmax(at);\ and \tag{15}$$

$$\sum_{j\in FEAS(ac,i,j,at)} freq(ac,i,j,at) = \sum_{j\in FEAS(ac,i,j,at)} freq(ac,j,i,at) \tag{16}$$

where *Q(ac,i,j,at)* is the number of passengers carried by the airline on the *i-j* flight sector and where *Qmax(at)* is the seating capacity of aircraft type *at*. Equation (14) says that the total number of people on the *i-j* flight sector is the sum of passengers from all origins and destinations that have been allocated seats on the *i-j* flight sector. Equation (15) says that the total number of people carried on the *i-j* flight sector does not exceed the total available capacity. Total available capacity is the frequency flown per aircraft times the seating capacity on the aircraft. Equation (16) ensures that airline *ac*'s frequency of service on aircraft type *at* out of origin *i* must equal its frequency of service on aircraft type *at* into destination *j*.

Define *s(ac,o,d,i,j,at)* the share of *pass(ac,o,d)* that are allocated to flight sector *i-j* on aircraft *at*,

$$s(ac,o,d,i,j,at) = seats(ac,o,d,i,j,at)\ /\ pass(ac,o,d)\ ,\ \forall(ac,o,d)\in MS(ac,o,d). \tag{17}$$

It is now possible to define the frequency of service from origin *o* to destination *d* on airline *ac*. Namely,

[8] Ordinarily, cost minimisation excludes loops. However, when airlines act strategically, looping increases total frequency (defined below) and therefore increases demand. As long as the looping increases profits, it is an optimal choice in the model. Looping does not occur in practice because passengers also care about flight duration. Flight duration is not an explicit part of the demand system in the model. The equations ensure that airlines behave, at least in a limited sense, as if flight duration mattered to passengers.

$$totfreq(ac,o,d) = \frac{\sum_{(i,j)\in FEAS(at,i,j|ac)} \left[\left(\sum_{at\in FEAS(at,i,j|ac)} s(ac,o,d,i,j,at) \right) \left(\sum_{at\in FEAS(at,i,j|ac)} freq(ac,i,j,at) \right) \right]}{\sum_{(at,i,j)\in FEAS(at,i,j|ac)} s(ac,o,d,i,j,at)} \quad (18)$$

That is, the total frequency of service between passenger origin *o* and destination *d* on airline *ac* is calculated based on the frequency of service over all flight sectors that are used by the airline for *o-d* passenger travel and the importance of those flight sectors for *o-d* passenger travel as given by their shares. For airlines that utilise only direct flights from *o* to *d*, *totfreq(ac,o,d)* is the sum over aircraft type of *freq(ac,o,d,at)*. For airlines that operate flights over one intermediate point, *totfreq(ac,o,d)* is the average frequency operated from *o* to the intermediate point and from the intermediate point to *d*. This definition of total frequency approximates an airline's ability to have a greater frequency than just the frequency of flights of shortest total travel time, arising, for example, from airline deals for enroute overnight stays in hotels.

ASAs specify frequency of service between two cities in two countries based on a standard aircraft, typically, the Boeing 747. The frequencies are then allocated to individual national carriers so that each carrier's capacity is constrained by the ASAs. In addition, negotiated formulas allow carriers to add or subtract frequencies on other aircraft so long as the total seating capacity is unchanged. Thus

$$\sum_{at\in FEAS(at|ac,i.j)} Qmax(at)\ freq(ac,i,j,at) \ \le \sum_{at\in FEAS(at|ac,i.j)} Qmax(AB)\ freq(ac,i,j,AB) \quad (19)$$

where *AB* is the standard aircraft that is used in the ASAs.

Network costs and profits

Network costs are divided into two categories, flight costs and overhead costs. Flight costs have three unit cost components, passenger-specific, flight-specific and (aircraft) capital-specific costs. All flight costs differ according to airline, flight sector and aircraft type.

Passenger-specific costs include the cost of provisioning, the incremental fuel cost associated with transporting passengers and their luggage, and any passenger-specific airport charges. The unit passenger-specific cost is given by *w(ac,i,j,at)*. Flight-specific costs include, among other things, the costs of the flight crew, the cost of fuel to transport the aircraft without passengers or freight, the cost of baggage handling, and all aircraft-specific airport charges. The unit flight-specific cost is given by *v(ac,i,j,at)*. Finally, capital-specific costs are the cost of the aircraft as capital. That cost is incorporated as a sector- and aircraft-specific charge with unit cost, *z(ac,i,j,at)*. Aircraft capital costs are an imputed hourly charge of the leased aircraft multiplied by the block hours of the flight.[9]

For a given flight sector and airline, the *i-j* flight sector costs to airline *ac* of transporting passengers *Q(ac,i,j,at)* with frequency *freq(ac,i,j,at)* on aircraft type *at* are

$$c(ac,i,j,at) = w(ac,i,j,at)\, Q(ac,i,j,at) + \big(v(ac,i,j,at) + z(ac,i,j,at)\big)\; freq(ac,i,j,at). \tag{20}$$

Overhead costs are defined as the costs incurred to support the flight network. They include all administrative expenses and the cost of ticketing, sales, and commissions and adjustments for overrides.[10] Discussions with industry suggested that the size of overheads partly depends on the number of cities served (for example, city offices) and the (anticipated) number of passengers carried on the network (for example, ticketing and sales) and a general network size (for example, advertising). Overhead costs are specified as

$$OC(ac) = OVER(ac) + UNITOVER(ac) \sum_{o,d \in MS(o,d|ac)} qs(ac,o,d) \tag{21}$$

The total costs (TC) to airline *ac* are then:

$$TC(ac) = \sum_{(at,i,j) \in FEAS(at,i,j|ac)} c(ac,i,j,at) + OC(ac) \tag{22}$$

The profits of airline *ac* are given by the following:

$$\pi(ac) = \sum_{(o,d) \in MS(o,d|ac)} p(ac,o,d)\, qs(ac,o,d) - TC(ac) \tag{23}$$

9 The block hours of a flight denote the time elapsed from the aircraft leaving the departure gate to arrival at the arrival gate. Aerocost2 employs annual block hour use data in computing the hourly charge of the lease. Annual block hour use is representative of observed usage for each aircraft type operating in Australia. It is a consequence of network design and may be affected by changes in ASAs. Such changes would be incorporated in model simulations as a change in airline productivity rather than as a reduction in the hourly charge.

10 Overrides are special conditions on discount tickets — for example, for passengers who stay overnight on a Saturday.

Airline behaviour

A number of airline behaviours can be considered in the context of markets which clear. The typical market clearing condition is that supply equals demand;

$$qd(ac,o,d) = qs(ac,o,d). \qquad (24)$$

However, market clearing conditions in this model are complicated by the non-price factors (here, total frequency of service *totfreq(ac,o,d)*) that influence demand and that producers choose.

A number of possible airline behaviours were considered in the study. They include price-setting, price-taking, quantity-setting and codesharing behaviours.[11] Each behaviour is coupled with a network choice which is constrained by international aviation agreements. All assume that airlines attempt to maximise profits over their networks. Two scenarios of airline behaviour were used extensively in the modelling work — price-taking behaviour and price-setting behaviour.[12] The results in the report are for models of price-setting behaviour. Results for price-taking behaviour are discussed in sensitivity simulations in the appendix.

Price-setting behaviour is preferred to price-taking behaviour as a behavioural assumption for three reasons. First, discussions with industry suggested that the airlines recognise that they have discretion in setting their prices. Second, observed levels of market concentration suggest that strategic behaviour between airlines is likely to be the rule rather than the exception, while the econometric literature shows that prices increase with market concentration. Third, the BTCE (1995) tested in a statistical sense whether published prices and the amount of travel were jointly determined or determined in sequence. It found that published prices were determined before the amount of travel with a lag of about one year.

Under price-setting behaviour, airlines recognise that non-price characteristics lead one carrier’s air travel to be an imperfect substitute for another carrier’s air

[11] Alternatively, the model can be reformulated to include multiple time dimensions. Then ‘predatory pricing’ and other more complicated behaviours, including yield management, could be modelled. The stated equilibrium would remain as one possible equilibrium, however. Multiple time dimensions would also allow an analysis of investment decisions including entry and exit.

[12] Quantity-setting ‘Cournot’ behaviour, where airlines determine price levels by restricting frequency of service in their networks, was initially tested but rejected as a working behavioural hypothesis. The demand parameters that were needed for a valid model (discussed later) were far outside the literature’s estimates of parameters. Time did not permit the incorporation of codesharing in the model.

travel. Consequently, they have discretion in setting the price of their services. Their price and network choices affect their competitors and the demand for their competitors' products.

Each airline takes into account the network and prices of its competitors (essentially computing the residual demand for its product) and chooses prices and flight frequencies to maximise its profits. An airline equates its marginal cost to the marginal revenues of its residual demand, leading to price discrimination. For example, a return price from Sydney to Tokyo may differ from a return price from Tokyo to Sydney. Prices differ across airlines because their marginal costs and market power differ. A lower cost airline will charge a higher price than that charged by a higher cost airline if its market power can support it. Equilibrium is the point at which the choices airlines assume for their competitors are consistent with the choices the competitors make.

A more formal statement is as follows: Under price-setting competition, the demand system given equations (1) to (5) implies that the quantities demanded *qd(ac,o,d)* for each airline are functions of the prices set by airlines *p(ac,o,d)* and the total frequency of service offered by airlines *totfreq(ac,o,d)*. Let *al* denote other airlines. Under market clearing, *qd(ac,o,d)* equals *qs(ac,o,d)* so that airline *ac*'s profits are

$$\pi(ac) = \sum_{(o,d)\in MS(o,d|ac)} p(ac,o,d)qd(ac,o,d; p(ac,o,d), p(al,o,d), totfreq(ac,o,d), totfreq(al,o,d))$$
$$- TC(ac; Q(ac,i,j,at), freq(ac,i,j,at), seats(ac,o,d,i,j,at),$$
$$qd(ac,o,d; p(ac,o,d), p(al,o,d), totfreq(ac,o,d), totfreq(al,o,d)))$$

By equation (18) above, *totfreq(ac,o,d)* is a function of *freq(ac,i,j,at)* and *seats(ac,o,d,i,j,at)* so that airlines choose prices, quantities, frequencies and passenger allocations (*p(ac,o,d), Q(ac,i,j,at), freq(ac,i,j,at)* and *seats(ac,o,d,i,j,at)*) across their networks to maximise profits given the choices of their competitors (*p(al,o,d), Q(al,i,j,at), freq(al,i,j,at)* and *seats(al,o,d,i,j,at)*). Let ***p***, ***Q***, ***freq*** and ***seats*** denote the vectors of *p(ac,o,d), Q(ac,i,j,at), freq(ac,i,j,at)* and *seats(ac,o,d,i,j,at)* for all *(ac,o,d,i,j,at)*. For given *ac*, let ***p(ac)***, ***Q(ac)***, ***freq(ac)*** and ***seats(ac)*** denote the vectors of *p(ac,o,d), Q(ac,i,j,at), freq(ac,i,j,at)* and *seats(ac,o,d,i,j,at)* for all *(o,d,i,j,at)*. Let ***p****, ***Q****, ***freq**** and ***seats**** denote equilibrium choices by airlines. Then an equilibrium ***(p*,Q*,freq*,seats*)*** is defined as

$$\text{For all } ac \text{ and } \mathbf{p(ac), Q(ac), freq(ac), seats(ac)},$$
$$\pi(ac; \mathbf{p^*, Q^*, freq^*, seats^*}) \geq$$
$$\pi(ac; \mathbf{p(ac), Q(ac), freq(ac), seats(ac), p^*(al), Q^*(al), freq^*(al), seats^*(al)})$$

The numerical solution for the equilibrium involves an iterative procedure as suggested by Berridge and Krawczyk (1997). The procedure maximises the joint profits of the industry where in each iteration the profit of each airline is disconnected from the decision variables of the other airlines. In addition, in the demand system above, the effects of other airlines' choices on the profit of airline *ac* can be summarised in the quality adjusted prices of the other airlines. As such, equations (3), (4) and (5) can be rewritten for each airline *ac* as

$$bpagg(ac,o,d) = \begin{pmatrix} \sum_{al \neq ac} \alpha(al,o,d)\, bpadj(ac,al,o,d)^{1-\sigma} \\ + \alpha(ac,o,d)\, padj(ac,o,d)^{1-\sigma} \end{pmatrix}^{1/(1-\sigma)}; \qquad (25)$$

$$bqagg(ac,o,d) = AGG(o,d)bpagg(ac,o,d)^{\eta}; \; and \qquad (26)$$

$$qdadj(ac,o,d) = \alpha(ac,o,d)\left(\frac{padj(ac,o,d)}{bpagg(ac,o,d)}\right)^{-\sigma} bqagg(ac,o,d). \qquad (27)$$

where the letter *b* when added to the variable denotes a price-setting 'Bertrand' behaviour to the *padj(al,o,d)* that airline *ac* takes as given. Airline *ac*'s profit function can be rewritten as

$$\begin{aligned} &\pi(ac|bpadj(al,o,d)) = \\ &\quad \sum_{(o,d)\in MS(o,d|ac)} p(ac,o,d)qd(ac,o,d;\, p(ac,o,d), bpadj(al,o,d), totfreq(ac,o,d)) \\ &\quad - TC(ac; Q(ac,i,j,at), freq(ac,i,j,at), seats(ac,o,d,i,j,at), \\ &\qquad qd(ac,o,d;\, p(ac,o,d), bpadj(al,o,d), totfreq(ac,o,d))) \end{aligned} \qquad (28)$$

The *bpadj(ac,al,o,d)* are part of a solution either to a previous iteration or to the price-taking equilibrium described above. Therefore, there are levels of profits associated with the *bpadj(ac,al,o,d)*, defined as $b\pi(ac)$. The profit maximisation problem to be solved at each iteration is

$$\begin{aligned} \max \Psi = \sum_{ac\in A}\left[\pi(ac|bpadj(ac,al,o,d)) - b\pi(ac)\right] \; s.t. \\ \text{Demand equations (1) – (2);} \\ \text{Price – setting demand equations (25) - (27);} \\ \text{Seat allocation equations (8) - (13); and} \\ \text{Flight capacity and passenger restriction (14) - (16).} \end{aligned} \qquad (29)$$

Thus the introduction of the *bpadj(ac,al,o,d)* creates a joint profit maximisation problem where each airline's profits are disconnected from the other's profits. At the end of each iteration, *bpadj(ac,al,o,d)* and bπ*(ac)* are updated according to

$$bpadj(ac,al,o,d) = \rho^n bpadj(ac,al,o,d) + (1-\rho^n)\, padj*(ac,o,d);\ and$$
$$b\pi(ac,al,o,d) = \rho^n b\pi(ac,al,o,d) + (1-\rho^n)\pi*(ac,o,d). \qquad (30)$$

where n denotes the iteration number and left and right hand side values for *bpadj(ac,al,o,d)* and *b*π*(ac)* are the new and old values, respectively. Berridge and Krawczyk show that this converges to a locally unique equilibrium. The algorithm converges more quickly if ρ diminishes with each iteration.

Model parameters

The application of the theoretical model to the Australia–Asia market is discussed in this section. The section has two major parts. Supply parameters, including the choice of airlines for each market, are discussed in the first section. Demand parameters, including the calibration of the demand system from observed quantities and prices and behavioural parameters, are discussed in the second section.

Supply parameters

The specification of supply-side parameters requires information on the number of airlines competing in each market and the flight and overheads costs by flight sector, airline and network.

Inclusion of airlines by market

Avstats origin–destination data (DTRD 1998) show the airlines that passengers (Australian residents and foreign visitors) identify as their carrier. The number of carriers is far greater than the number of national carriers directly connecting Australia to the other economy. The modelling problem is to include enough third-economy carriers to capture their competitive effects while keeping the problem numerically tractable.

The starting point for including or excluding airlines was computing the inverse of the Herfindahl index of market concentration for each origin–destination market (see Table 1). The inverse of the Herfindahl index is the number of equal-sized airlines that would also have the same Herfindahl index.[13] In 8 of 12

[13] The Herfindahl index is the sum of the squared market shares of the existing competitors in a market. A value of 1 occurs if the market is a monopoly and 0 occurs if the market is perfectly competitive. If h is the Herfindahl index, then the number of equal-sized competitors is 1/h.

economies, the number of national airlines is less than the number of equal-sized firms calculated from the Herfindahl index, indicating a degree of competition greater than the number of national airlines offering direct connections.

Table 1: **Market concentration in Australian international air travel market, 1995**

Country	*National airlines serving Australia*	*Herfindahl equal-sized airlines*	*Airlines included as competitors in model*
China	3	5.5	11
Hong Kong	3	3.1	6
Indonesia	4	3.4	5
Japan	4	3.1	8
Korea	3	3.3	6
Malaysia	3	2.7	5
North America	2	2.7	4
Singapore	3	2.9	4
Taiwan	3	3.4	6
Thailand	2	3.3	8
UK/Ireland	2	5.8	14
Rest of Europe	8	7.0	14

Source: Avstats and Commission estimates.

For most markets, it was possible then to exclude those airlines which in total had a smaller market share than the smallest included airline. The United Kingdom/Ireland and the Rest of Europe were exceptions, because there are a number of airlines with market shares that are less than 3 per cent. For them, airlines with a market share smaller than 5 per cent of the largest market share were candidates for exclusion. The number of included airlines is larger than the Herfindahl number, erring on the side of competition in setting the list of effective competitors.

Cost parameters

Network costs in the model have two components. The first is the flight sector component and comprises the costs incurred in moving passengers along the flight sector. The Commission derived its flight cost estimates from Aerocost2 (BTCE 1997). The second is an overhead component and includes all administrative expenses and the costs of ticketing, sales, commissions and adjustments for overrides. Flight sector costs were adjusted for freight services and differences in airline input prices and productivity. Industry found the Commission's cost estimates to be a reasonable reflection of those that are actually incurred. For transparency, the method used by the Commission to estimate airline costs is explained below.

Flight sector costs

The following outlines the specification of airline and passenger service specific costs by flight sector and aircraft type using Aerocost2 data (BTCE 1997) with adjustments for freight service and differences in airline input prices and productivity. The estimates can only be viewed as approximations of actual airline costs. The estimated costs per passenger by flight sector are reproduced in table 11 in the appendix to this paper. The Commission received comment from the industry who estimated that Aerocost2's range of error was within plus or minus fifteen per cent of their costs.

