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Airline Strategies For Aircraft Size And Airline Frequency With Changing Demand And Competition: A Two-Stage Least Squares Analysisfor Long Haul Traffic On The North Atlantic

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Airline Strategies for Aircraft Size and Airline Frequency with changing Demand and Competition: A Two-Stage Least Squares Analysis for long haul traffic on the North Atlantic.

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Abstract

Over time, as demand fluctuates around an underlying trend of growth, it can be observed that airlines adjust the size of the aircraft in their fleets and change the frequency of the service that they offer. In addition, on some routes, the advent of competition in the form of an additional carrier responding to demand opportunities can affect the aircraft size and the frequency of the incumbent airlines. All the airlines will, after entry, continue to adjust size and frequency.

The objective of this paper is to empirically examine these phenomena for the long haul sector. A simultaneous equations approach is needed as there is two way causation between demand and frequency and aircraft size and any simple equation model that ignores this will produce biased and inconsistent estimates.

Data is examined from 1990 for ten routes linking UK airports to airports in the USA. Departures from London Heathrow (LHR), London Gatwick (LGW) and Manchester (MAN) are covered. The airports served and the UK departure airport are respectively, LGW to Atlanta, LGW to Boston, MAN to Chicago, LGW to Dallas, LHR to Los Angeles, LGW to Miami, LGW and LHR to New York (JFK), LHR to San Francisco and LHR to Washington. These routes were chosen to cover a variety of stage lengths and degrees of

competition. It was felt that 1990 was an appropriate start date because this history encompasses the dismantling of the London area distribution rules and the relaxation of regional airport North Atlantic access, and also gives a sufficient time series.

Conclusions are suggested on the basis of each route and on more robust estimates for the larger pooled time series-cross section data. This represents a novel attempt to examine changes and the impact of competition on routes at both the aggregate and the disaggregate level. Due credit is given for the effects of slot and route entry constraints, and also for the establishment of more intensive hubbing at either end of the routes.

1. Introduction

The relationship between aircraft size and frequency is important both because of the lack of runway capacity and because frequency is an important driver in the passengers' choice of airport, route and airline. Passenger schedule delay will be lower as frequency is increased (Yeng, 1987; Bowen et al, 1991, Headley and Bowen, 1992). The UK Civil Aviation Authority (CAA) has developed a model to investigate the extent to which UK regional airports can offload the London airports. This was formulated in the late 1980s (CAA, 1990) and has been successively refined, the latest version being SPAM 2. It assesses the ability to start new regional routes and the consequent airline decisions on frequency by means of a sub-model called LARAME. It was found necessary to use a large number of separate models to describe the airlines' behaviour on different types of route. There was, however, some common evidence that airlines start a route with small turboprop aircraft, building up a critical frequency before starting to operate larger aircraft with better unit costs. The published versions did not consider the influence of the number of airlines or their nationality. Either of these could affect the absolute frequency and its relationship with traffic. The average result was that there was a one per cent increase in aircraft size for every five per cent increase in traffic.

At an aggregate level, there has been no consistent increase in average aircraft size since the mid 1980s on scheduled routes in Europe, in the US or on the North Atlantic, as the airlines have concentrated on competing by frequency. The competition has been mostly through hubs. This competition expresses itself by an increase in the number of spoke routes and in the frequency of connections across the hub. Even in Europe, the hubbing carriers are mounting six or seven waves of arrivals and departures per day. It might therefore be expected that routes into hubs would tend to have higher frequencies and smaller aircraft than point-to-point services of the same traffic density, as also would routes with more carriers.

While short haul routes in the US and Europe have been liberalised for some time, long haul routes have almost all been regulated by bilaterals that often result in collaboration between two national carriers rather than competition. The long haul routes have also

tended to operate on a maximum of one flight per day, due to the large size of aircraft required for the long range and also to the difficulty of scheduling conveniently across many time zones.