The parameter estimates of flight sector costs were derived using flight sector cost data from Aerocost2. Aerocost2 allows the user to compute flight sector costs between a number of Australian and foreign cities. Aerocost2's default values for flight sector costs were used. Among the choices that the user can make are type of plane, load factor and aircraft purchase/leasing arrangements.

Variable cost adjustments

Incremental passenger costs for a given flight sector and aircraft were estimated by taking the difference in costs for two load factors. The difference in costs between the two load factors is the increased fuel and provisioning costs from the additional passengers.[14] Dividing the incremental increase in costs by the increase in the number of passengers yields the incremental cost per passenger (identified by $w(ac,i,j,at)$). Multiplying the incremental cost per passenger by the number of passengers carried at a 75 per cent load factor yields the total incremental cost for passengers on the flight.

Flight specific costs do not vary with load factor and are identified by $v(ac,i,j,at)$. They were computed by subtracting the total incremental cost for passengers at a 75 per cent load factor from the estimated total flight costs at a 75 per cent load factor.

[14] Only two load factors were used because the differences in estimated incremental costs per passenger for three or more load factors were on the order of cents per passenger per flight when total flight costs were in the range of $100,000 per flight.

Aircraft capital costs are an output of Aerocost2. Aerocost2 provides data on the costs of purchasing aircraft or leasing them. The leasing option was chosen so that returns above the lease cost are the returns to the entrepreneurial use of the aircraft including market risk. The sector cost of capital is given by the annual lease cost of the aircraft divided by the block hours it can fly in a year and multiplied by the flight duration of the sector, *z(ac,i,j,at)*. A model with a multi-dimensional time component (eg daily, weekly, monthly and multi-year dimensions) would endogenously determine this sector-specific capital cost component. However, this model has only an annual dimension, so the cost of capital is incorporated as a sector and aircraft specific charge (see the discussion of load factors for more explanation of this point).

Aerocost2 data indicate that passenger-specific costs on a flight are small relative to total flight costs. The industry confirmed this cost structure. For example, passenger-specific costs for a Boeing 747–400 flying with a 75 per cent load factor from Sydney to Tokyo are approximately 15 per cent of total flight sector costs (including the capital cost of the plane).

Passenger, freight and mail services are joint products in flying. The latter two account for about 25 per cent of all airline revenues as identified in ICAO data (ICAO 1996). The ideal solution would be to include freight and mail services in the model. However, the extensive data, parameter estimates, computational power and time required for their incorporation in the model make the ideal solution infeasible. Consequently, the decision was taken to concentrate on passenger service and to adjust the marginal cost of variable flight and capital specific inputs that are shared by passenger and freight services for the absence of the marginal revenue from freight and mail services.

The Commission estimates that 85 per cent of total flight-specific costs are attributable to passenger services. The remaining 15 per cent arises from freight transport. These estimates were derived by adjusting total marginal flight costs by the estimated impact of the marginal revenue of freight services on shared marginal flight-specific costs. For flight-specific costs, the model adjusts *v(ac,i,j,at)* by the scalar value, *flfrght*, computed in the following equation:

$$flfrght = \frac{shared\ flight\ costs * (1 - share\ of\ freight\ in\ revenue) + unshared\ passenger\ flight\ costs}{total\ flight\ costs} =$$

$$\left.\begin{pmatrix} (total\ flight\ costs - unshared\ passenger\ flight\ costs) * \\ share\ of\ passenger\ revenue\ in\ total\ revenue + unshared\ flight\ costs \end{pmatrix}\middle/ total\ flight\ costs\right.$$

The term in the small parentheses is an estimate of shared flight costs on a sector. They include the cost of baggage handling and the cost of the flight crew except cockpit staff. The shared flight costs are multiplied by the share of passenger service revenue in total revenue to obtain the proportion of shared marginal flight costs to be covered by marginal passenger revenue. Then the passenger-specific flight cost items are added back to obtain the total flight-specific costs of passenger service. The sum is divided by total flight costs to obtain the proportion of estimated total flight-specific passenger costs to total costs.

The share of capital costs of the aircraft that are borne by passenger services in total capital costs *capfrght* was computed in a similar fashion. The Commission estimated that 85 per cent of total capital costs are borne by passengers with the remainder borne by freight. The estimate was applied to all flight sectors and aircraft. The sale prices for Boeing B747-400 passenger- and Boeing B747-F freight-aircraft were used as the basis of the calculation (Avmark Aviation Economist, 1997).

$$capfrght =$$

$$\frac{shared\ capital\ value * (1 - share\ of\ freight\ in\ revenue) + \ passenger\ specific\ capital\ value}{total\ value\ of\ capital}$$

$$= \left(\begin{array}{l} Price(B747-F) * share\ of\ \ passenger\ revenue\ in\ total\ revenue \\ \ + (Price(B747-400) - Price(B747-F)) \end{array} \right) \Big/ Price(B747-400)$$

The sale price of the Boeing B747-F was used as an estimate of the value of shared capital and multiplied by the share of passenger service revenue in total revenue to obtain the estimated cost of shared capital. The difference in the sale prices of the two aircraft is taken as an estimate of aircraft cost that is solely for passenger use and added to the value of shared capital cost that will be covered by passenger service to obtain the total capital cost to be borne by passenger service. Their sum is divided by the sale price of the Boeing B747-400 to obtain the ratio of the total capital cost borne by passenger service to the total sale price of the passenger aircraft.

Airline-specific cost adjustments

Industry representatives and the BTCE voiced concern that differences in airline costs and efficiencies be included in the model. Their concerns are based on the premise that individual airlines' costs of operation differ according to their relative productivity and the input prices that they face. In order to address these concerns, the Commission used empirical research by Oum and Yu (1995) on different airlines productivity levels and input prices. The study by Oum and Yu is the most comprehensive and up-to-date study available on different airline networks productivity levels, input prices and competitiveness. The Commission's modelling applies Oum and Yu's estimates to its base cost data to construct costs for individual airlines. Because Aerocost2 is based on Australian data, we take Qantas as the base and make adjustments relative to the base to estimate other airlines' costs. The Oum and Yu estimates, adjusted to have Qantas as the base, are given in Table 2.

The adjustment parameters are *airprod(ac)*, *labshare* and *labour(ac)*. They correspond, respectively, to airline productivity, the share of labour costs in flight costs and the difference in labour price from Qantas. Passenger-specific flight costs are not adjusted on the assumption that fuel and provisioning costs should be similar for airlines at each airport. Flight-specific costs for a given airline, flight sector and aircraft are given by the following:

$$v(ac,i,j,at) = (100 + airprod(ac) + labshare(at) * labour(ac)) / 100 * flfrght * mcf(ac,i,j,at); \qquad (31)$$

where *mcf(ac,i,j,at)* is the base marginal cost of the flight.

That is, the unit flight-specific cost for airline *ac* using aircraft type *at* on an *i-j* flight sector is the passenger service flight cost (ie *flfrght*mcf(ac,i,j,at)*) times an adjustment for the airline reflecting its productivity relative to Qantas, its share of labour in the flight costs times its difference in labour price relative to Qantas.

Table 2: Differences in cost competitiveness, efficiency and input prices[a]

Airline	*Labour price*	*Efficiency*	*Input prices*
Air China	-12.0	31.3	-43.2
Air New Zealand[a]	0.0	0.0	0.0
Alitalia[a]	13.9	4.4	34.0
All Nippon	60.8	11.5	49.3
Ansett[a]	0.0	0.0	0.0
BA	4.6	-1.4	6.1
Cathay	-6.5	-9.0	2.7
Eva[a]	-12.0	31.3	-43.2
Garuda[a]	-12.0	31.3	-43.2
JAL	50.0	2.7	47.5
KLM	-3.9	-1.4	6.1
Korean Air	-25.6	-10.8	-14.7
Lauda[a]	13.9	4.4	34.0
Lufthansa[a]	13.9	-8.1	29.3
Malaysia Airlines[a]	-12.0	31.3	-43.2
Olympic[a]	13.9	4.4	34.0
Qantas	0.0	0.0	0.0
Sempati[a]	-12.0	31.3	-43.2
Singapore Airlines	-19.0	-7.7	-11.2
Thai	-12.0	31.3	-43.2
United Airlines	-2.8	-15.4	12.7

a Estimates for Ansett, ANZ, Sempati, Garuda, Olympic, Eva, Air China and Malaysia airlines were not available. Those given in the table have been assigned. Estimates set at Qantas levels for Ansett and ANZ, at Thai levels for Sempati, Garuda, Malaysia, and Eva, and at Alitalia levels for Olympic.

Source: Derived from Oum and Yu, 1995 or applied by assumption (see footnote a, this table).

Similarly for the capital flight costs, one obtains

$$z(ac,i,j,at) = cpfrght * capflght(ac,i,j,at); \quad (32)$$

where the passenger service costs of capital are equal to the base capital costs (*capflght(ac,i,j,at)*) adjusted for freight services (*cpfrght*).

Load factors

The final adjustment to the supply side of the model is the use of flight sector specific annual load factors. That is, the total number of seats available on a flight on aircraft type *at* is given by *Qmax(at)*load(i,j)*. *Qmax(at)* is the seating capacity of aircraft type *at*. *load(i,j)* is the observed annual load factor on the *i-j* flight sector taken from DTRD uplift-discharge data. Differences in load factors by airlines would be one reason for the productivity differences described above.

Load factors on any given flight sector vary according to a complex interaction of demand variability and network constraints. Airlines must choose their fleets taking into account variations in demand according to the time of day, the day in week, the week in month and the month in year. For example, airlines may choose to fly an aircraft with a low load factor over one sector so that it can be available to fly another sector with a better load factor. In addition, because aircraft are held for a year or longer, seasonal demand variations may lead to high load factors at one time of year and low load factors at another time of year. The empirical model is limited by its annual data and cannot endogenise load factors as a consequence of these demand and network interactions. Instead endogenous load factors are replaced by observed annual load factors which are average load factors owing to variations in demand through the year and fleet constraints.

As mentioned above, the empirical model captures the industry at a point in time. Cost and load factors are particularly sensitive to point in time comparisons. Therefore it needs to be borne in mind that conditions at a point in time may not be indicative of the long-run or typical state of the industry or of individual airlines in the industry.

Frequencies

A computational approach is taken to estimating frequencies, rather than using observed frequencies. Observed frequencies depend on each airline’s fleet choice. The range of aircraft in the model is narrower than the observed range. Therefore, frequencies are computed using observed passenger flows and the range of aircraft available in the model. This maintains a consistency between model calibration and the use of frequency in the model. However, if the representativeness of the model’s range of aircraft capacities differs by airline there will be some implied imprecision in demand calibration. The observed frequency of an airline serving city pair *o-d*, *fobs(ac,o,d)*, is estimated as a total frequency *totfreq(ac,o,d)* computed in a cost minimisation problem, where each airline minimises the cost of its network in meeting its observed demand.

$$\begin{aligned}&\min_{seats(ac,o,d,i,j,at),\,freq(ac,i,j,at),Q(i,j,at),QS(ac,o,d),\,pass(ac,o,d)}\\&\sum_{at,i,j\in FEAS(i,j,at|ac)} w(ac,i,j,at)\,Q(ac,i,j,at) +\\&(v(ac,i,j,at)+z(ac,i,j,at))\,freq(ac,i,j,at)\quad s.t.\\&QDOBS(ac,o,d)\le QS(ac,o,d);\\&\textit{Seat allocation equations (7)} - \textit{(13); and}\\&\textit{Passenger and flight capacity (14)} - \textit{(16).}\end{aligned}\tag{33}$$

Let * denote a solution to the cost minimisation problem. The frequency of service used by consumers that is implied by this problem is

$$totfreq^*(ac,o,d) = \frac{\sum_{at,i,j\in/ FEAS(at,i,j|ac)} s^*(ac,o,d,i,j,at)\,freq^*(ac,i,j,at)}{\sum_{at,i,j\in/ FEAS(at,i,j|ac)} s^*(ac,o,d,i,j,at)}\ . \tag{34}$$

The minimum cost associated with this problem is also the estimated flight costs used to compute overheads discussed in the next section.

Overheads

The value of overhead costs was computed as being proportional to the total flight sector costs of the network at observed quantities. This proportion was estimated using ICAO’s breakdown of costs into various cost categories with adjustments for freight and the above-average flight distances in the region (PC 1998). The computation estimated an average overhead charge of $260 per passenger. The industry provided a range of opinion on this estimate and judged it acceptable for working purposes. Its reasonableness depends in part on how cost items, such as maintenance, are allocated to overhead and flight costs categories and on which sales commissions are included in the net fare. [15]

The equation linking overheads cost (support activities to flight services) to passenger flows and network operation (equation (5)) was estimated by assessing the degree to which models under the assumed behaviours need/do not need overheads to increase with the passengers carried in order to replicate observed quantities and prices.

Omitting overheads can have economic welfare implications. If overhead costs were excluded from the model, then the returns covering overheads would be

[15] For example, one industry source suggested an imputation of a share of overhead as a charge per revenue passenger kilometre. Unfortunately, time did not permit constructing a model and performing the relevant simulations with this overhead assumption.

wrongly identified as economic rents rather than as the return necessary to recover costs. Prices that do not cover overhead costs represent a transfer from producers to consumers, and cannot be sustained in the long run. For example, the effect of Ansett's entry on Australian economic welfare depends in part on Ansett's overhead cost because overheads are incurred as a cost of entry.

Demand calibration

Demand is calibrated in the model using the observed passenger flows, confidential net fares,[16] and (computed) frequencies, given the three behavioural parameters: the CES substitution elasticity $\sigma(o,d)$, the aggregate demand price elasticity $\eta(o,d)$ and the frequency parameter $\beta(o,d)$.[17] The calibration procedure computes the scaling coefficient for aggregate demand *AGG(o,d)* and the interior weights of the CES nest $\alpha(ac,o,d)$. The latter coefficients capture the residual influence of each airline in demand that is not explained by differences in estimated flight frequencies. Using the suffix 'obs' to denote observed values, the equations to be solved are

$$qdadj^{o}(ac,o,d) = fobs(ac,o,d)^{\beta(o,d)}\, qdobs(ac,o,d) \;\; \textit{for all ac}; \tag{35}$$

$$padj^{o}(ac,o,d) = fobs(ac,o,d)^{-\beta(o,d)}\, pobs(ac,o,d) \;\; \textit{for all ac}; \tag{36}$$

$$\sum_{ac\in MS(ac|o,d)} \alpha(ac,o,d) = 1; \tag{37}$$

$$pagg(o,d) = \left(\sum_{ac\in MS(ac|o,d)} \alpha(ac,o,d)\, padj^{o}(ac,o,d)^{1-\sigma(o,d)} \right)^{1/(1-\sigma(o,d))}; \tag{38}$$

$$qagg(o,d) = AGG(o,d)\, pagg(o,d)^{\eta(o,d)}; \textit{ and} \tag{39}$$

$$qdadj^{o}(ac,o,d) = \alpha(ac,o,d) \left(\frac{padj^{o}(ac,o,d)}{pagg(o,d)} \right)^{-\sigma(o,d)} qagg(o,d), \;\; \textit{for all ac.} \tag{40}$$

$qdadj^{o}(ac,o,d)$ and $padj^{o}(ac,o,d)$ denote that *qdadj(ac,o,d)* and *padj(ac,o,d)* are determined from observed frequencies, quantities and prices given the frequency parameter $\beta(o,d)$ and independently of the other variables and parameters to be determined. The other equations identify *pagg(o,d), qagg(o,d),*

[16] Net fares are fares exclusive of discounts but inclusive of sales commissions and over-rides. Net fares were supplied by two airlines servicing the routes.

[17] β(o,d) is computed using the relationship that the elasticity of aggregate demand with respect to a uniform increase in airline frequency is given by -η(o,d)*β(o,d).

AGG(o,d) and $\alpha(ac,o,d)$ (the relevant GAMS program is very similar to the one included inthe appendix).

BTCE (1995) estimated aggregate price elasticities for a number of markets and market segments (leisure and business travellers). However, because data for passenger type by airline were not available, average estimated price elasticities were calculated using the shares of each passenger type in the respective market. Estimated demand elasticities show some variation across economies and the direction of travel (Table 3). For most markets, foreign aggregate demand is estimated to be price inelastic. The exceptions are the long-haul markets (the United Kingdom/Ireland, the Rest of Europe and North America) and Singapore and Indonesia. By contrast, Australian aggregate demand in all markets is estimated to be price inelastic.

Table 3: **Average aggregate demand price elasticities for travel to/from Australia**

Country	*Australian resident elasticity*[a]	*Foreign visitor elasticity*[a]
China[a]	-0.70	-0.76
Hong Kong[a]	-0.72	-0.96
Indonesia	-0.42	-1.41
Japan	-0.84	-0.77
Korea	-0.88	-0.48
Malaysia	-0.79	-0.75
North America[a]	-0.56	-1.58
Singapore	-0.42	-1.73
Taiwan[a]	-0.86	-0.80
Thailand	-0.75	-0.79
United Kingdom/Ireland	-0.15	-1.66
Rest of Europe	-0.35	-1.03

a No BTCE estimates given for China and Hong Kong. They were computed using averages of Asian elasticities. Differences between them owe to the composition of travel between leisure and business travellers. No BTCE estimates for Malaysian business, Australia to Japan business and any business travel between Taiwan and Australia. US estimates taken for North America.

Source: Commission estimates based on Avstats passenger flows and BTCE elasticity estimates.

These estimates are the best publicly available estimates for the Australian market. However, they are subject to a number of qualifications. First, estimates for some markets were not available. There were no estimated foreign visitor or Australian resident elasticities for China and Hong Kong. Each passenger type was given the average elasticity for the Asia region for the passenger type. The average was then computed on the basis of the composition of travel by passenger type. There were also no published BTCE estimates for Malaysian business, business travel from Australia to Japan and any business travel between Taiwan and Australia. US estimates were used for North American traffic. Second, they reflect the relationship between lagged published airfares and travel. Demand responses to specials are omitted. Consequently, the total elasticity may be understated.

Economic welfare estimates

The model measures the economic welfare benefits of liberalisation by consumer surplus and airline profits for both domestic and foreign markets. Economic welfare changes in an economy are the sum of changes in consumer surplus arising from air services in the country and the profits of its national carrier(s). Given that prices are net fares, consumer surplus will include not only the consumer surplus of travellers but also any profits and taxes further along the marketing chain from the net fares.

This is a partial equilibrium analysis, so it does not measure the economy-wide benefits of any increase in tourism that may occur as a result of liberalisation. Airport congestion, pollution and impacts on government revenue and price characteristics of air travel are not addressed. Nor is the spill-over effect on freight measured. It is presumed that any capacity increases in response to liberalisation will have a neutral effect on freight profitability, although they will result in more freight being carried.

Two partial equilibrium effects do point to likely economy-wide effects, however. Changes in total passenger movements indicate the direction of change in air services such as baggage handling, boarding gate staff, air traffic control and terminal infrastructure. Demand for these services are not limited to the Australian carriers but extend to all airlines, regardless of nationality. These increases are not included in the calculations of the economic welfare analysis.

Changes in net passenger flows to Australia are used as an indicator of the direction of change in profits of industries associated with travel (such as tourism).[18] Net passenger movements are better than inbound visitor movements

[18] Net passenger movements are inbound visitor movements minus outbound resident movements. A positive projected change means that inbound visitor passenger movements grew by more than outbound resident passenger movements. When net passenger movements are negative (more Australian outbound traffic than foreign inbound traffic), a

as an indicator of the effect on tourism services because they account for changes in the numbers of Australians that travel abroad (and not at home).

Effect of Ansett International's entry

One aim of current Australian policy is to encourage new (Australian) entrants in the air services market. Ansett International has entered a number of Asian markets, but the outstanding question is how Ansett's entry has affected prices, travel and economic welfare in Australia and in the other countries it serves.[19] Model results suggest that Ansett's entry:

- reduced airfares;
- increased passenger flows to Australia; and
- increased Australian and foreign net economic welfare.

Sensitivity simulations, discussed below, were conducted to test the sensitivity of these results to changes in model assumptions. Model results are found to be generally robust.

Two years, 1995 and 1997, are used for simulating the effects of Ansett's entry. As Ansett's market share increased in a number of markets from 1995 to 1997 (Table 4), results for 1995 would tend to understate the effects of Ansett's entry. Total demand also increased in this period.

positive projected change means the difference grew smaller. When net passenger movements are positive, a positive projected change means the difference grew larger.

[19] This study does not account for recent changes to Ansett's network as a result of the Asian economic crises.

Table 4 **Ansett's model market share, 1995 and 1997, and growth in total passengers, 1995–1997[a]**

	Ansett's market share		*Growth in passengers*
Market	*1995*	*1997*	*1995–97*
	%	%	%
China	13	13	43
Hong Kong	17	18	6
Indonesia	10	14	36
Japan	8	9	6
Malaysia	1	10	22
Korea, Republic of	0	10	43
Taiwan	2	18	19
Total	**8**	**12**	**18**

a Computed from base data used in the model. Only includes carriers in the model. Ansett had minimal Korean market share in 1995 and was not included in the model for 1995.

Source: Commission estimates based on DTRD (1998).

Simulations are conducted by removing Ansett from the model to estimate what the market would have been like if Ansett had not entered it. Other airlines' cost structures are assumed not to change when Ansett is present, though flight sector costs change to reflect altered network choices.

It should be emphasised that the results follow from a short-run model which captures the industry at a point in time. The industry at a point in time may or may not reflect the typical or the long-run state of the industry. It can not identify whether the industry or individual airlines in the industry are unprofitable and therefore whether some airlines may be expected to leave the industry or alternatively whether airlines are making supernormal profits which may invite new entry.

The Ansett entry simulations compare two states. One is factual; Ansett entered the market. The other is counterfactual; Ansett did not enter the market. The relevant comparison is then how do economic variables resulting at a point in time from a market structure with Ansett's entry differ from economic variables from a hypothetical market structure without Ansett's entry.

Simulations discussed below focus on the scenario in which Ansett is removed from the demand system with other airlines' weights ($\alpha(ac,o,d)$) being unchanged. Aggregate demand is reduced because the sum of the other airlines weights sum to less than one. An alternative assumption is that Ansett is removed from the demand system but other airlines' weights are proportionately increased so that they sum to one with aggregate demand unchanged. The latter scenario presents a 'worst case' scenario for Ansett's entry to be welfare improving because it assumes that Ansett's entry did not create more service diversity. This second assumption was used to test the sensitivity of the model's results and is discussed in the appendix.

The effects of Ansett's entry on the market can be placed in three categories: cost, competition and demand. The cost effect of Ansett's entry hinges on Ansett's costs relative to the industry. In the network model, Ansett is likely to have lower costs than the industry because Ansett's direct service is less costly than the indirect service offered by third-country carriers.[20] The competitive effect of Ansett's entry is increased competition in price and frequency. Both cost and competitive pressures should reduce prices and increase frequencies of service. The demand effects relate to product differentiation and the frequency of service offered by the larger number of airlines.

One feature of the demand specification and parameter values in the model is that consumers are assumed to prefer (with total frequency remaining constant) more frequent service on fewer airlines to less frequent service on more airlines.[21] That is, although consumers benefit from the lower prices induced by increased competition, they face an offsetting effect of reduced flight quality through the spreading of frequencies over more airlines. In fact, increased competition can reduce consumer surplus if no significant increase in aggregate quantity occurs and dominant airlines reduce their frequency of flights (see section below on Ansett entry sensitivity simulations).

In addition to the frequency effect, Ansett's entry offers the opportunity for greater product differentiation. Product differentiation increases observed aggregate demand by better serving existing demand and by tapping into latent demand.[22] For example, if Ansett introduced a new non-stop service between two cities then, even though the airfare for travel between them may not change,

[20] Results reported in the draft report did not have a large cost effect, because the model was based on the single market models described above. Results reported here rely on the network model and therefore differ from those in the draft report.

[21] For example, passengers who miss flights can board the next flight offered by the same airline without undue delay. Similarly, time-conscious business travellers can travel on the same airline at times that allow them to coordinate with appointments at their destination and a return to their origin without undue delays.

[22] Latent demand is demand that would otherwise not be served. Incumbents airlines have incentives to create product diversity but only if it increases current profits. In contrast, entrants have enhanced incentives to create product diversity precisely because it takes profits away from incumbents.

observed travel between them would increase because people residing in or near one of the cities obtain better service.[23] Some existing passengers fly more frequently. Other people who would not fly indirectly now choose to fly directly. In this example, however, the source of the increased market diversity reflects both Ansett's decision to provide the service and governments' decisions to negotiate it. It is not possible to unravel the two. Consequently, the following results reflect both. The simulation assumes that Ansett successfully differentiated its service from those of its competitors.

Results

Ansett's entry is estimated to decrease price and increase quantity in every market it entered in 1995 and 1997 (Table 5). The price and quantity effects tend to be larger for those markets where Ansett obtained higher market shares. For example, the least affected markets are Malaysia, the Republic of Korea and Taiwan in 1995 where Ansett had little market share. By 1997, however, Ansett had increased its market shares. Its estimated effects on prices and quantities are therefore greater in 1997 than in 1995.

Ansett's entry leads to price increases in the Republic of Korea in 1995 through its entry's effects on its competitors' price and frequency choices. Ansett's entry takes customers from third country airlines and forces them to use smaller aircraft in their networks to maintain their frequency. Smaller aircraft are more expensive to operate over the flight sectors in the model. Therefore prices increase.

The increases in quantity imply an increase in some aviation services in Australia regardless of nationality of airlines.

[23] Lederer represents this as a reduction in the total cost of travel which includes, for example, the passenger's valuation of time in travel, possible delays and the convenience of a non-stop flight.

Table 5 **Estimated changes in price and quantity by market from Ansett's entry, 1995 and 1997**

Between Australia and:	*1995*	*1997*
Prices	%	%
China	-4.1	-4.4
Hong Kong	-7.0	-6.8
Indonesia	-7.4	-7.7
Japan	-3.8	-4.3
Korea, Republic of[a]	0.1	-2.4
Malaysia	-0.9	-4.0
Taiwan	-1.1	-4.3
Quantities		
China	2.3	2.6
Hong Kong	5.3	5.3
Indonesia	1.5	3.4
Japan	2.6	3.0
Korea, Republic of[a]	0.1	0.6
Malaysia	0.8	2.7
Taiwan	1.0	2.7

a Ansett had minimal Korean market share in 1995, and was not included in the Korean demand for 1995.
Source: Commission estimates.

Ansett's entry is also estimated to have increased Australian and foreign economic welfare in 1995 and 1997 (Table 6). In addition to the increase in economic welfare, Ansett's entry is estimated to have redistributed airline profits to consumer surplus through lower prices.[24] In both years, the resulting economic welfare effect, although substantial, is much smaller than the underlying transfer of profit to consumer surplus.

[24] These results are presented in an aggregated manner to protect detailed confidential data provided by airlines.

Table 6 Estimated changes in Australian and foreign gross profits, consumer surplus and economic welfare from Ansett's entry, 1995 and 1997

	1995	*1997*
Australian	$m	$m
Profits (gross)	-41.6	-57.5
Consumer surplus	70.0	89.9
Economic welfare	28.4	32.4
Foreign		
Profits (gross)	-75.9	-121.8
Consumer surplus	88.3	153.5
Economic welfare	12.4	31.7

Source: Commission estimates.

Ansett's entry increases consumer surplus for both Australian and foreign consumers in every country except for the Republic of Korea in 1995 (Table 7). The Korean market in 1995 experiences a price increase which reduces Korean consumer surplus. For Australian consumers, the major gains are achieved in Hong Kong and Indonesia in both 1995 and 1997. For foreign consumers, the gains are largest in Japan, although Japan's gains are not nearly as big a share of the increase in foreign consumer surplus in 1997 as in 1995.

Table 7 **Estimated changes in Australian and foreign consumer surplus from Ansett's entry by market, 1995 and 1997**

Between Australia and:	*1995*	*1997*
Australian consumer surplus	$m	$m
China	5.5	7.6
Hong Kong	24.2	23.3
Indonesia	36.3	44.6
Japan	3.5	4.6
Korea, Republic of[a]	0.0	1.3
Malaysia	0.5	7.1
Taiwan	0.0	1.4
Total	**70.0**	**89.9**
Foreign consumer surplus		
China	3.5	5.4
Hong Kong	16.8	19.5
Indonesia	0.2	10.4
Japan	65.2	79.2
Korea, Republic of[a]	-0.6	11.6
Malaysia	0.9	9.0
Taiwan	2.3	18.4
Total	**88.3**	**153.5**

a Ansett had minimal Korean market share in 1995. It was not included in the Korean demand for 1995.
Source: Commission estimates.

Projected changes in net passenger movements can be examined to gain a sense of the likely impact of Ansett's entry on the demand for tourism services in Australia (Table 8). Ansett's entry leads to larger positive net passenger movements or smaller (in absolute value) negative net passenger movements for four of the countries (Japan, the Republic of Korea, Malaysia and Taiwan) in 1995 and for all countries except China in 1997. The changes in net passenger movements tend to reflect price reductions from Ansett's entry. That is, if net passenger movements are positive (more inbound visitors than outbound residents), then Ansett's entry leads to a bigger positive net passenger movement and consequently a percentage increase in net passenger movements. The negative net passenger movements for China, Hong Kong and Indonesia in 1995 reflect a tilt in Ansett's passengers towards outbound resident movements that is greater than that for the industry. Total net passenger movements are estimated to increase by 2 per cent.

The increase in total net passenger movements is larger in 1997 (3.7 per cent) than in 1995 (2 per cent). This is because the estimated price effects for Malaysia, the Republic of Korea and Taiwan are larger in 1997 than in 1995, leading to a larger increase in net passenger movements in both absolute number and percentage.

Despite their large percentage changes in 1997, changes in net passenger movements for China and Hong Kong make only a small contribution to total net passenger movements. Indonesia and Japan are the most important markets in determining total net passenger flows. The results for China and Hong Kong reflect the balance in the market between the Australian resident and foreign visitor flows, leading to a small base value for net passenger movements. Thus even though the price reductions from Ansett's entry induce a small change in net passenger movements and a small contribution to total net passenger movements, the percentage changes in net passenger movements are large.

Table 8 **Estimated changes in net passenger movements to and from Australia from Ansett entry, 1995 and 1997[a]**

Between Australia and:	*1995*	*1997*
	%	%
China	-3.1	-47.0
Hong Kong	-7.1	92.8
Indonesia	-2.4	5.2
Japan	2.7	2.9
Korea, Republic of[b]	0.1	0.4
Malaysia	1.4	2.3
Taiwan	1.2	2.7
Total	**2.0**	**3.7**

a Net passenger movements are inbound visitor movements minus outbound resident movements.
b Ansett had minimal Korean market share in 1995. It was not included in Korean demand for 1995.
Source: Commission estimates.

Effects of a plurilateral open club

The Government asked the Commission to assess various options for reform of Australia's ASAs. One option is a plurilateral open club characterised by a single liberal 'open skies' agreement applying to all club members (PC 1998). The network model developed for the Ansett entry simulations was used to explore how freeing up airline networks and competition in an open club affects the economic welfare of club members. Because of limitations to the model, data and scenarios, simulation results are illustrations, not predictions, of how the economic forces unleashed by an open club agreement could transform international air travel markets inside and outside the open club. The results illustrate that open clubs that allow airlines to achieve efficiency gains and to construct their most profitable networks increase the economic welfare of club members.

Network effects in open clubs and modelled scenarios

Current ASAs place constraints on airline networks. Open clubs release club members from these constraints inside the club and, through network economies, can tangentially affect markets for travel to non-member countries. Model simulations explicitly consider the two likely network effects of open clubs:

- open club airlines become more efficient; and
- open club airlines can enter all open club markets and fly directly between any two 'foreign' countries in the club.

Less efficient airlines in an open club are forced to lift their game or leave club markets. More efficient airlines will face greater competition as other airlines improve their efficiency. Incentives to improve efficiency will increase because profit opportunities are enhanced for any airline that improves its efficiency or carves out a larger slice of the market. Finally, improvements in network management may spill over from open club markets to all markets in the airline's network.

The *airline efficiency gains* effect is modelled as follows. All airlines in the open club are assumed to attain a benchmark level of efficiency as estimated by Oum and Yu (1995).[25] The assumed increase in efficiency is due to competitive pressures within the club. No incumbent airline exits any market.

Under current ASAs, airlines of open club members must fly through their home country or obtain fifth freedom permission in order to fly passengers from one foreign country to another. Under the open club, they can choose to fly directly between the foreign countries in the club, or set up hub and spoke networks with

[25] Oum and Yu (1995) estimated that Cathay Pacific is the most efficient airline among the open club airlines.

hubs in other member countries to fly passengers between any two spoke countries within the club. Consequently, airlines of open club members will be able to enter any market within the club and construct networks on the basis of market fundamentals with only those restrictions imposed by the capacity- and freedom-dictates of ASAs with non-member countries.

Market entry with direct flights is modelled as follows. Club airlines can fly direct flights between any two countries in the open club. They can also enter markets for travel between other club members (Japanese carriers can enter the Australia–Hong Kong and Australia–China markets. Chinese carriers can enter the Australia–Japan market.). Each entrant is assumed to add five per cent to the size of the market.[26] It does this by tapping into latent demand for travel, for example, by providing better connections or departure times than incumbents provide. No incumbent airline exits any market.

The effects are used in three scenarios:

- scenario A applies efficiency gains and market entry with direct flights between foreign countries;
- scenario B applies efficiency gains only; and
- scenario C applies market entry with direct flights between foreign countries.

Scenario A reflects that, by freeing airlines to form their most profitable networks, open clubs will unleash many effects. The final two scenarios allow the respective economic effects to be separated.

The choice of club members is illustrative and not based on any expectations by the Commission of the likelihood of any of the countries entering into such a club. The simulations assume the following club, country, market and airline coverage:

- open club members are Australia, China, Hong Kong and Japan;
- country, market and airline coverage is that for the Ansett simulations (markets for travel between Australia and China, Hong Kong, Indonesia, Japan, the Republic of Korea, Malaysia and Taiwan); and

[26] Five per cent was chosen for illustrative purposes. It is less than one half that observed for Ansett in its smallest market. Thus it represents a minimum market penetration that entrants would aim to achieve. Nevertheless, the Commission stresses that this is an assumption only and the results flowing from it are illustrative, not forecasts. A greater or lesser level of additional traffic could be assumed, thereby affecting the magnitude but not the direction of the results.

- the club airlines are Ansett, Qantas, China Airlines, China Southern Airlines, China Eastern Airlines, Cathay Pacific, Japan Airlines and All Nippon Airlines.

Club membership was chosen because the distances between China, Hong Kong and Japan allow hub and spoke networks to be set up by all club members in any of the countries. In addition, aircraft can fly one long sector from Australia and be turned around to fly a short sector in the northern part of the club within a day, arriving at the final destination at a convenient hour for travellers and within airport curfew times. The latter feature increases aircraft utilisation and the revenue each aircraft can generate in a day. Without the club, aircraft arriving from Australia may have to sit for an extended period at a foreign port to obtain desirable departure times to and arrival times in Australia.

Limitations of open club scenarios and their implications

Three limitations of the open club scenarios bear specific mention:

- Oum and Yu’s efficiency estimates are representative of uniform differences in efficiency between networks;
- assumptions are made in the scenarios regarding airline entry, exit, and product differentiation; and
- markets are limited to those involving travel to and from Australia.

The limitations have important consequences for the interpretation of results.

Efficiency estimates

Oum and Yu (1995) formulate their efficiency estimates by constructing indices of inputs and outputs for each airline. The output index is calculated using a revenue weighted average of each airline’s passenger and freight service output adjusted for average stage length. If these adjustments aggregate outputs correctly, then the estimated efficiency differences are attributable to the relative ability of airline management to produce output with the least amount of inputs.