The US . UK routes have been subject to the .Bermuda 2. bilateral since 1977 (HMSO, 1977), but the large route density and changes in circumstances have nonetheless given the opportunity for serious competition to develop. These changes include:

- the lifting of the 270,000 movement per year limit to London Heathrow
- the British Airways take-over of British Caledonian operations at London Gatwick
- the emergence of Virgin Atlantic as the new British .second force. airline
- the replacement of the traditional US .flag carriers. (Pan Am and TWA) by the more forceful US carriers
- the relaxation of entry on routes to UK regional airports

Thus the UK .US route is one of the few long haul routes that fulfil the UK CAA.s criteria for genuine competition to develop, namely that a minimum of three carriers is needed (CAA, 1993; CAA, 1995).

2. The Data

This paper examines the way in which airlines on 10 specific routes have behaved in order to throw more light on the frequency/aircraft size decision. These routes were chosen because, despite the slot constraints, the traffic levels are high enough to allow competition to develop. These routes are examined individually and as a pooled data set. This represents a novel attempt to examine changes on and the impact of competition on routes at both the aggregate and the disaggregate level.

The annual route flows are taken from the CAA's Airport Statistics, which gives only totals for all the carriers on each route. The supply data are obtained from the Official Airline Guide, using the available issues for each year between 1990 and 1997. Before 1990, the statistics were only available on a city pair rather than an airport pair basis. The total scheduled departures per week were noted for each carrier, giving the frequency, together with the type of aircraft used for each departure. There is also an indicator revealing

whether the service is part of a code-sharing agreement as under Bermuda 2, no more than two US and two UK carriers are permitted at London Heathrow. The flight numbers can be checked to see if they show a shared airline designator code and of course, apparent flight timings are identical. The tie-up between Virgin Atlantic and Delta is reflected in these indicators for the routes to New York, San Francisco and Los Angeles. The number of seats in each aircraft are taken from the data in the Flight International annual surveys of commercial aircraft supplemented where possible by the airlines' in-house magazines and timetables¹.

The traffic and supply data are given for each route in Figures 1 and 2, and the relationship between traffic and frequency for the pooled data set is given in Figure 3. It can be seen from the pooled data that an additional frequency may be added for every 170 additional passengers. Given that the smallest aircraft in common use in these markets has 225 seats and the load factor is 75 percent approximately, little of the growth is taken by variation in individual route behaviour around these pooled results.