Three reservations must be stated. First, even if Oum and Yu’s methodology and interpretations of efficiency are correct, the estimates are only as good as the data used and the data’s comparability across airlines. ICAO data were the primary source of industry information for Oum and Yu. As noted by the industry, airlines use different accounting definitions which may undermine the comparability of ICAO data across airlines. Second, their aggregation of airline output may have deficiencies. For example, other output characteristics, such as the number of cities served or the frequency of service, are omitted

(Kirby 1986). The omissions would bias efficiency estimates favourably towards airlines that have lower frequencies of service and serve fewer cities because both characteristics increase network costs for the same number of passengers carried in a network. Third, Oum and Yu did not estimate efficiency and input prices for the Chinese airlines. Chinese airlines' efficiencies and input prices are assumed to be those estimated for Thai Airways.

If Oum and Yu's estimation and interpretation of efficiency differences are reasonably correct and Thai Airways costs and efficiency are representative of those for Chinese airlines, then Scenario B offers insights into the direction of change that efficiency improvements will push the industry. However, given the above reservations, a more conservative interpretation is that they are a specific formulation of the general effects discussed above and thus illustrate those general effects for a special case.

Entry, exit and product differentiation

The directions of change in airline profits, consumer welfare and, therefore, economic welfare by country depend on the assumption of no exit.

Under the efficiency gains scenario, the assumption of no exit implies that all airlines improve their efficiency. When all airlines improve to the benchmark, the benchmark airline suffers reductions in profits, because by assumption it is the benchmark. In contrast, the inefficient airlines enjoy increases in profits, because by assumption they improve to the benchmark, competing more vigorously against their erstwhile more efficient competitor.

An alternative and no less plausible assumption is that open club airlines achieve the benchmark efficiency because efficient airlines force inefficient airlines to exit the market. The opposite effect on airline profits would be observed in this case: Efficient airlines increase their profits as they dominate markets and inefficient airlines suffer reductions in profits as they lose market share or exit the market.

In the context of direct flights with market entry, the assumptions of no exit and of a modest increase in product diversity imply an unknown a priori net effect on consumer surplus that depends on three factors. First, an assumed entry with no exit of incumbent airlines increases the number of airlines serving a market. Prices can be expected to decrease from the increase in competitors. Second, new entrants on routes are also assumed to add modestly to product diversity, increasing consumer surplus. However, the modest increase also limits their ability to compete effectively in the market. Finally, entry confronts the consumer preference for more frequent service on fewer airlines. The net effect on consumer surplus is only known after the simulation is completed.

In reality, the industry has indicated that a significant market presence is crucial to compete effectively. Obtaining a minimum market presence may not be an optimal strategy. Instead the optimal strategy may be attaining a large market presence. In this case, the product diversity that taps into latent demand may also take customers from incumbents. A long-run outcome may see one or more airlines exit the market.

Travel to and from Australia

Because of data limitations,[27] the model does not explicitly account for markets between non-Australian club members (for example, the market for travel between Hong Kong and Japan). Consequently, the simulation cannot provide estimates of the total economic welfare effects of the open club. In particular, its estimates omit:

- increases in Australian airline profits and Australian economic welfare from Australian airlines' entry into completely foreign markets;
- decreases in foreign airline profits from Australian airlines' entry into completely foreign markets; and
- increases in foreign consumer surplus in travel between two foreign countries from Australian airlines' entry into those markets.

Implications

Given the limitations of the model and the modelled scenarios as described above, the most reliable estimates of changes in profits, consumer surplus and economic welfare are for open club members in total; they are reported here. Individual country estimates are not reliable and depend strongly on scenario assumptions; they are not reported.

For example, the use of the efficiency estimates and the assumptions of airline entry and exit imply that model results for changes in profits by airline are direct consequences of scenario assumptions and not consequences of any underlying economic behaviour in the model. Therefore, estimated changes in profits by airline in markets for travel to and from Australia have little descriptive worth. They are even less appropriate as estimates of changes in profits by airline for all markets in the open club, because, as noted above, the exclusion of completely foreign markets omits likely increases in profits for Australian airlines and likely reductions in profits for foreign airlines. However, the estimated changes in profit for all airlines in club countries are more reliable

[27] For example, for non-Australian routes there were no price data or passenger origin-destination data as found in Avstats.

and relevant, because they do not imply specific winners and losers. They estimate the total effect on profits across all airlines reflecting the net change in profits among airlines.

Results for Australian markets

The net economic welfare gains in all three scenarios show a large gain for club members and a small loss for non-club countries (Table 9). The principal reasons for the results can be traced to the modelled effects of open clubs:

- As club airlines' productivity improves, their costs fall and they compete more vigorously against other airlines by cutting their prices or increasing the frequency of their services.
- Freed from the constraints of current ASAs, all club airlines redesign their networks to serve their markets to and from Australia better. In doing so they can offer both direct flights and indirect flights in a hub and spoke system. Direct flights keep costs down while the hub and spoke system increases frequency of service.
- Market entry by club airlines on routes increases competition because it is assumed that no incumbent airlines leave. The competitive pressures of entrants increase with their size because large entrants compete more strongly against incumbents in frequency and ticket prices.

Scenario A combines all these effects. Scenario B isolates the first effect. Scenario C isolates the second and third effects. But there are some important interactions between the three effects, so that the results of Scenario A are not simply the sum of results for Scenarios B and C. The separate impacts of Scenarios B and C are discussed first before their combined impact in Scenario A is analysed.

Table 9 Estimates of changes in net economic welfare from various open club scenarios[a,b]

	Scenario A	*Scenario B*	*Scenario C*
	Efficiency gains plus direct flights and market entry by club airlines on routes to and from Australia	*Efficiency gains*	*Direct flights and market entry by club airlines on routes to and from Australia*
	1997	*1997*	*1997*
	$m	$m	$m
Club members[c]			
Profit (gross)	-38.4	15.6	-30.4
Consumer surplus	291.6	152.1	73.2
Economic welfare	253.2	167.6	42.8
Non-club members			
Profit (gross)	-29.7	-24.7	-4.3
Consumer surplus	23.4	24.3	-0.3
Economic welfare	-6.3	-0.4	-4.6

a Estimates exclude economic welfare effects in markets between non-Australian countries in the club. These could not be estimated due to the lack of data on prices and passenger flows (by origin–destination and airline) between non-Australian countries in the club.
b Markets covered are between Australia and: China, Japan, Hong Kong, Malaysia, Republic of Korea, Taiwan and Indonesia.
c Club countries are Australia, China, Hong Kong and Japan. Club airlines are Ansett, Qantas, China Airlines, China Southern Airlines, China Eastern Airlines, Cathay Pacific, Japan Airlines and All Nippon Airlines.
Source: Commission estimates.

Scenario B results

Scenario B shows that the main beneficiaries of efficiency improvements are consumers (Table 9). The consumer surplus gains in club countries are nearly ten times the size of the increased club airline profits. In non-club countries, consumer surplus increases whilst the profits of non-club airlines fall. In addition, the fall in profits for all airlines (club and non-club combined) suggests that efficiency gains are passed on to consumers, while airlines that improve their efficiency take profits from their rivals.

Efficiency gains are passed on to consumers in lower prices and increased flight frequencies. Consumer surplus increases in both club and non-club countries as a result. Prices in non-club markets fall because club airlines become more efficient in all their markets, and they lower prices to passengers flying to non-club destinations. Examples of this could be more efficient uses of aircraft which are used in club and non-club countries. In addition, the competitive lessons learned in open club competition can be applied in non-club markets too. These lessons could be in the areas of network design, fleet usage and marketing, among others.

Airlines that become relatively more efficient (all club airlines except the benchmark) gain at the expense of those that become relatively less efficient (non-club airlines and the benchmark). Consequently club airlines' profits increase in total, while non-club airlines' profits fall. Competitive forces compel club airlines to pass on some of these cost savings to consumers through lower prices. This would create pressures for non-club airlines to either join the club, improve their efficiency or scale back their presence in markets served by club airlines.

Scenario C results

In Scenario C, the assumed increases in the number of airlines competing on routes between club members lead to price reductions in most club markets, profit declines for club and non-club airlines, and consumer surplus and economic welfare gains in club countries.

The price falls in Scenario C are driven by increased competition in the markets that club airlines enter and by their ability to cut costs by flying passengers directly to their final destinations. Club airline profits fall in Scenario C mainly as a result of the price falls. Non-club airline profits fall because they are unable to modify their networks to reduce costs while club airlines enter markets and restructure their networks.

Consumer surplus increases in open club countries because prices fall, frequency increases and the number of airlines connecting some club countries to Australia rises. Consumer gains in club countries are more than twice as large as profit losses. Economic welfare increases as a result.

Non-club consumer surplus declines marginally. This result is not surprising since non-club flights remain constrained and cannot benefit from the open club's improved network design or greater competition. In fact, the increase in direct flights by some club airlines out of Australia reduces the number of flights in some airlines' hub and spoke networks. This reduces their frequency of service to non-club destinations and adversely affects the consumer surplus of those non-club countries.

Scenario A results

The results of Scenario A are best explained as the efficiency gains of Scenario B compounding the competitive and network effects of Scenario C — improving productivity enhances the competition of freer networks. In particular, Scenario A shows:

- greater profit declines in moving from Scenario C to Scenario A come mostly at the expense of airlines in non-club countries ($8 million reduction in club profits compared to a $25 million reduction in non-club profits); and
- more vigorous competition increases consumer welfare by approximately 20 per cent more than the sum of Scenarios B and C would suggest.

In addition, the combined effects of efficiency gains and direct flights with market entry lead to considerable gains in club member consumer surplus and economic welfare with, by comparison, small changes in club airline profits. For non-members there is a net economic welfare loss, despite the spill-over efficiency benefits from open club airlines, because non-club airlines lose competitiveness to club airlines.

The gains in club members' consumer surplus are because the three open club effects have increased the vigour of competition, resulting in prices being pushed down.

The combined effects of productivity improvements, network design changes and market entry have a compound, rather than additive, effect on the degree of competition within the club. Within the club, new entrants compete with incumbents on price, frequency and cost, raising the level of competition above that in Scenarios B and C. Unlike Scenario B, incumbents cannot afford to retain some of the benefits of the productivity improvement, because new entrants can undercut them by charging prices that are closer to reduced costs faced by club airlines. These price effects are reflected in the consumer surplus and profit results across the three scenarios.

The deep price cuts within the club in Scenario A result in open club consumer surplus rising substantially. For club countries the increase in consumer surplus is greater than the sum of consumer surplus gains in Scenarios B and C.

Non-club consumer surplus increases as club airlines' productivity gains and frequency increases spill over into their non-club operations. Because there is no entry to these markets, the effects of Scenario A are approximately the sum of those for Scenarios B and C.

In Scenario A, club airlines sustain a net fall in the profits on their operations to and from Australia which is a result of these price falls. Consumers benefit from lower prices, increased frequency and greater choice. This result indicates that most of the benefits from the efficiency gains and improved network designs are passed on to passengers. The change in the net economic welfare of club countries is strongly positive because the gains in consumer surplus more than offset the combined profit declines of the eight club airlines.

Non-club countries suffer a small loss in their economic welfare as a result of the open club. This is because the profit decreases suffered by their airlines are greater than the gains in consumer surplus by non-club residents. Both effects are driven by the price falls to non-club destinations.

Network design changes as a result of the open club

Simulations A and C show that club airlines create new networks which utilise direct flights and hub and spoke systems. These new network designs permit airlines to fly lower cost direct flights from a club member, while increasing frequency of service via a hub and spoke system. These changes are illustrated for Ansett, Cathay Pacific and Qantas (Table 10). Scenario B reflects the old network constraints which prevents Ansett and Qantas using Hong Kong as a hub and Cathay from flying its passengers directly to Japan from Australia.

Table 10 **Shares of passengers flying from Australia to selected open club destinations using direct and indirect routes, selected club airlines**

	Scenario A		*Scenario B*		*Scenario C*	
	Direct routes	*Indirect routes*	*Direct routes*	*Indirect routes*	*Direct routes*	*Indirect routes*
Passengers by airline and origin–destination	%	%	%	%	%	%
Cathay Pacific						
Australia to Japan	58	42	0	100	63	37
Australia to China	0	100	0	100	0	100
Ansett						
Australia to Japan	100	0	100	0	100	0
Australia to China	0	100	100	0	0	100
Qantas						
Australia to Japan	100	0	100	0	100	0
Australia to China	94	6	100	0	94	6

Source: Commission estimates

Table 10 shows the network changes in both Scenarios A and C are:

- Cathay Pacific chooses to fly most of its Australia–Japan passengers directly, rather than flying all of them through its Hong Kong hub. It continues to fly the remainder of these passengers via Hong Kong.
- Ansett switches to using Hong Kong as hub for all its China bound passengers, who are flown to Hong Kong then transferred on to smaller aircraft for the flight to China.
- Qantas continues to fly the vast majority of its open club passengers directly to their destinations from Australia. However, it too finds Hong Kong a useful hub for marginally increasing the frequency of its services to China, thereby giving it a competitive advantage.

The unconstrained networks of the open club allow airlines to construct networks that provide better services in both price and quality terms. As the sectors that club airlines are allowed to fly increase, the airlines are able to increase flight frequency by establishing hub and spoke networks to service passengers flying between club countries. The model results show that Hong

Kong is preferred as a hub over Beijing and Tokyo. Club airlines weigh up the cost savings from lower cost direct flights against the competitive benefits of greater frequency to many of their destinations by using Hong Kong as a hub. Airlines choosing to set up hub and spoke systems also incur marginally higher costs as they trade off higher costs from operating smaller aircraft on some flight sectors serving a hub against the competitive advantages of increased frequency.

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Appendix

Table 11: **Flight cost per passenger by flight sector at 75 per cent load factor[a] ($)**

Flight sector (airport abbreviations)	*Boeing B747-400*	*Boeing B767-300ER*
Auckland—Los Angeles (akl.lax)	610	na
Auckland—Seoul (akl.sel)	581	646
Auckland—Sydney (akl.syd)	177	189
Auckland—Tokyo (akl.tyo)	562	614
Bangkok—Hong Kong (bkk.hkg)	141	163
Bangkok—Jakarta (bkk.jkt)	172	184
Bangkok—London (bkk.lhr)	577	644
Bangkok—Rome (bkk.rom)	526	585
Bangkok—Sydney (bkk.syd)	489	530
Hong Kong—Beijing (hkg.pek)	164	168
Hong Kong—Seoul (hkg.sel)	166	177
Hong Kong—Tokyo (hkg.tyo)	237	255
Hong Kong—Bangkok (kul.bkk)	100	106
Kuala Lumpur—Hong Kong (kul.hkg)	182	203
Kuala Lumpur—Jakarta (kul.jkt)	109	113
Kuala Lumpur—London (kul.lhr)	625	na
Kuala Lumpur—Rome (kul.rom)	568	633
Kuala Lumpur—Sydney (kul.syd)	436	468
Singapore—Bangkok (sin.bkk)	116	124

a Flight costs do not include overheads.

b na denotes infeasible flight.

Source: Commission estimates from Aerocost2.

Table 11: (continued) Flight cost per passenger by flight sector at 75 per cent load factor[a] ($)

Flight sector (airport abbreviations)	*Boeing B747-400*	*Boeing B767-300ER*
Singapore—Hong Kong (sin.hkg)	189	212
Singapore—Jakarta (sin.jkt)	91	94
Singapore—Kuala Lumpur (sin.kul)	46	49
Singapore—London (sin.lhr)	644	na
Singapore—Rome (sin.rom)	600	669
Singapore—Seoul (sin.sel)	364	391
Singapore—Tokyo (sin.tyo)	375	402
Sydney—Hong Kong (syd.hkg)	459	505
Sydney—Jakarta (syd.jkt)	365	391
Sydney—Los Angeles (syd.lax)	701	na
Sydney—Beijing (syd.pek)	549	602
Sydney—Seoul (syd.sel)	505	550
Sydney—Singapore (syd.sin)	409	437
Sydney—Tokyo (syd.tyo)	510	553

a Flight costs do not include overheads

b na denotes infeasible flight.

Source: Commission estimates from Aeorocost2.

Validation and sensitivity simulations

Two types of tests were carried out on the model:

- model validation simulations; and
- Ansett entry simulations under various assumptions about costs and demand behaviour.

Validation simulations test the ability of the price-setting model for various demand and cost parameters to replicate observed prices and quantities. In this context, a model is valid if its projected prices and quantities are close to observed prices and quantities. These tests showed that valid price-setting models depict a market in which travellers view airlines as offering highly substitutable services. A second finding was that the cost data in Aerocost2 are representative of airline costs.

The sensitivity of policy results arising from Ansett's entry are tested using different demand and cost parameters that produce valid models. Policy sensitivity simulations assess to what extent the estimated results of a policy change are dependent on the parameters used in the model. A model's policy conclusions are robust when they are insensitive to changes in the parameters used. In contrast, there must be strong grounds for justifying chosen parameters values if a model's policy results change significantly when parameters values are changed. In the model used here, the main policy results are the changes in prices, economic welfare and net tourism arising from a simulated change in the airlines' operating environment. The qualitative results of the effects of Ansett's entry are not changed when different demand and cost parameters are used.

Validation simulations

The complete model is not calibrated to observed quantities, airfares and costs, because the data come from different sources and are not necessarily consistent. In addition, only the aggregate demand price elasticities have been estimated for the Australian market. Therefore, one aim of the validation simulations is to find the range of demand and cost parameter values for which model solutions replicate observed quantities and prices. The parameters that are varied are the frequency, substitution and aggregate price elasticities of demand, the Aerocost2 costs and the estimated differences in airline costs.

Validation results are reported for two types of models, single market models and network models. Single market models[28] were built as prototypes for the larger, more complex network model:

- to test whether they were able to replicate observed prices and quantities;
- to suggest parameter value magnitudes for the network model being developed; and
- to provide indicative results for the Ansett entry simulations as published in the draft report.

Single market models treat each market separately. As such they simplify airline networks, especially for third country airlines, but still allow airlines to compete strategically in setting prices and frequencies of service. The main effects of the simplification are to reduce third-country airlines' cost levels and restrict their frequency of service in the market. The biases of the two effects on projected prices and quantities tend to offset each other. Nevertheless, the tolerance for errors in valid single market models must be larger than that for valid network models which include more network complexities.

Multi-market network models are expected to perform better than single market models. The network model was built to examine the possible effects of changes in airline networks arising from changing ASA flight restrictions, in particular the possibilities to restructure networks. This is an important issue for assessing the possible impacts of an open club, but is not a significant issue for analysing the effects of Ansett's entry. Sensitivity tests were carried out on the network model to clarify the range of parameter values that could produce valid models.