Figure 1: Traffic by Route, 1990-97

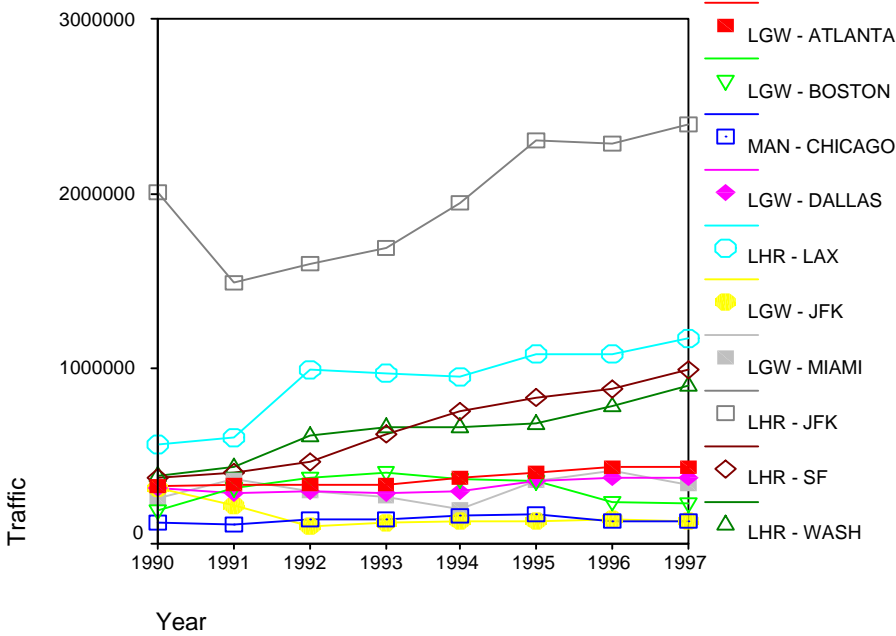


Figure 2 : Frequency by Route, 1990-97

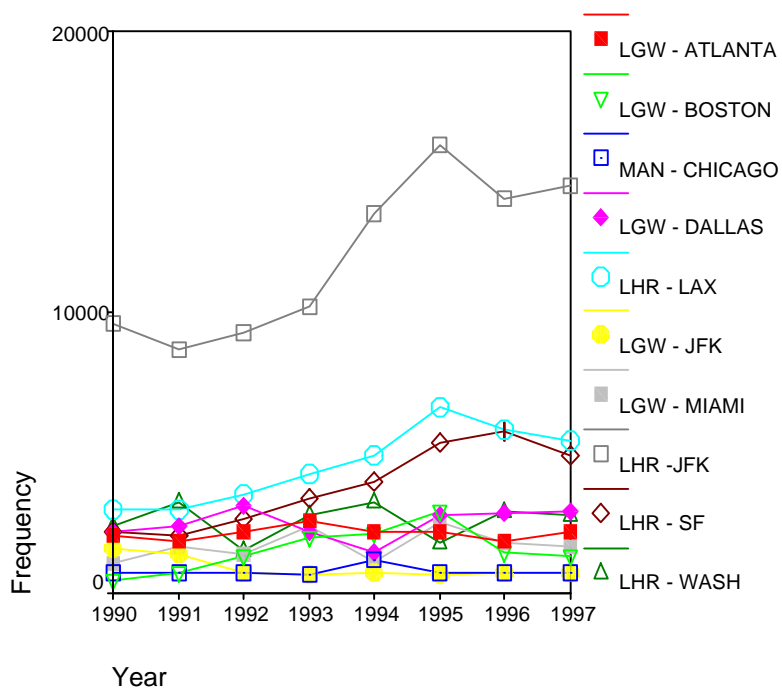
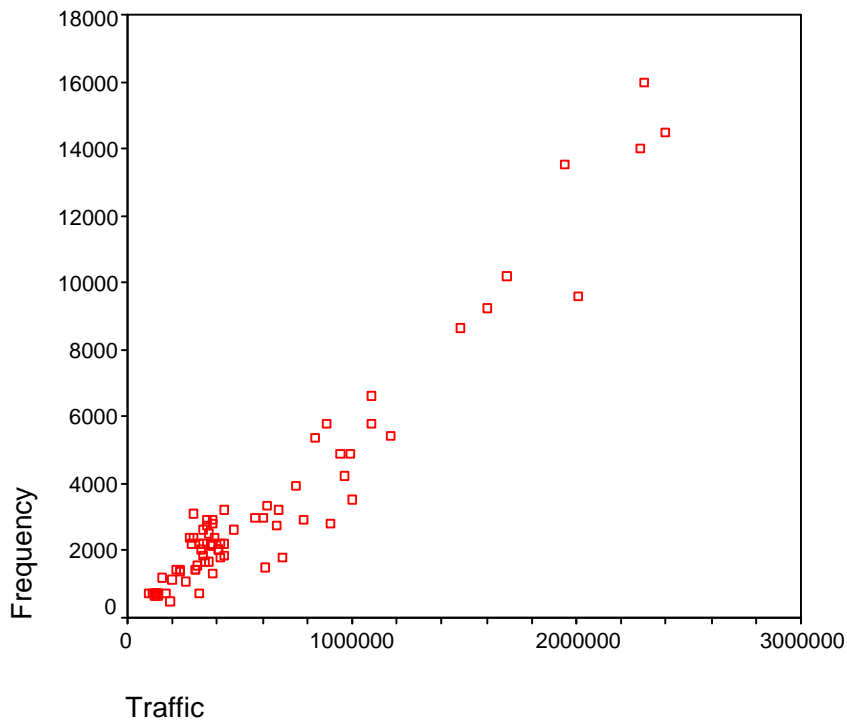