Three demand parameters are tested in the validation simulations:

- Substitution elasticity between airlines. This reflects the degree to which airlines are substitutes for each other. A range of values between 2 and 4.5 are used. No published estimates are available for Australian markets. Oum and Zhang (1995) found a median value of 2 among econometric studies that attempted to estimate the degree of substitutability between airlines. However, the industry suggested the degree of substitutability for Australian markets was much larger than this.
- Frequency elasticity of demand. This measures the responsiveness of demand to increases in the frequency of flights. An increase in the frequency of flights reflects an increase in the convenience of flying. As

[28] The single market models are restricted versions of the generalised network model explained above.

with the substitution elasticities, no published frequency elasticity estimates are available for Australian markets, so Oum and Zhang's study suggested a range of values to test. In the sensitivity analyses, the values of 0.05, 0.1, 0.15 and 0.2 are used. Oum and Zhang report a median value of 0.1 in studies that attempt to measure this responsiveness.

- Aggregate price elasticities of demand. The initial elasticities used in the model were estimated using Australian data (BTCE 1995). Inquiry participants were sceptical of the accuracy of these initial price elasticity estimates, suggesting more elastic values should be used. Therefore an experiment using the median price elasticity for non-Australian markets (Oum and Zhang 1995) was conducted. The experiment involved replacing the BTCE elasticities, which centre around -0.8, with a uniform price elasticity for all markets of -1.35.

The validation simulations also test the cost parameters used in the model. Two experiments were conducted:

- one varies the cost data by plus and minus fifteen per cent; and
- one applies uniform productivity, input and labour prices across all airlines.

Base cost data are varied because unlike the demand and price data, cost data are not observed in the market. They are Aerocost2 estimates that the Commission transformed to its cost classifications. A range of plus and minus 15 per cent was used because industry sources suggest Aerocost2 is correct to within 15 per cent. Validation experiments that vary costs by these amounts test whether the initial assessments of the range of demand parameters and behavioural assumptions for valid models are robust to these changes in costs, and whether the costs are representative at all.

Oum and Yu's estimated differences in airline productivity and input and labour prices are open to question. Therefore, it is important to determine whether conclusions about the validity of demand parameters and Aerocost2 costs depend on their estimates.

Results are reported in averages and standard errors to protect confidential data.

Results

Table 12 presents average price errors under the price-setting scenario using single market and network models and 1995 data with different demand parameters.[29] These price errors arise when the parameters in the first column are imposed on the model. Resulting prices are compared to observed values and the average is then taken over the markets covered.

Table 12: Average price errors under various demand parameter specifications in single market and network models

Demand specification	*Heterogenous airline costs*	
	Average error	*Standard deviation*
	per cent	*per cent*
Single market model[a]		
W (2, 0.1, BTCE)[b]	70.6	31.9
X (2, 0.2, BTCE)	56.2	29.3
Y (4, 0.1, BTCE)	-0.7	13.7
Z (4, 0.2, BTCE)	-11.0	13.0
Network model[c]		
K (4,0.1,BTCE)	5.9	7.4
L (3.5,0.15,BTCE)	11.2	8.5
M (4.5,0.05,BTCE)	4.1	6.9
N (3.5,0.1,-1.35)	12.3	6.9

a Countries covered are: China, Hong Kong, Indonesia, Japan, Malaysia, Republic of Korea, Singapore, Taiwan, Thailand, North America, UK & Ireland, and Rest of Europe.
b In brackets are (CES parameter, Aggregate frequency elasticity, aggregate demand elasticity). BTCE (1995) is the source of the aggregate demand elasticities used in all models except model N.
c Countries covered are: China, Hong Kong, Indonesia, Japan, Malaysia, Republic of Korea, Taiwan.
Source: Commission estimates.

Single market models with a CES parameter of 2 with either frequency elasticity lead to prices that are considerably different from observed prices. The direction of the error implies that the degree of competition inherent in the assumed behaviour and parameters values is too low for observed market outcomes. As a comparison of the average error to the standard deviation implies, the magnitude of error is large in all markets. In contrast, a value of the CES elasticity of 4 for both frequency elasticity values leads to errors in prices and quantities that are significantly smaller than a CES value of 2. Given a CES elasticity value of 4,

[29] Quantity errors were also calculated, but for brevity are not reported. These follow the pattern and magnitude of the price errors, given downward sloping aggregate demand curves. Tests using 1997 data were also carried out, with similar results to those reported.

the average errors for a value of 0.1 for the frequency elasticity are smaller than for a value of 0.2.

The single market results suggest that the network model sensitivity tests use a narrower range of parameter values around the (CES 4, Freq., 0.1) case. The CES elasticity is varied by 12.5 per cent (from 4 to 3.5), and the frequency elasticity by plus or minus 50 per cent (from 0.1 to either 0.15 or 0.05). These ranges may be contrasted to the doubling of both parameter values in the single market sensitivity tests.

The network models K, L, M and N are all able to replicate observed prices with an average error of less than 15 per cent. All are valid models being within the plus or minus 15 per cent range accepted by industry. The four models replicate observed prices well in all markets because the standard deviation on their errors is small. The small standard deviation implies that prices are narrowly dispersed around observed prices.

Network model K has a somewhat higher average error in price (5.9 per cent) compared to its single market equivalent, model Y (-0.7 per cent). There are two reasons. First, the network model's price and standard errors are averaged over the seven Ansett markets, rather than the twelve markets of the single market simulations. The network model excludes the markets of Thailand, Singapore, UK and Ireland, Rest of Europe, and North America. Second, the network model imposes greater flight costs on third economy airlines than the single market models. In the network model third country airlines must fly through their home country when transporting passengers to and from Australia. In the single market model, these airlines were assumed to fly passengers directly from their origin to their destination, without stopping in the airlines' home countries.

Model N tests the sensitivity of the model to changes in the price elasticity of aggregate demand by imposing a single price elasticity of -1.35, the median value observed by Oum and Zhang (1995). The network models K, L and M use price elasticities for travel between individual countries that centre around -0.8. These country specific elasticities are based on the econometric estimates of the BTCE. Comparing models K and N, the approximate 70 per cent increase in the price elasticity of aggregate demand requires no more than a 13 per cent decrease in the substitution elasticity to maintain model validity. This implies that large changes in the aggregate demand elasticity have less of an effect on model validity than small changes in the substitution elasticity. Comparing models L and N, the 33 per cent decrease in frequency elasticity required an approximate 70 per cent increase in aggregate demand elasticity; implying that changes in the frequency elasticity have a greater impact on model validity than changes in the aggregate demand elasticity.

These results suggest that any demand sensitivity studies that are undertaken on liberalisation scenarios using either a single market or a network model should be in a range around the (CES 4, Frequency 0.1) case with a smaller variation in parameter values than was attempted here.

Two additional kinds of cost sensitivity simulations are performed using the single market models with the preferred parameter values (CES 4, Frequency 0.1). The first tests the extent to which previous validation results are sensitive to changes in the underlying network costs. Industry sources placed an error bound of 15 per cent on total Aerocost2 estimates. Therefore simulations are conducted that vary costs by plus or minus 15 per cent. The second kind of cost sensitivity simulation tests whether model results change markedly when airlines have *homogeneous* cost structures — no differences in productivity or input prices between airlines — as compared to *heterogeneous* cost structures created after adjusting for estimated productivity and input price differences.[30]

The cost sensitivity simulations varying costs by plus or minus 15 per cent reaffirm the model with CES elasticity of 4 and frequency elasticity of 0.1 as preferred to the others considered. When costs are varied by plus or minus fifteen per cent, the average price errors are 11.6 and -15.6 per cent, respectively (Table 13). For most markets, a cost change within the range is sufficient to reconcile projected prices and quantities exactly to observed prices and quantities. In addition, the cost and demand simulation results imply that, within the general modelling framework, Aerocost2 estimates would have to be more that 50 per cent too high to reconcile projected and observed quantities and prices for a CES elasticity of 2.

[30] Homogenous cost structures could also be taken as the ‘fall back’ position for the differences in airlines input prices and productivity as identified by Oum and Yu if their network estimates are not taken as representative of differences in costs and productivity for individual flight sectors across airlines.

Table 13: **Average price errors and standard deviations of projected prices from observed average prices for airlines with homogeneous and heterogeneous costs in single market models[a]**

	Demand specification Y (4, 0.1, BTCE)[b]	
	average error	*standard deviation*
	per cent	*per cent*
Heterogenous airline costs		
Base costs	-0.7	13.7
Costs plus 15 per cent	11.6	18.4
Costs minus 15 per cent	-15.6	13.1
Homogeneous airline costs		
Base costs	-2.1	13.4

a Countries covered are: China, Hong Kong, Indonesia, Japan, Malaysia, Republic of Korea, Singapore, Taiwan, Thailand, North America, UK & Ireland, and Rest of Europe.

b In brackets are (CES parameter, Aggregate frequency elasticity, aggregate demand elasticity). BTCE (1995) is the source of the aggregate demand elasticities.

Source: Commission estimates.

Comparing results of simulations that rely on heterogeneous or homogeneous base cost structures, the average price error is larger for homogeneous airline costs, but not so large that they undermine the conclusions drawn from the demand and Aerocost2 validity simulations or suggest that average prices are strongly affected by the estimated differences in airline productivity and input price levels.

Three conclusions can be drawn from the sensitivity simulations. First, valid models depict a market in which travellers view airlines as offering highly substitutable services, represented by CES and frequency elasticity values in a range around 4 and around 0.1, respectively. Second, varying cost data by plus or minus 15 per cent, the error range of Aerocost2 suggested by the industry, can reconcile the model’s project prices to observed prices without appreciably altering the range of valid demand parameters. Third, the validity of the models does not depend on the assumption of heterogeneous costs. In particular, relaxing this assumption does not overturn the first conclusions about demand and Aerocost2.

Ansett entry simulations

The main results of the Ansett simulations are that Ansett's entry reduced airfares, increased passenger flows to Australia and increased Australian and foreign net economic welfare. These results were tested in sensitivity experiments against the following alternative behavioural, cost, and demand scenarios:

- demand parameters are different (but the model is still valid);
- airlines act as price-takers;
- Ansett does not increase product diversity; and
- airlines have identical productivity and input prices.

The major results for prices, total and net passenger inflows and economic welfare are unchanged for changes in demand parameters that still lead to valid models. The pattern of economic welfare changes is altered somewhat for more price elastic aggregate demand. When aggregate demand is assumed to be price elastic (the alternative suggested by Inquiry participants), the economic welfare gains are positive and larger in absolute value relative to the reduction in airline profits. That is, the efficiency gains of Ansett's entry are increased relative to its redistributive effects.

The cost scenario assumes there are no productivity or input price differences among airlines. The main results are the same for this scenario. The importance of this result, given that airlines have cost differences, is that differences in airlines' costs would have to be considerably greater than those estimated by Oum and Yu to reverse the model's results. Although the industry criticised individual productivity estimates, the suggested alternatives meant that airlines' productivity were more alike and were not large enough to overturn the significant model results.

Two additional scenarios are considered. Each significantly limits the degree of increased competition introduced by Ansett's entry. The scenarios offer much less plausible descriptions of the Australia-Asia air travel market, for reasons cited below. As a consequence, their results stand in contrast with previous sensitivity results, in which the robustness of model results are tested. Instead, their results illustrate the importance of non-price features in determining economic welfare gains from Ansett's entry.

The price-taking scenario is interesting because it explores the cost and demand effects of Ansett's entry without any effects from price competition. That is, it is assumed that incumbent airlines already act as if they are competitors in a perfectly competitive market. The observed degree of market concentration and discussions with the industry suggest that this mind-set among airlines is a highly improbable description of their behaviour. The significant result of this scenario is that Ansett's entry is more likely to be welfare enhancing if it reduces industry costs or if it contributes to product diversity.

The final scenario assumes that demand is diverted to new entrants without drawing on any latent demand. It is a 'worst case' scenario for Ansett's entry to be economic welfare improving because it assumes Ansett's international network was not significantly different in its city or client focus from that of its competitors. That is, despite profit incentives, it did not, or could not because of ASAs, differentiate its service from that of other airlines and simply diverted passengers from them. Under this scenario, consumer surplus gains are still obtained, but they do not outweigh the profit declines of incumbent airlines.

The methodologies used in these four scenarios and their results are discussed in detail below. All reported results use 1995 data, however sensitivity tests using 1997 data were also conducted. The results of the 1997 tests are not reported for brevity and because they do not change any of the conclusions about model sensitivity.

Demand parameters

The following discusses the effects of Ansett's entry when different demand parameters are used. The network model is used with the four sets of demand parameters employed in the validation simulations above. It is assumed that Ansett successfully differentiates it product from those of its competitors.

Prices fall after Ansett's entry in every demand scenario (Table 14). The magnitude of price changes are similar for scenarios K, L and M.[31] Price changes under scenario N are smaller but similar in magnitude to those of scenario M. Scenario K's results were reported above and in the Commission's final report (PC 1998).

31 The dominant parameter change appears to be the frequency elasticity. Changes are largest for scenario L (CES of 3.5, Freq of 0.15, and BTCE demand elasticities), second largest for scenario K (CES of 4.0, Freq of 0.1 and BTCE demand elasticities), and smallest for scenario M (CES of 4.5, Freq of 0.05 and BTCE demand elasticities). However, the result is not surprising because the frequency parameter changes by 50 per cent while the CES parameter changes by 13 per cent.

Table 14: **Estimated price changes under Ansett entry using various demand parameters, 1995[a]**

Economy	*K (4,0.1,BTCE)*[b]	*L (3.5,0.15,BTCE)*	*M (4.5,0.05,BTCE)*	*N (3.5,0.1,-1.35)*
	per cent	per cent	per cent	per cent
China	-4.1	-3.6	-3.8	-3.5
Hong Kong	-7.0	-7.6	-6.1	-5.0
Indonesia	-7.4	-8.3	-6.7	-5.0
Japan	-3.8	-4.0	-3.6	-3.2
Korea, Republic of[c]	0.1	0.0	0.0	0.0
Malaysia	-0.9	-1.1	-0.8	-0.6
Taiwan	-1.1	-1.4	-0.9	-0.7

a Ansett is assumed to successfully differentiate it product from those of its competitions.

b In brackets are (CES parameter, Aggregate frequency elasticity, aggregate demand elasticity). BTCE(1995) is the source of the aggregate demand elasticities used in all scenarios except scenario N.

c Ansett had minimal Korean market share in 1995. It was not included in Korean demand for 1995.

Source: Commission estimates

Australian economic welfare increases in every demand scenario (Table 15). The pattern of welfare changes is also similar across the first three scenarios with consumer surplus gains and airline profit losses being greater in absolute magnitude than the net economic welfare gain. In contrast, profit losses are considerably smaller than the economic welfare gains under scenario N. Gains in consumer surplus are smaller under scenario N than under the other scenarios. Nevertheless, Australian economic welfare gains under scenario N are second in size only to those under scenario L.

Foreign economic welfare also increases for every model (Table 15). The pattern of foreign economic welfare changes for Ansett's entry is similar to Australian economic welfare changes. Economic welfare gains are small compared to changes in consumer surplus and profit in the first three scenarios. A difference in pattern, however, is that economic welfare gains are similar in magnitude to changes in foreign profits for scenario N and considerably larger than the gains in the other three scenarios.

Table 15: **Estimated changes in Australian and foreign economic welfare for Ansett entry using various demand parameters, 1995[a]**

	K (4,0.1,BTCE)[b]	*L (3.5,0.15,BTCE)*	*M (4.5,0.05,BTCE)*	*N (3.5,0.1,-1.35)*
	$m	$m	$m	$m
Australian				
Profit (gross)	-41.6	-40.6	-40.9	-18.3
Consumer surplus	70.0	80.1	62.7	57.3
Economic welfare	28.4	39.5	21.8	39.0
Foreign				
Profit (gross)	-75.9	-83.5	-70.3	-48.9
Consumer surplus	88.3	93.7	85.1	92.1
Economic welfare	12.4	10.2	14.8	43.3

a Ansett is assumed to successfully differentiate it product from those of its competitions.

b In brackets are (CES parameter, Aggregate frequency elasticity, aggregate demand elasticity). BTCE(1995) is the source of the aggregate demand elasticities used in all scenarios except scenario N.

Source: Commission estimates

For both Australian and foreign welfare changes, the increase in the size of the change in economic welfare relative to changes in consumer surplus and profit owes to the increase in the aggregate price elasticity. This is because a given price change will lead to a larger change in the consumer surplus welfare that is not a transfer from producers (the triangle behind the aggregate demand curve after the price change).

Net passenger movements to Australia increase in every model with differences in total net passenger movements being relatively small across models (Table 16). Net passenger movements for China, Hong Kong and Indonesia are more sensitive to model changes. This reflects the relative balance in passenger flows between foreign visitor and domestic resident travel and the implied base case of each model. As a consequence, the absolute magnitude is volatile, but the direction of change is not altered and its impact on total net passenger movements is small.

Table 16: **Estimated changes in net passenger movements to and from Australia under Ansett entry using various demand parameters, 1995[a,b]**

Economy	*K (4,0.1,BTCE)*[c]	*L (3.5,0.15,BTCE)*	*M (4.5,0.05,BTCE)*	*N (3.5,0.1,-1.35)*
	per cent	per cent	per cent	per cent
China	-3.1	-5.6	-2.8	-12.1
Hong Kong	-7.1	-10.4	-3.4	-33.8
Indonesia	-2.4	-2.1	-2.6	-37.2
Japan	2.7	2.7	2.5	5.5
Korea, Republic of[d]	0.1	0.1	0.1	0.0
Malaysia	1.4	2.1	0.9	1.5
Taiwan	1.2	1.4	0.9	1.5
Total	**2.0**	**2.1**	**1.8**	**1.5**

a Net passenger movements are inbound visitor movements minus outbound resident movements.

b Ansett is assumed to successfully differentiate it product from those of its competitions.

c In brackets are (CES parameter, Aggregate frequency elasticity, aggregate demand elasticity). BTCE(1995) is the source of the aggregate demand elasticities used in all scenarios except scenario N.

d Ansett had minimal Korean market share in 1995. It was not included in Korean demand for 1995.