Figure 3: Frequency against Traffic: Pooled Data



3. Model and Variable Specification

It is clear from an understanding of airline decision making that the volume of traffic expected will determine the frequency of service and aircraft size offered. Here we have annual traffic and frequency data. We suspect that the appropriate lag in this relationship might be of the order of six months but, clearly, our data do not allow us to investigate this.

In addition, partly because of the uncertainty over the period of lag inherent in the relationship, it seems clear that a problem of simultaneity exists here giving rise to biased and inconsistent results if Ordinary Least Squares (OLS) regression is used, as although it is known that the direction of causation is that traffic gives frequency, with some lag, it can be argued that frequency gives rise to traffic, also with some lag and indeed is used to manage market share (Janic, 1997). This is a demand-led, supply-led dichotomy. Statistically, therefore, rather than empirically, it is necessary to account for this bias by invoking a two-stage procedureⁱⁱ.

As well as traffic, the impact of competition is of interest. If the data is examined for each of the ten routes it can be seen that both the number of airlines, the particular airlines offering service and the aircraft size used varies over timeⁱⁱⁱ So a variety of dummy variable specifications could be used to reflect these aspects of competitive behaviour. After some preliminary examination, the competition dummy variable takes the value zero when two airlines are operating the route and the value of one when other airlines also offer service. Clearly this is not a specification that allows more complicated changes to be reflected but this simple specification suits the data for this period for these ten routes. The coefficient for this variable should certainly be positive.

Another possible explanatory variable, the variation in aircraft size, is a response to the volume of traffic and the frequency offering deemed desirable on the route. Consequently, if the model is able to determine frequency, given traffic, then aircraft size is also known, given desired load factors and it does not seem sensible to deal with this on the right-hand-side (RHS) of the equation.

So if we take F = frequency, T = traffic and C = competition dummy variable then on the above basis our initial model specification using OLS regression is that

$$F = f(T, C) \quad (1)$$

Where traffic might be unlagged or lagged one year. However because of the dual direction of causation it is necessary to replace T with \hat{T} where \hat{T} can be derived from

$$\hat{T} = f(T_{-1}, F_{-1}) \quad (2)$$

The specification of the RHS here follows Koyck (1954) where the lagged value of T replaces a stream of variously lagged values of F . The justification is that these explanatory variables will be less collinear^{iv}.

So the final model is

$$F = f(\hat{T}, C) \quad (3)$$

where to the extent that this differs from eq (1) indicates that simultaneous equation bias has been dealt with in this Two Stage Least Squares (2SLS) procedure. In the OLS model some of the effect of the error term u has been wrongly absorbed by the coefficients of the explanatory variables.

As there is no good evidence for the contrary, a simple linear specification was adopted throughout.

Instead of the competition dummy variable, competition may alternatively be measured by an integer variable counting the number of airlines offering service on a route by year (AC). This seems likely to be a more suitable proxy for competition, particularly on some of the

individual routes where for every year there are more than two carriers operating. So using the same model structure as in (1)–(3) above, the alternative final model becomes,

$$F = f(\hat{T}, AC) \quad (4)$$

Further, some of the destination airports are major hubs of the US carriers and we might expect relatively greater frequency on these routes than would be indicated by the traffic and **AC** variables. Consequently a hub dummy variable, **HUB**, is added to the model for Atlanta, hubbing by Delta Airlines; Chicago, hubbing by American Airlines and United Airlines and Dallas, hubbing by American Airlines.