Source: Commission estimates

Efficiency differences

The differences in airline productivity and input costs estimated by Oum and Yu (1995) are not critical in determining the policy results of the Ansett entry simulations. In addition, differences in airline costs would have to be considerably larger than those estimated by Oum and Yu to reverse the model's results. Although the industry criticised the assumptions of the productivity estimates, the industry's suggested alternative productivity differences are not large enough to overturn the significant model results**.**

Prices fall when Ansett enters, regardless of whether homogeneous or heterogeneous costs are imposed (Table 17). Price falls are larger when costs are heterogeneous and airlines compete by setting prices than when costs are homogeneous and airlines set prices. In the homogeneous cost, price-setting scenario, price falls result from the relative cost advantage Ansett has over third country carriers who fly indirectly. In the heterogeneous cost, price-setting scenario, Ansett's relative cost advantage is greater because it arises from two sources — direct flights and Oum and Yu's relative productivity and input price estimates. Because Ansett's productivity and input prices are average (that is, same as Qantas), it gains an advantage over airlines that have higher cost or lower productivity. This advantage combined with the cost savings from direct flights means that Ansett's costs are lower than some incumbent airlines. In the price-setting simulation, these lower costs are passed on to consumers, leading to greater price falls in the heterogeneous cost scenario than the homogeneous cost scenario.

Table 17: **Estimated price changes under Ansett's diversity creating entry using heterogeneous and homogeneous airline costs and price-setting airline behaviour, 1995[a]**

	Heterogeneous costs	*Homogeneous costs*
	Price setting K (4,0.1,BTCE)[a]	*Price setting K (4,0.1,BTCE)*
	per cent	per cent
China	-4.1	-2.3
Hong Kong	-7.0	-7.5
Indonesia	-7.4	-4.6
Japan	-3.8	-2.9
Korea, Republic of[b]	0.1	0.1
Malaysia	-0.9	-1.1
Taiwan	-1.1	-0.4

a In brackets are (CES parameter, Aggregate frequency elasticity, aggregate demand elasticity). BTCE (1995) is the source of the aggregate demand elasticities.

b Ansett had minimal Korean market share in 1995. It was not included in Korean demand for 1995.

Source: Commission estimates

The economic welfare results of the model are not overturned when homogeneous costs are imposed (Table 18). Australian and foreign economic welfare improves in both cases. The magnitudes of estimated changes in profit and consumer surplus are little altered between scenarios, indicating that the policy results are not dependent on Oum and Yu's estimates.

Table 18: **Estimated changes in Australian and foreign economic welfare for Ansett's demand creating entry using heterogeneous and homogeneous airline costs and price setting airline behaviour, 1995**

	Heterogenous cost	*Homogeneous cost*
	Price setting K (4,0.1,BTCE)[a]	*Price setting K (4,0.1,BTCE)*
	$m	$m
Australian		
Profit (gross)	-41.6	-40.3
Consumer surplus	70.0	62.8
Economic welfare	28.4	22.5
Foreign		
Profit (gross)	-75.9	-72.6
Consumer surplus	88.3	82.0
Economic welfare	12.4	9.4

a In brackets are (CES parameter, Aggregate frequency elasticity, aggregate demand elasticity). BTCE (1995) is the source of the aggregate demand elasticities.

Source: Commission estimates

Price-taking and demand diversity scenarios

As previously discussed, Ansett's entry has three competitive effects on the market: price, frequency and product diversity. Results for the price-taking scenario will reflect the frequency and product diversity effects because it is assumed that airlines act as if they competed in a perfectly competitive market. Results for the demand diversity scenario reflect only price and frequency effects because it assumes that Ansett does not differentiate its service from that of its competitors.

The estimated effect of Ansett's entry on prices does not depend on Ansett's ability to differentiate its service and tap into latent demand. Comparing the two price setting results or the two price taking results, there is little difference between price changes whether Ansett's entry increased diversity or had no effect on diversity (Table 19). The result for the price-setting model tends to re-enforce an earlier result that price changes were largest for those markets in which Ansett attained the largest market share. That is, the price effect depends on the relative size of Ansett in the market and not the total market size.

Table 19: **Estimated price changes under Ansett entry, with diversity increased and unchanged, under price-setting and price-taking behavioural assumptions, 1995**

	Create diversity		*Same diversity*	
	Price-setting	*Price-taking*	*Price-setting*	*Price-taking*
	K (4,0.1,BTCE)[a]	*K (4,0.1,BTCE)*[a]	*K (4,0.1,BTCE)*[a]	*K (4,0.1,BTCE)*[a]
	per cent	per cent	per cent	per cent
China	-4.1	-1.0	-4.1	-1.0
Hong Kong	-7.0	0.3	-7.0	0.3
Indonesia	-7.4	-0.1	-7.3	0.0
Japan	-3.8	-0.4	-3.8	-0.4
Korea, Republic of[b]	0.1	0.0	0.0	0.0
Malaysia	-0.9	0.2	-0.9	0.2
Taiwan	-1.1	-0.1	-1.2	-0.1

a In brackets are (CES parameter, aggregate frequency elasticity, aggregate demand elasticity). BTCE (1995) is the source of the aggregate demand elasticities.

b Ansett had minimal Korean market share in 1995. It was not included in Korean demand for 1995.

Source: Commission estimates

The demand diversity and price-taking scenarios also underscore the importance of price, frequency and diversity effects of Ansett’s entry on changes in economic welfare. For example, the slight price changes seen under price-taking behaviour suggest that very little change in economic welfare could be attributed to price changes. When, by assumption, Ansett’s entry does not lead to greater service diversity, Australian and foreign consumer surpluses fall by \$14.3 and \$32.6 million, respectively (Table 20). In contrast, when, by assumption, Ansett’s entry does increase diversity, there are net Australian and foreign consumer surplus gains of \$22 and \$31.5 million, respectively, which reflect the losses in consumer surplus from the frequency effect and gains in consumer surplus due to increased diversity.

Table 20: **Estimated changes in Australian and foreign economic welfare for Ansett entry, heterogeneous costs, with diversity increased and unchanged, under price-setting and price-taking behavioural assumptions, 1995**

	Create diversity		*Same diversity*	
	Price setting	*Price-taking*	*Price setting*	*Price-taking*
	K (4,0.1,BTCE)[a]	*K (4,0.1,BTCE)*	*K (4,0.1,BTCE)*	*K (4,0.1,BTCE)*
	$m	$m	$m	$m
Australian				
Profit (gross)	-41.6	0.0	-37.1	0.0
Consumer surplus	70.0	22.0	32.0	-14.3
Economic welfare	28.4	22.0	-5.1	-14.3
Foreign				
Profit (gross)	-75.9	0.0	-72.1	0.0
Consumer surplus	88.3	31.5	21.6	-32.6
Economic welfare	12.4	31.5	-50.5	-32.6

a In brackets are (CES parameter, aggregate frequency elasticity, aggregate demand elasticity). BTCE (1995) is the source of the aggregate demand elasticities.

Source: Commission estimates

Similarly for the price-setting scenarios, the minimal differences in estimated price effects for the creating diversity and same diversity simulations suggest that the difference in estimated changes in economic welfare owes to assumed inability of Ansett's entry to create more diversity. As a consequence, Australian and foreign consumer surplus estimates are $40 and $65 million less when Ansett's entry is assumed not to create more diversity. It should be repeated, however, that this scenario is a worst case scenario. It is also a highly improbable scenario because it is in Ansett's commercial interest to differentiate its service from its competitors.

Solution algorithm for price-taking behaviour

Under price-taking behaviour, airlines are assumed to act as if they take prices as given when maximising profits. Perfectly competitive equilibria can typically be solved for using a social planner's problem which maximises the sum of producer and consumer surplus. An exception occurs if there are externalities. Total frequency is an externality in this model formulation, because there is an imperfect connection between the consumer's valuation of total frequency and the price that the airlines receive for a trip.[32] Therefore the social planner's problem will not identify the competitive equilibrium. To find the competitive equilibrium, a condition is added to the social planner's problem that price equals marginal cost. The modified social planner's optimisation problem is:

$$\max_{seats,p,F,Q,q} \sum_{(o,d)\in MS(ac,o,d)} CS(pagg(o,d);o,d) + \sum_{ac\in A} \pi(ac)$$

$$\begin{aligned} &\text{s.t. Demand equations (1) - (5);} \\ &\text{Seat allocation equations (7) - (13);} \\ &\text{Passenger and flight capacity (14) - (16);} \\ &\text{Total cost equation (22);} \\ &\text{Profit equations (23);} \\ &\text{Market clearing equation (24); and} \\ &\text{Price equals marginal cost.} \end{aligned} \tag{41}$$

32 Multi-part pricing schemes that allow airlines to charge for total frequency could internalise this externality and admit the possibility that the solution to the social planner's problem is a competitive equilibrium.