The model specified is overidentified and so is amenable to 2SLS. This model form cannot be implemented using an instrumental variable approach as that is insufficiently flexible although it can be shown to give identical results to 2SLS depending on which variables are taken to be exogenous (instrumental) and endogenous. However we need to assume that we have knowledge of the predetermined exogenous variables of the complete system of simultaneous equations even if knowledge of the exact mathematical form of these equations is unknown and if that cannot be assumed, then the estimates will be liable to specification bias. However, it is likely that given the complexity of economic phenomena, that some such error is inevitable.

It could be argued that a three-stage least squares procedure (3SLS) is appropriate to the estimation of the model. This would allow for contemporaneously dependent error terms which are likely if variables are omitted from the equations. In such cases, 2SLS estimates are inefficient but to implement 3SLS requires that the mathematical forms of all equations in the system are known.

On balance, if we believe that important variables have not been omitted and that as we are unsure of the mathematical form of all of the equations, then 2SLS is to be preferred. In the case of both 2SLS and 3SLS, the estimates are not asymptotically efficient if based on

small samples so not too much notice should be given to the route by route results reported later.

Finally, the question of aircraft size is returned to where airlines simultaneously make decisions on the aircraft size to be used and the frequency of service to be offered. Together, this gives us the seats (S) offered per route.

If the model above can be used to determine F , then a similar model can be used to derive seats (S) as,

$$S = f(T, C) \quad (5)$$

$$\hat{T} = f(T_{-1}, F_{-1}) \quad (6)$$

$$S = f(\hat{T}, C) \quad (7)$$

and if equation (7) is divided through by equation (3) then aircraft size (AC) can be determined. In other words, equation (3) can tell us at what level of traffic and competition that an extra frequency will be generated and the calculation just explained can tell us the aircraft size.

4. Pooled Results

4.1 10 routes 90-97

Data for each year for each route was pooled to give an extensive sample consisting of 80 observations. Using eq.1 with no lags gives, with standard errors in brackets:

$$F = -156.763 + 0.005438 T + 226.153 C + e \quad R^2 = 0.935 \quad (8)$$

(0.000) (206.630) (801.450)

This shows that only the traffic variable is significant. The t statistics are 28.624 and 1.094 respectively and overall F statistic is 556.823.

If we turn to the estimation of eq.2 then,

$$\hat{T} = 21015.984 + 0.860 T_{-1} + 29.209 F_{-1} \quad R^2 = 0.960 \quad (9)$$

(0.099) (16.943) (110277.5)

Armed with an estimate of \hat{T} , eq.3 can be estimated.

$$F = -314.596 + 0.00535 \hat{T} + 422.424 C \quad R^2 = 0.924 \quad (10)$$

(0.000) (242.964) (888.27)

with t = 24.414 and 1.739 with F = 409.716.

The main difference is that the competition dummy variable C approaches a significant level but still remains insignificant at the five percent level.

Experimenting with the AC variable, gives,

$$F = -837.682 + 0.0044393 \hat{T} + 496.054 AC \quad R^2 = 0.939 \quad (11)$$

(0.000) (112.516) (799.50)

with t = 12.518 and 4.409 with F = 513.611. This equation clearly shows the significant impact of the number of airlines on frequency offered. Indeed, it suggests that an additional airline will result in just under ten additional frequencies per week on a route, although this seems a little high.

One further modification of interest is to represent the hub destinations. More service might be expected to be offered to these destinations, so that their spokes may be fed, than would be indicated by traffic on the point to point service. As a

result a hub dummy variable was included to take the value of one when Atlanta, Chicago and Dallas were the destinations^v.

This gives,

$$F = -1026.822 + 0.004512\hat{T} + 496.337 AC + 390.895 HUB$$

$$(0.000) \quad (110.736) \quad (219.529)$$

$$R^2 = 0.942 \quad (12)$$

$$(786.85)$$

with t = 12.410, 4.482 and 1.781 and F = 354.557.

This shows that the *HUB* variable is not quite significant but that such a destination could appear to expect 391 greater frequencies per annum than a non-hub destination. In addition, the relative stability of the *AC* variable can be seen.