GAMS program for network Ansett simulations base model

```
* This file is c:\gams\ANSNET4B.gms.
* It models a network
* of routes in South-east and North Asia served by major
* carriers operating out of Australia.

* The model is used to assess the impact of ANSETT's ENTRY
* into various market routes. The model can also be used
* assess the impact of an OPEN CLUB on profitablity of airlines
* and the gains and losses to various members of the club.

* It shows how the major airlines serving Australia's markets in
* North Asia and South-East Asia operate under conditions of Price taking,
* and Bertrand (price-setting) competition. Profits are maximised according to
* the competitive conjectures each airline uses about its competitors.
* Under all three forms of competition, airlines must solve the cost
* minimisation sub-problem of allocating their passengers to flight legs (i,j),
* using aircraft types (at), in order to get the passengers from their origins to
* destinations (o,d).


$OFFSYMLIST OFFSYMXREF
OPTION SOLPRINT=OFF;
OPTION DECIMALS=4;
OPTION INTEGER3=1 ;
OPTION LIMROW=0 ;
OPTION LIMCOL=0 ;
*OPTION NLP=MINOS5 ;
OPTION NLP=CONOPT2 ;
OPTION LP = OSL;
OPTION RESLIM = 4000;


SETS
  O cities /AKL  Auckland
            BKK  Bangkok
            HKG  Hong Kong
            JKT  Jakarta
            KUL  Kuala Lumpur
            PEK  Beijing
            SEL  Seoul
            SIN  Singapore
            SYD  Sydney
            TPE  Taipei
            TYO  Tokyo (Narita)   /

  AC major airlines flying out of Australia
             / AN   Ansett
               BA   British Airways
               BR   Eva Airlines
```

```
          CA   Air China
          CX   Cathay Pacific Airlines
          GA   Garuda Airlines
          JL   Japan Airlines
          KE   Korean Air
          MA   Malaysian Airlines
          MR   Mandarin Air
          NH   All Nippon Airways
          NZ   Air New Zealand
          QF   Qantas
          SG   Sempati Air
          SQ   Singapore Airlines
          TG   Thai Airways /

 CH(AC) airlines serving China / QF, CX, CA, AN, SQ, JL, NZ, NH, MA, BR, TG /
 HK(AC) airlines serving Hong Kong / QF, AN, SQ, CX, MA, NZ /
 ID(AC) airlines serving Indonesia / QF, GA, SG, AN, SQ /
 JP(AC) airlines serving Japan / NH, QF, JL, AN, KE, SQ, CX, NZ/
 KO(AC) airlines serving Korea /QF, JL, SQ, CX, NZ, KE, AN /
 ML(AC) airlines serving Malaysia / MA, QF, SQ, BA, AN /
 SP(AC) airlines serving Singapore / QF, SQ, BA, MA, GA /
 TW(AC) airlines serving Taiwan / QF, AN, SQ, CX, BR, NZ, MR /
 AT aircraft /B7474, B7673ER/

 QDLBL name to identify demand for seats /QDOB, POB/

 LABELS names to identify variable costs
   / LF load factor on aircraft flying sector ij
     MCP marginal cost of passenger on sector ij ($000 per passenger)
     MCF  marginal cost of flight on sector ij ($000 per flight)
     FCK  fixed cost of leasing aircraft for one flight on ij ($000 per flight)/

 PRODLBL productvity and price adjustment parameter names
   /AIRP, LABP, INPP/ ;

ALIAS(O,D);
ALIAS(D,I);
ALIAS(I,J);
ALIAS(AC,AL);


SETS
 LK(i,j) LINKS BETWEEN EACH AIRPORT IN THE NETWORK
   /AKL.(SYD,SEL,TPE,TYO)
    BKK.(SYD,HKG,KUL,SIN,JKT)
    HKG.(SYD,PEK,SEL,TPE,TYO,KUL,BKK,SIN)
    JKT.(BKK,SIN,KUL,SYD)
    KUL.(SYD,SIN,BKK,HKG,JKT)
    PEK.(SYD,HKG)
    SEL.(SYD,HKG,AKL,SIN)
    SIN.(SYD,JKT,KUL,BKK,HKG,SEL,TPE,TYO)
    SYD.(BKK,SIN,JKT,KUL,HKG,PEK,SEL,TPE,TYO,AKL)
    TPE.(HKG,SYD,AKL,SIN)
    TYO.(SYD,HKG,SIN,AKL)                          /
```

```
  SERV(ac,o) Cities connected by each airline's network

   /AN.(AKL,HKG,JKT,KUL,PEK,SEL,SIN,SYD,TPE,TYO)
    BA.(BKK,KUL,SIN,SYD)
    BR.(AKL,HKG,PEK,SIN,SYD,TPE)
    CA.(HKG,PEK,SYD)
    CX.(BKK,HKG,KUL,PEK,SEL,SIN,SYD,TPE,TYO)
    GA.(BKK,JKT,KUL,SIN,SYD)
    JL.(AKL,HKG,PEK,SEL,SYD,TYO)
    KE.(AKL,HKG,SEL,SIN,SYD,TYO)
    MA.(BKK,HKG,JKT,KUL,PEK,SIN,SYD)
    MR.(TPE,SYD)
    NH.(AKL,HKG,PEK,SYD,TYO)
    NZ.(AKL,BKK,HKG,PEK,SEL,SYD,TPE,TYO)
    QF.(AKL,BKK,HKG,JKT,KUL,PEK,SEL,SIN,SYD,TPE,TYO)
    SG.(BKK,JKT,SIN,SYD)
    SQ.(BKK,HKG,JKT,KUL,PEK,SEL,SIN,SYD,TPE,TYO)
    TG.(BKK,HKG,JKT,KUL,PEK,SIN,SYD)
    / ;

* The next operation maps the origin-destination pairs that an airline can
* connect given the cities it serves. The condition (ord(O) NE ord(d))
* ensures that the connected cities are not the same. That is, the 1xN
* set of cities served is converted into an NxN set of city connections.
* The new set is displayed as a matrix, with the element YES indicating
* that the indexed city pairs can be connected using the airline's network
* and are therefore elements of the new NxN set. A blank element means that
* the city-pairs cannot be conneted using the airline's network and are
* therefore not members of the new set.

SET
   PF(ac,o,d) Possible flights on airline network by od pair;
   PF(ac,o,d) =(ord(O) + ord(D))$((SERV(ac,o)) AND (ord(O) NE ord(d))) ;

SET
   MF(o,d) Impossible flights on airline network by od pair;
   MF(o,d) =(ord(O) + ord(D))$(ord(O) EQ ord(d)) ;

SETS

SECTR1(ac,i,j) Outbound flight legs available to each airline

 /
  AN.SYD.(AKL,SIN,HKG,JKT,KUL,PEK,SEL,TPE,TYO)
  BA.BKK.SYD
  BA.KUL.SYD
  BA.SIN.SYD
  BR.TPE.(AKL,HKG,SIN,SYD)
  BR.HKG.PEK
  CA.PEK.(HKG,SYD)
  CX.HKG.(BKK,KUL,PEK,SEL,SIN,SYD,TPE,TYO)
  GA.JKT.(BKK,KUL,SIN,SYD)
  JL.TYO.(AKL,HKG,SYD)
```

```
  JL.SYD.(PEK,SEL)
  KE.SEL.(AKL,HKG,SIN,SYD)
  KE.SYD.(TYO)
  MA.KUL.(BKK,HKG,JKT,SIN,SYD)
  MA.HKG.(PEK)
  MR.TPE.SYD
  NH.TYO.(AKL,HKG,SYD)
  NH.SYD.(PEK,TPE)
  NZ.AKL.(SEL,SYD,TPE,TYO)
  NZ.SYD.(BKK,HKG,PEK)
  QF.SYD.(AKL,BKK,HKG,JKT,KUL,PEK,SEL,SIN,TPE,TYO)
  SG.JKT.(BKK,KUL,SIN,SYD)
  SQ.SIN.(BKK,HKG,JKT,KUL,SEL,SYD,TPE,TYO)
  SQ.HKG.PEK
  TG.BKK.(HKG,JKT,KUL,SIN,SYD)
  TG.HKG.PEK

 / ;

SET
  SECTR2(AC,J,I) Inbound flight legs by airline ;
  SECTR2(AC,J,I) = SECTR1(AC,I,J) ;


SET
  SECTR(AC,I,J) Flight legs INBOUND AND OUTBOUND by airline ;
  SECTR(AC,I,J) = SECTR1(AC,I,J) + SECTR2(AC,I,J) ;


SET
  MK1(o,d) Outbound markets
  /SYD.(HKG,JKT,KUL,PEK,SEL,TPE,TYO) /;

SET
  MK2(D,O) Inbound markets;
  MK2(D,O) = MK1(O,D) ;

SET
  MK(O,D) INBOUND AND OUTBOUND markets;
  MK(O,D) = MK1(O,D) + MK2(O,D) ;

SETS
  MS1(ac,o,d) Outbound markets served by airline
 /
   AN.SYD.(HKG,JKT,KUL,PEK,TPE,TYO)
   BA.SYD.(KUL)
   BR.SYD.(PEK,TPE)
   CA.SYD.(PEK)
   CX.SYD.(HKG,PEK,SEL,TPE,TYO)
   GA.SYD.(JKT)
   JL.SYD.(TYO,PEK,SEL)
   KE.SYD.(SEL,TYO)
   MA.SYD.(HKG,KUL,PEK)
   MR.SYD.(TPE)
```

```
   NH.SYD.(PEK,TYO)
   NZ.SYD.(HKG,PEK,SEL,TPE,TYO)
   QF.SYD.(HKG,JKT,KUL,PEK,SEL,TPE,TYO)
   SG.SYD.(JKT)
   SQ.SYD.(HKG,JKT,KUL,PEK,SEL,TPE,TYO)
   TG.SYD.(PEK)
 /;

SET
  MS2(AC,D,O) Inbound markets served by airline ;
  MS2(AC,D,O) = MS1(AC,O,D) ;

SET
  MS(AC,O,D) INBOUND AND OUTBOUND markets served by airline ;
  MS(AC,O,D) = MS1(AC,O,D) + MS2(AC,O,D) ;

SET
  KNOWNLF(I,J) SECTORS WHOSE LOAD FACTORS ARE KNOWN
    /SYD.PEK
     SYD.HKG
     SYD.JKT
     SYD.TYO
     SYD.SEL
     SYD.KUL
     SYD.SIN
     SYD.TPE
     SYD.BKK
     PEK.SYD
     HKG.SYD
     JKT.SYD
     TYO.SYD
     SEL.SYD
     KUL.SYD
     SIN.SYD
     TPE.SYD
     BKK.SYD  / ;

SET NT  iteration number for do loop /1*100/;

PARAMETERS

   ALPHA(AC,O,D)   interior ces coefficient sum to one
   BETA(AC,O,D)    parameter for frequency adjustment
   GAMMA(O,D)      negative of ces substitution elasticity
   ETA(O,D)        aggregate demand elasticity
   AGG(O,D)        aggregate demand coefficient
   W(AC,I,J,AT)    marginal cost of occ seats ($000 per passenger)
   V(AC,I,J,AT)    marginal cost of frequency ($0'000 per flight)
   Z(AC,I,J,AT)    marginal cost of capital ($0'000 per flight)
   QMAX(AT)        max passenger capacity (TENS OF PERSONS)
   SECTNUM(AC,I,J) dummy variable for counting number of sectors an airline can fly
   TOTSECTR(AC)    total number of sectors INBOUND AND OUTBOUND an airline can fly on its
network
   INPUT(AC)       input price adjustment
```

```
  LABOUR(AC)      labour input index
  LABSHARE        labour share in flight costs
  AIRPROD(AC)     airline productivity adjustment
  FLFRGHT         flight cost adjustment for freight
  UNITCOST(AC,AT)    total adjust for freight input and effeciency
  CPFRGHT         adjustment to capital costs for freight
  CAPFLGHT(AC,O,D,AT) capital cost of airplane ($000)
  FOBS(AC,O,D,AT)  observed freqency (HUNDREDS OF FLIGHTS)
  QDOBS(AC,O,D)   observed quantity (THOUSANDS)
  POBS(AC,O,D)    observed price ($000)
  LOAD(I,J)       observed load factor on sector ij
  MARGP(AC,O,D,AT) ticket price at marginal cost for competitive equilibrium ($000)
  MARKUP(AC)      overhead costs relative to operating costs
  COSTNWPP  Average cost of moving a person around the network formed by all airlines ($000)
  OVERHEAD(AC)    overhead costs ($MILLION)
  UNITOVER(AC)    overhead cost per observed traveller ($000 PER PASSENGER)
  INITPROF(AC)    profit at observed values ($MILLION)

*  Parameters initially used to weight IJ flight frequencies when calculating OD frequencies
  SM(AC,O,D,I,J,AT)  share of od passengers allocated to flight leg ij

*Bertrand equilibrium parameters
  BPADJ(AC,O,D)    assumed by jj qual adj price for j in i ($000)
  BPROFIT(AC)      bertrand profit at iteration beginning  ($MILLION)
;

*Parameter values that will not change and are used for initial values

SECTNUM(AC,I,J) = 1$sectr(ac,i,j) ;

TOTSECTR(AC) = SUM((I,J), SECTNUM(AC,I,J)) ;

TABLE VARCOSTS(i,j,at,labels) Variable Costs data for each route and aircraft

* Data below assumes that (D,O) flights have the same costs as (O,D) flights.
* In reality the costs differ because of different airport charges. However,
* these cost differences are small compared to the major cost drivers - fuel,
* crew costs, maintenance and lease costs. (O,D) costs are listed first - these
* are the costs that were estimated within Aerocost2.

                       LF           MCP            MCF            FCK
*                 (per cent)    ($'000/pass)   ($'000/Flight)   ($'000/Flight)
*
* NOTE!!!:
*
* Taipei flights have yet to be costed within Aerocost2 (20 April 1998).
* The data below assumes that: TPE.SYD and TPE.AKL flight costs are
* the same as those of HKG.SYD; the TPE.HKG costs are the same as SHA.HKG costs;
* and the TPE.SIN costs are the same as the SYD.PER costs. This is because
* the flight distances are similar.
*

TABLE TALPHA(AC,O,D) interior ces coefficients sum to one (from calibration)
```

```
          HKG        JKT        KUL        PEK        SEL        SYD

    +        TPE        TYO

ALPHA(AC,O,D) = TALPHA(AC,O,D) ;

GAMMA(O,D)$mk(o,d) = -4;

* Assign uniform value to all price elasticities. Later
* equations use ms(ac,o,d) to exclude (o,d) pairs that aren't
* feasible for particular airlines.

ETA(O,D)$mk(o,d) = -0.1;

* Assign specific values to price elasticities that have been estimated.
* These values overwrite the uniform value initially assigned to these
* (o,d) pairs

  ETA('HKG','SYD') =   -0.96309;
  ETA('SYD','HKG') =   -0.71946;
  ETA('PEK','SYD') =   -0.76324;
  ETA('SYD','PEK') =   -0.69747;
  ETA('JKT','SYD') =   -1.40916;
  ETA('SYD','JKT') =   -0.42185;
  ETA('TYO','SYD') =   -0.77;
  ETA('SYD','TYO') =   -0.84;
  ETA('SEL','SYD') =   -0.48268;
  ETA('SYD','SEL') =   -0.88246;
  ETA('KUL','SYD') =   -0.74573;
  ETA('SYD','KUL') =   -0.78843;
  ETA('TPE','SYD') =   -0.79961;
  ETA('SYD','TPE') =   -0.86231;

BETA(AC,O,D)$ms(ac,o,d) = -0.1/ETA(O,D) ;

* Beta's for SYD.JKT route are fixed in a way that calibrates the prices
* implied by the model's theory to observed price data.
BETA(AC,'JKT','SYD') = -0.0503592*ETA('JKT','SYD') ;
BETA(AC,'SYD','JKT') = -0.0503592*ETA('SYD','JKT') ;

display eta, beta;

TABLE  TAGG(O,D)    aggregate demand coefficients (from calibration)

        HKG        JKT        KUL        PEK        SEL        SYD

+        TPE        TYO

AGG(O,D) = TAGG(O,D);

TABLE PRODVTY(AC,PRODLBL) Airline productivity and price adjustment parameters
```

```
*  Based on estimates by Oum and Yu.

              AIRP        LABP        INPP

AIRPROD(AC) = PRODVTY(AC,'AIRP') ;
LABOUR(AC)  = PRODVTY(AC,'LABP') ;
INPUT(AC)   = PRODVTY(AC,'INPP') ;

PARAMETERS
LABSHARE(AT)
  /B7474    0.237
   B7673ER  0.245 /;
* See h:\epb05\projects\aviation\costdata\fltcost.xls for calculation

W(AC,I,J,AT)$lk(i,j)=  VARCOSTS(I,J,AT,'MCP');
V(AC,I,J,AT)$lk(i,j) =  VARCOSTS(I,J,AT,'MCF')/10 ;
CAPFLGHT(AC,I,J,AT)$lk(i,j) = VARCOSTS(I,J,AT,'FCK')/10 ;

* Set exhorbitant MARGINAL PASSENGER COSTS for impossible links or aircraft choices
W(AC,I,J,AT)$(NOT lk(i,j)) = 10;

* Set exhorbitant MARGINAL FLIGHT COSTS for impossible links or aircraft choices
V(AC,I,J,AT)$(NOT lk(i,j)) =  200 ;

* Set exhorbitant CAPITAL costs for impossible links or aircraft choices
CAPFLGHT(AC,I,J,AT)$(NOT lk(i,j)) =  200 ;


FLFRGHT = 0.850779 ;
UNITCOST(AC,AT) = FLFRGHT*(100+AIRPROD(AC)+LABSHARE(AT)*LABOUR(AC))/100 ;
CPFRGHT = 0.850802 ;
Z(AC,I,J,AT) = CPFRGHT*CAPFLGHT(AC,I,J,AT);

PARAMETERS
QMAX(AT)
 /B7474    39.6
  B7673ER  21.0/

PARAMETERS
LOAD(I,J)

LOAD(I,J)$(NOT knownlf(I,J)) = 0.70 ;

SM(AC,O,D,I,J,AT)$(ms(ac,o,d) AND sectr(ac,i,j)) = 1;

MARGP(AC,O,D,AT)$ms(ac,o,d)
 = 2*SUM((i,j)$sectr(ac,i,j), SM(AC,O,D,I,J,AT)$(ms(ac,o,d) AND sectr(ac,i,j))*(W(AC,I,J,AT)
                   + (UNITCOST(AC,AT)*V(AC,I,J,AT) + Z(AC,I,J,AT))/QMAX(AT)/LOAD(I,J))) ;

TABLE TQD(AC,O,D,QDLBL) Demand and Price data by origin destination
                  QDOB          POB
*            (000s MOVEMENTS   ($000 per
*                 per year)   return ticket)
```

```
* NOTE: Halving the number of MOVEMENTS gives the number of return tickets sold
* and therefore the number of PASSENGERS travelling from O to D.

QDOBS(AC,O,D)$ms(ac,o,d) = TQD(AC,O,D,'QDOB')/2 ;

POBS(AC,O,D)$ms(ac,o,d) = TQD(AC,O,D,'POB');

FOBS(AC,O,D,AT)$ms(ac,o,d) = QDOBS(AC,O,D)/QMAX(AT)/LOAD(O,D);

MARKUP(AC) = 0.3;

OVERHEAD(AC) = (100 + INPUT(AC))/100*MARKUP(AC)
               *SUM((O,D,AT)$ms(ac,o,d),MARGP(AC,O,D,AT)*QDOBS(AC,O,D));

UNITOVER(AC) = OVERHEAD(AC)/SUM((O,D)$ms(ac,o,d),QDOBS(AC,O,D));

INITPROF(AC) = SUM((O,D,AT)$ms(ac,o,d),(POBS(AC,O,D)-MARGP(AC,O,D,AT))
                *QDOBS(AC,O,D)$ms(ac,o,d)) - OVERHEAD(AC);

DISPLAY SM;
DISPLAY MARGP;
DISPLAY OVERHEAD;
DISPLAY UNITOVER;
DISPLAY INITPROF;

SCALAR N        iteration number for do loop /1/;
SCALAR SIGMA    iteration weight between old and new ;

POSITIVE VARIABLES

  QD(AC,O,D)   ij tickets purchased and passengers carried on route od (THOUSANDS)
  QDADJ(AC,O,D)  quality adjusted tickets and passengers on route od (THOUSANDS)
  P(AC,O,D)  price of ij tickets ($000)
  PADJ(AC,O,D)   quality adjusted ij ticket price ($000)
  QDAGG(O,D)      agg ces qlty adjusted quantity demanded
  PAGG(O,D)       agg ces qlty adjusted price THOUSAND DOLLARS
  QUAL(AC,O,D)  ticket quality
  UTIL(O,D)       indirect utility in i market
  FREQ(AC,I,J,AT)  frequency of flights by sector by city and airline (HUNDREDS OF FLIGHTS)
  TOTFREQ(AC,O,D)  total frequency of flights between cities by airline (HUNDREDS OF FLIGHTS)
  QS(AC,O,D)  passengers originating in o flying to d (THOUSANDS)
  PASS(AC,O,D)     passenger flying from o to d
  COST(AC)        cost to airline ($MILLION)

*  Variable used in SEATS model formulation
  SEATS(AC,O,D,I,J,AT)   seats occupied on the ij sector using at aircraft for ac airline (HUNDREDS)

*  Variables used in SHARES model formulation
  S(AC,O,D,I,J,AT)  share of od passengers allocated to flight leg ij
  SI(AC,O,D)   inverse share of od passengers

*Additional variables for Bertrand equilibrium
  BPAGG(AC,O,D)    implied aggregate qlty adjusted price for j  ($000)
  BQDAGG(AC,O,D)   implied aggregate qlty adjusted quantity for j  ($000)
```

```
;

FREE VARIABLES

   COSTNW       total cost of all airlines on network ($MILLIONS)
   COMOBJ       objective for social planner not quite competitive
   PROFIT(AC)    profit for airline j ($MILLIONS)
   RENT         joint profits for the two airlines ($MILLIONS)
BERTOBJ       objective for bertrand equilibrium of nikk iso fcn ($MILLIONS)

;

* Initial values and lower and upper bounds for monopoly simulations
* -----------------------------------------------------------------

* observed quantities
QD.L(AC,O,D)$ms(ac,o,d)    = TQD(AC,O,D,'QDOB')/2 ;
QD.L(AC,O,D)$mf(o,d)       = 0 ;
QS.L(AC,O,D)$ms(ac,o,d)    = QD.L(AC,O,D);

PASS.L(AC,O,D)$ms(ac,o,d)     = QS.L(AC,O,D) + QS.L(AC,D,O);

display pass.l;

* observed frequencies
SEATS.L(AC,O,D,I,J,AT)$(ms(ac,o,d) AND sectr(ac,i,j)) = PASS.L(AC,O,D)/TOTSECTR(AC) ;
FREQ.L(AC,I,J,AT)$sectr(ac,i,j)   =
SUM((O,D)$ms(ac,o,d),SEATS.L(AC,O,D,I,J,AT))/QMAX(AT)/LOAD(I,J) ;

* Observed shares
S.L(AC,O,D,I,J,AT)$(ms(ac,o,d) AND sectr(ac,i,j)) = SEATS.L(AC,O,D,I,J,AT)/PASS.L(AC,O,D) ;

* observed price net airfare
P.L(AC,O,D)$ms(ac,o,d)    = TQD(AC,O,D,'POB');

COST.L(AC)  =  SUM((O,D,I,J,AT),(W(AC,I,J,AT)*SEATS.L(AC,O,D,I,J,AT))$(ms(ac,o,d) AND
sectr(ac,i,j)))
             + SUM((I,J,AT),UNITCOST(AC,AT)*(V(AC,I,J,AT)*FREQ.L(AC,I,J,AT))$sectr(ac,i,j))
             + SUM((I,J,AT),(Z(AC,I,J,AT)*FREQ.L(AC,I,J,AT))$sectr(ac,i,j))
             + OVERHEAD(AC);

COSTNW.L       =  SUM(ac,COST.L(ac));
PROFIT.L(AC)       = SUM((O,D),(P.L(AC,O,D)*QS.L(AC,O,D))$ms(ac,o,d)) - COST.L(AC);
RENT.L           = SUM(AC, PROFIT.L(AC));

P.LO(AC,O,D)$ms(ac,o,d)  = 0.04 ;
P.UP(AC,O,D)$ms(ac,o,d)  = 10;
PAGG.LO(O,D)$mk(o,d)   = 0.08 ;
QUAL.LO(AC,O,D)$ms(ac,o,d)  = 0.001 ;
PADJ.LO(AC,O,D)$ms(ac,o,d)  = 0.5 ;
BPAGG.LO(AC,O,D)$ms(ac,o,d)  = 0.08;
*FREQ.LO(AC,I,J,AT)$sectr(ac,i,j) = 0.001;
*TOTFREQ.LO(AC,O,D)$ms(ac,o,d) = 0.001;
```

```
Parameter
 Chkpass(ac,o,d) Check that passengers are correctly calculated;
 Chkpass(ac,o,d)$ms(ac,o,d) = pass.l(ac,o,d) - (qd.l(ac,o,d) + qd.l(ac,d,o)) ;


EQUATIONS

   EQTOTFREQ(AC,O,D)  equation defining total frequency bewteen O and D
   EQQUAL(AC,O,D)   equation defining quality
   EQQDADJ1(AC,O,D) equation defining quality adj demand
   EQQDADJ2(AC,O,D) equation linking qlty adj demand agg demand and prices
   EQPADJ(AC,O,D)   equation defining quality adj price
   EQPAGG(O,D)     equation defining quality adj aggregate price for i
   EQQDAGG(O,D)    equation agg qlty adj demand fcn for i
   EQUTIL(O,D)     equation defining utility for i
   EQCOMOBJ        equation defining objective function
   EQCOST(AC)       equation defining airline costs
   EQCCOST(AC)  equation defining airline total costs for with shadow values
   EQCOSTNW  equation defining total network costs
   EQCAP(AC,I,J,AT)        equation defining flight passenger carrying
   EQMC(AC,O,D)     market clearing equations
   EQDEM(AC,O,D)  Demand is fixed
   EQPASS(AC,O,D)   passenger are sum of both direction fliers
   EQSEAT1(AC,O,D,I) number of seats on sector ij equals number of seats on sector ji
   EQSEAT2(AC,O,D) passengers flying od equals sum of pass at j intermediate ports flying od
   EQSEAT3(AC,O,D) passengers must get a seat from their last stop to their destination
   EQSEAT4(AC,I,AT)  airlines must make round trips using their aircraft
   EQSEAT5(AC,O,D,I,O,AT)  no looping through O to increase frequency
   EQSEAT6(AC,O,D,D,J,AT)  no looping through D to increase frequency
   EQPROFIT(AC)     equation defining airline profits
   EQRENTS          joint profits for the two firms
   EQZEROPI(AC)  equation to ensure zero rents
   EQMARGP(AC,O,D,AT)  equation to ensure marginal cost price for soc plan

* Test formulation equations
   EQS1(AC,O,D,I,J,AT)  equation defining share of od passengers carried on ij sector
   EQS2(AC,O,D)   equation defines inverse of the sum of shares

*additional equations needed for bertrand equilibrium
   EQBPAGG(AC,O,D)     defines aggregate price for j
   EQBQDAGG(AC,O,D)    defines aggregate quantity for j
   EQBQDADJ(AC,O,D)    defines commodity demands for j
   EQBERTOBJ           defines nikkaido isoda obj fcn for bertrand
;

EQQUAL(AC,O,D)$(ms(ac,o,d) AND (ORD(O) NE ORD(D)))..
   QUAL(AC,O,D) =E= TOTFREQ(AC,O,D)**BETA(AC,O,D) ;

EQQDADJ1(AC,O,D)$ms(ac,o,d)..
   QDADJ(AC,O,D) =E= QUAL(AC,O,D)*QD(AC,O,D) ;

EQQDADJ2(AC,O,D)$ms(ac,o,d)..
   QDADJ(AC,O,D)*PAGG(O,D)**GAMMA(O,D) =E=
ALPHA(AC,O,D)*(PADJ(AC,O,D))**GAMMA(O,D)
```

```
                *QDAGG(O,D) ;

EQPADJ(AC,O,D)$ms(ac,o,d)..
   PADJ(AC,O,D) =E= P(AC,O,D)/QUAL(AC,O,D)  ;

EQPAGG(O,D)$mk(o,d)..
   PAGG(O,D) =E= SUM(AC$ms(ac,o,d),ALPHA(AC,O,D)*PADJ(AC,O,D)**(1+GAMMA(O,D)))
              **(1/(1+GAMMA(O,D)));

EQQDAGG(O,D)$mk(o,d)..
   QDAGG(O,D) =E= AGG(O,D)*PAGG(O,D)**ETA(O,D) ;

EQUTIL(O,D)$mk(o,d)..
   UTIL(O,D) =E= AGG(O,D)/(ETA(O,D)+1)*(1000**(ETA(O,D)+1)
              - PAGG(O,D)**(ETA(O,D)+1));

EQMC(AC,O,D)$ms(ac,o,d)..
   QS(AC,O,D)   =E=  QD(AC,O,D);

EQDEM(AC,O,D)$ms(ac,o,d)..
  QD(AC,O,D) =E= TQD(AC,O,D,'QDOB')/2 ;

EQPASS(AC,O,D)$ms(ac,o,d)..
   PASS(AC,O,D) =E= QS(AC,O,D) + QS(AC,D,O) ;

EQSEAT1(AC,O,D,I)$(ms(ac,o,d) AND (ORD(I) NE ORD(O)) AND (ORD(I) NE ORD(D)))..
  SUM((J,AT)$(ORD(J) NE ORD(I)),SEATS(AC,O,D,I,J,AT)$sectr(AC,I,J)) =E=
            SUM((J,AT)$(ORD(J) NE ORD(I)),SEATS(AC,O,D,J,I,AT)$sectr(ac,i,j));

EQSEAT2(AC,O,D)$ms(ac,o,d)..
  PASS(AC,O,D) =E= SUM((J,AT)$(ORD(J) NE ORD(O)),SEATS(AC,O,D,O,J,AT)$sectr(ac,o,j));

EQSEAT3(AC,O,D)$ms(ac,o,d)..
  PASS(AC,O,D) =E= SUM((J,AT)$(ms(ac,o,d) AND (ORD(J) NE ORD(D)) AND
sectr(ac,j,d)),SEATS(AC,O,D,J,D,AT));

EQSEAT4(AC,I,AT)..
    SUM(j$sectr(ac,j,i), FREQ(ac,j,i,at)) =E= SUM(j$sectr(ac,i,j), FREQ(ac,i,j,at)) ;

EQSEAT5(AC,O,D,I,O,AT)$(ms(ac,o,d) AND sectr(ac,i,o))..
    SEATS(AC,O,D,I,O,AT) =E= 0 ;

EQSEAT6(AC,O,D,D,J,AT)$(ms(ac,o,d) AND sectr(ac,d,j))..
    SEATS(AC,O,D,D,J,AT) =E= 0 ;

EQCAP(AC,I,J,AT)$(sectr(AC,I,J) AND (ORD(I) NE ORD(J)))..
   0      =L=  QMAX(AT)*LOAD(I,J)*FREQ(AC,I,J,AT) -
SUM((O,D)$ms(ac,o,d),SEATS(AC,O,D,I,J,AT)$sectr(AC,I,J)) ;

EQCOST(AC)..
  COST(AC)  =E=  SUM((O,D,I,J,AT)$(ms(ac,o,d) AND
sectr(ac,i,j)),W(AC,I,J,AT)*SEATS(AC,O,D,I,J,AT))
             + SUM((I,J,AT)$sectr(ac,i,j),UNITCOST(AC,AT)*V(AC,I,J,AT)*FREQ(AC,I,J,AT))
             + SUM((I,J,AT)$sectr(ac,i,j),Z(AC,I,J,AT)*FREQ(AC,I,J,AT))
```

```
            + OVERHEAD(AC);

EQCOSTNW..
   COSTNW  =E=  SUM(ac, COST(AC)) ;

EQCCOST(AC)..
  COST(AC) =E=   SUM((O,D,I,J,AT)$(ms(ac,o,d) AND
sectr(ac,i,j)),W(AC,I,J,AT)*SEATS(AC,O,D,I,J,AT))
            + SUM((I,J,AT)$sectr(ac,i,j),UNITCOST(AC,AT)*V(AC,I,J,AT)*FREQ(AC,I,J,AT))
            + SUM((I,J,AT)$sectr(ac,i,j),Z(AC,I,J,AT)*FREQ(AC,I,J,AT))
            + SUM((O,D)$ms(ac,o,d),UNITOVER(AC)*QS(AC,O,D));

EQPROFIT(AC)..
  PROFIT(AC) =E= SUM((O,D)$ms(ac,o,d),P(AC,O,D)*QS(AC,O,D)) - COST(AC);

EQCOMOBJ..
  COMOBJ =E= SUM((O,D)$mk(o,d),UTIL(O,D)) + SUM(AC,PROFIT(AC));

EQRENTS..
 RENT =E= SUM(AC, PROFIT(AC));

EQZEROPI(AC)..
 0 =L= PROFIT(AC);

EQMARGP(AC,O,D,AT)$ms(ac,o,d)..
 MARGP(AC,O,D,AT) + UNITOVER(AC) =L= P(AC,O,D);

* Test formulation.
* -------------------------

EQS1(AC,O,D,I,J,AT)$(ms(ac,o,d) AND sectr(ac,i,j))..
    S(AC,O,D,I,J,AT) =E= SEATS(AC,O,D,I,J,AT)$(ms(ac,o,d) AND
sectr(ac,i,j))/PASS(AC,O,D)$ms(ac,o,d) ;

EQS2(AC,O,D)$ms(ac,o,d)..
    SI(AC,O,D) =E= 1 / SUM((I,J)$sectr(ac,i,j),SUM(AT, S(AC,O,D,I,J,AT)$(ms(ac,o,d) AND
sectr(ac,i,j)))) ;

EQTOTFREQ(AC,O,D)$ms(ac,o,d)..
    TOTFREQ(AC,O,D)$ms(ac,o,d) =E=
SUM((I,J)$sectr(ac,i,j),SUM(AT,S(AC,O,D,I,J,AT)$(ms(ac,o,d) AND sectr(ac,i,j)))
                              *SUM(at$sectr(ac,i,j),FREQ(AC,I,J,AT)))*SI(AC,O,D);

*    TOTFREQ(AC,O,D) =E= SUM((I,J,AT)$sectr(ac,i,j),
S(AC,O,D,I,J,AT)$ms(ac,o,d)*FREQ(ac,i,j,at))*SI(AC,O,D)$ms(ac,o,d) ;

* end of  test formulation


* Start of additional equations needed for bertrand equilibrium
* ============================================================

EQBPAGG(AC,O,D)$(ms(ac,o,d) AND mk(o,d))..
  BPAGG(AC,O,D) =E= (SUM(AL$(ORD(AL) EQ ORD(AC)),ALPHA(AL,O,D)
```

```
              *PADJ(AL,O,D)**(1+GAMMA(O,D)))
             + SUM(AL$(ORD(AL) NE ORD(AC)),ALPHA(AL,O,D)*BPADJ(AL,O,D)**
            (1+GAMMA(O,D))))**(1/(1+GAMMA(O,D)));

EQBQDAGG(AC,O,D)$(ms(ac,o,d) AND mk(o,d))..
  BQDAGG(AC,O,D) =E= AGG(O,D)*BPAGG(AC,O,D)**ETA(O,D);

EQBQDADJ(AC,O,D)$(ms(ac,o,d) AND mk(o,d))..
  QDADJ(AC,O,D)*BPAGG(AC,O,D)**GAMMA(O,D)=E=
ALPHA(AC,O,D)*(PADJ(AC,O,D))**GAMMA(O,D)
                *BQDAGG(AC,O,D) ;

EQBERTOBJ..
  BERTOBJ =E= SUM(AC,PROFIT(AC) - BPROFIT(AC));

*end of additional equations needed for bertrand equilibrium

MODEL SEATALLOC /EQCOSTNW, EQCOST, EQMC,EQDEM, EQCAP,EQPASS,
         EQSEAT1,EQSEAT2,EQSEAT3,EQSEAT4 / ;

MODEL SOCEQ social planner's equilibrium / EQQUAL,EQQDADJ1,EQQDADJ2,EQPADJ,
         EQPAGG,EQQDAGG,EQUTIL,EQMC,EQCCOST,EQCAP,EQPROFIT,EQCOMOBJ,
         EQPASS,EQSEAT1,EQSEAT2,EQSEAT3,EQSEAT4,EQSEAT5,EQSEAT6,EQTOTFREQ,
EQS1
         EQS2 /;

MODEL COMPEQ  competitive equilibrium / EQQUAL,EQQDADJ1,EQQDADJ2,EQPADJ,
         EQPAGG,EQQDAGG,EQUTIL,EQMC,EQCCOST,EQCAP,EQPROFIT,EQCOMOBJ,
         EQPASS,EQSEAT1,EQSEAT2,EQSEAT3,EQSEAT4,EQSEAT5,EQSEAT6,
         EQMARGP,EQTOTFREQ, EQS1, EQS2 / ;

MODEL BERTRAND bertrand equilbrium / EQBPAGG,EQBQDAGG,EQBQDADJ,EQQUAL,
              EQQDADJ1,EQPADJ,EQMC,EQCOST,EQCAP,EQPROFIT,
              EQPAGG,EQBERTOBJ,EQUTIL,EQPASS,EQSEAT1,
              EQSEAT2,EQSEAT3,EQSEAT4,EQSEAT5,EQSEAT6,
              EQTOTFREQ,EQS1, EQS2  /;


* Solve seat allocation LP to provide starting values for NLPs that follow

SOLVE SEATALLOC MINIMIZING COSTNW USING LP ;

* Recalculate UNITOVER(AC) & OVERHEAD(AC) using COSTNW solved for in seat alloction
problem

COSTNWPP = COSTNW.L/SUM((AC,O,D)$ms(ac,o,d),QDOBS(ac,o,d));
UNITOVER(AC) = MARKUP(AC)*COSTNWPP*(100 + INPUT(AC))/100;
OVERHEAD(AC) = SUM((o,d)$ms(ac,o,d),QDOBS(ac,o,d))*UNITOVER(AC) ;

* Recalculate MARGP using S.L(AC,O,D,I,J,AT) solved for in seat alloction problem
MARGP(AC,O,D,AT)$ms(ac,o,d)
 = 2*SUM((i,j)$sectr(ac,i,j), S.L(AC,O,D,I,J,AT)*(W(AC,I,J,AT)
    + (UNITCOST(AC,AT)*V(AC,I,J,AT) + Z(AC,I,J,AT))/QMAX(AT)/LOAD(I,J)));
```

```
* Recalculate INITPROF using revised values of MARGP and OVERHEAD
INITPROF(AC) = SUM((O,D,AT)$ms(ac,o,d),(POBS(AC,O,D)-MARGP(AC,O,D,AT))
                    *QDOBS(AC,O,D)$ms(ac,o,d)) - OVERHEAD(AC);

DISPLAY COSTNWPP;
DISPLAY INITPROF, OVERHEAD, UNITOVER;
DISPLAY MARGP;

* Resolve SEATALLOCATION problem with new OVERHEAD and MARGP

SOLVE SEATALLOC MINIMIZING COSTNW USING LP ;


* Parameter updates for competitive equilibrium
* ==============================================

* Recalculate UNITOVER(AC) & OVERHEAD(AC) using COSTNW solved for in 2nd iteration of
seat alloction problem

COSTNWPP = COSTNW.L/SUM((AC,O,D)$ms(ac,o,d),QDOBS(ac,o,d));
UNITOVER(AC) = MARKUP(AC)*COSTNWPP*(100 + INPUT(AC))/100;
OVERHEAD(AC) = SUM((o,d)$ms(ac,o,d),QDOBS(ac,o,d))*UNITOVER(AC) ;

* Recalculate MARGP using S.L(AC,O,D,I,J,AT) solved for in 2nd iteration of seat alloction problem
MARGP(AC,O,D,AT)$ms(ac,o,d)
 = 2*SUM((i,j)$sectr(ac,i,j), S.L(AC,O,D,I,J,AT)*(W(AC,I,J,AT)
    + (UNITCOST(AC,AT)*V(AC,I,J,AT) + Z(AC,I,J,AT))/QMAX(AT)/LOAD(I,J)));

* Recalculate INITPROF using values of MARGP and OVERHEAD from 2nd iteration of
INITPROF(AC) = SUM((O,D,AT)$ms(ac,o,d),(POBS(AC,O,D)-MARGP(AC,O,D,AT))
                    *QDOBS(AC,O,D)$ms(ac,o,d)) - OVERHEAD(AC);


* Test formulation.
* --------------------------
S.L(AC,O,D,I,J,AT)$(ms(ac,o,d) AND sectr(ac,i,j)) = SEATS.L(AC,O,D,I,J,AT)$(ms(ac,o,d) AND
sectr(ac,i,j))/PASS.L(AC,O,D)$ms(ac,o,d) ;

SI.L(AC,O,D)$ms(ac,o,d) = 1 / SUM((I,J,AT)$sectr(ac,i,j),S.L(AC,O,D,I,J,AT)$(ms(ac,o,d) AND
sectr(ac,i,j))) ;

* The total frequency between two cities is the weighted sum of all freqencies of direct
* flights (I EQ O) and the frequencies of flights to and from
* intermediate points I (I NE O), between O and D, to D. The weights used are
* shares of OD passengers flying on sector IJ.

TOTFREQ.L(AC,O,D)$ms(ac,o,d) =
SUM((I,J)$sectr(ac,i,j),SUM(AT,S.L(AC,O,D,I,J,AT)$(ms(ac,o,d) AND sectr(ac,i,j)))
                              *SUM(at$sectr(ac,i,j),FREQ.L(AC,I,J,AT)))*SI.L(AC,O,D);


*TOTFREQ.L(AC,O,D)$ms(ac,o,d) = SUM((I,J,AT)$sectr(ac,i,j),S.L(AC,O,D,I,J,AT)$ms(ac,o,d)
*                          *FREQ.L(AC,I,J,AT))*SI.L(AC,O,D)$ms(ac,o,d);
```

```
DISPLAY FREQ.L, TOTFREQ.L ;
DISPLAY PASS.L, S.L, SI.L ;

* end of test formulation

* Monopolisticaly competitive price net airfare
P.L(AC,O,D)$ms(ac,o,d)    = SUM(AT, MARGP(AC,O,D,AT)) + UNITOVER(AC);

QUAL.L(AC,O,D)$ms(ac,o,d)  = TOTFREQ.L(AC,O,D)**BETA(AC,O,D) ;
QUAL.L(AC,O,D)$(NOT ms(ac,o,d)) = 0.1;

QDADJ.L(AC,O,D)$ms(ac,o,d)   = QUAL.L(AC,O,D)*QD.L(AC,O,D) ;

PADJ.L(AC,O,D)$ms(ac,o,d) = P.L(AC,O,D)/QUAL.L(AC,O,D);

DISPLAY P.L, PADJ.L;

PAGG.L(O,D)$mk(o,d) =
SUM(AC$ms(ac,o,d),ALPHA(AC,O,D)*PADJ.L(AC,O,D)**(1+GAMMA(O,D)))
            **(1/(1+GAMMA(O,D)));

PADJ.L(AC,O,D)$(ms(ac,o,d) and (ord(O) NE ord(D))) = P.L(AC,O,D)/QUAL.L(AC,O,D) ;
QDAGG.L(O,D)$mk(o,d)   = AGG(O,D)*PAGG.L(O,D)**ETA(O,D);

UTIL.L(O,D)$mk(o,d)   = AGG(O,D)/(ETA(O,D)+1)*(1000**(ETA(O,D)+1)
                 - (PAGG.L(O,D)**(ETA(O,D)+1)));

COMOBJ.L          = SUM((O,D),UTIL.L(O,D)) + SUM(AC,PROFIT.L(AC));
COUROBJ.L          = 0;

PASS.LO(AC,O,D)$ms(ac,o,d) = 0.210;

SOCEQ.OPTFILE = 1;
SOLVE SOCEQ USING NLP MAXIMIZING COMOBJ ;

COMPEQ.OPTFILE = 1;
SOLVE COMPEQ USING NLP MAXIMIZING COMOBJ ;

*initial values for bertrand simulation and parameter updates

SIGMA     = 0.5;

BPROFIT(AC) = PROFIT.L(AC);

BPADJ(AC,O,D)$ms(ac,o,d) =  TOTFREQ.L(AC,O,D)**BETA(AC,O,D)*POBS(AC,O,D) ;
BPAGG.L(AC,O,D)$(ms(ac,o,d) AND mk(o,d))    = SUM(AL,ALPHA(AC,O,D)*BPADJ(AC,O,D)
                            **GAMMA(O,D))**(1/GAMMA(O,D));
BQDAGG.L(AC,O,D)$(ms(ac,o,d) AND mk(o,d))   = AGG(O,D)*BPAGG.L(AC,O,D)**ETA(O,D);

N = 1 ;

LOOP (NT $ (N LT 100),
```

```
      BERTRAND.OPTFILE=1;
      SOLVE BERTRAND USING NLP MAXIMIZING BERTOBJ ;
        IF (ABS(BERTOBJ.L) LE 0.000001,
            N = 100 ;
        ELSE
            N = N+1;

          ) ;

        SIGMA = SIGMA**N ;
        BPADJ(AC,O,D) = (1-SIGMA)*PADJ.L(AC,O,D) + SIGMA*BPADJ(AC,O,D);
        BPROFIT(AC) = (1-SIGMA)*PROFIT.L(AC) + SIGMA*BPROFIT(AC);

    ) ;

*CLOSE BRACKET TERMINATES THE LOOP
```