The standardised regression coefficients, β , are 0.757, 0.260 and 0.057 respectively showing the greater contribution to changes in frequency from traffic when the coefficients are put on a common basis. Elasticity, \hat{a} , on average can be determined for the range of the data as

$$\hat{a}_i = \hat{b}_i \cdot (\bar{X}_i / \bar{Y}) \quad (13)$$

So $\hat{a}(T) = 0.86$, $\hat{a}(AC) = 0.46$ and $\hat{a}(HUB) = 0.04$. This shows that the traffic variable is inelastic with a 1% change resulting in a 0.86% change in frequency. The other two variables are also inelastic.

The seats model gives,

$$S = -185672 + 1.253\hat{T} + 130065.8 AC - 48730.1 HUB \quad R^2 = 0.949 \quad (14)$$

$$(0.092) \quad (28926.334) \quad (57345.008) \quad (205540.14)$$

with t = 13.636, 4.496 and .0.850 and F = 412.663.

Together these models show that 222 passengers calls forth an extra frequency and that one seat is called for by 0.80 passengers. Dividing (14) by (12) shows aircraft size at 278 seats.

4.2 Route by route results

Examination of individual routes is based on a small number of observations but has the advantage that alternative specifications of the dummy variable, representing competition, can be tried for each route. Indeed, guidance can be sought here on the correct specification of the variable for the previously reported pooled analysis.

4.2.1 London Gatwick – Atlanta

For most of the period, two airlines operated on this route, but for three years from and including 1993, British Airways (BA) and Delta (DL) were joined by Continental (CO). This initially resulted in a steep increase in frequencies but was not matched by an increase in traffic until 1994 onwards. Frequencies then declined whilst average aircraft size at first increased and then fell. For the whole period there is a positive correlation of 0.574.

Because of the abrupt change in frequencies and the non-matching trend in traffic, the level of explanation using both models (10) and (11) is poor and there is no difference between the numerical value of the competition dummy variable (C) and the number of airlines variable (AC) in Tables 1 and 2 which are also insignificant.

Using different lag structures on the traffic variable did not appreciably change the results. There is no compelling evidence for the whole of the period that competition exists on this route.

4.2.2 London Gatwick – Boston

This route began the period with one incumbent airline, North West Airlines. Frequency about doubled when Virgin Atlantic (VS) entered the route in 1992 and went up by the same again when CO entered the next year. A slight increase in

frequency and decline in aircraft size took place in 1994 and in 1995 the route reverted to CO and VS and DL code sharing with a further large increase in frequencies and decline in aircraft size.

From 1996, CO ceased offering service leaving DL and VS with much reduced frequencies and increased aircraft size. The relationship between size and frequency is weak at 0.156 and the overall level of explanation shown in Tables 1 and 2 is poor. In neither case is the representation of competition significant and indeed, the *AC* variable has the wrong sign a priori, but the correct sign in view of the outline of the activity on the route given here.

4.2.3 Manchester – Chicago

This route is of little interest as for every year only American Airlines (AA) offers services, and as traffic has grown so aircraft size has increased. In 1994 for one year, frequency was increased by more than one a day and this explains the relatively poor match with traffic.

4.2.4 London Gatwick – Dallas

A steady growth in traffic from 1993 has been matched by mirrored changes in frequency but relatively stagnant traffic in the earlier part of the period was accompanied by volatile changes in frequency. In 1990 AA and BA were on the route. Frequency went up as Trans World Airways (TW) joined in 1991 and went up again in 1992 when CO replaced TW as did aircraft size as CO's services were all with 747s. Frequencies fell in 1993 as a wider range of aircraft types were tried by AA and BA and fell again to their lowest level when CO ceased operations in 1994. Since then frequencies have increased with traffic and aircraft size fallen as initially DL joined and CO rejoined, the latter only for one year.

The models reported in Tables 1 and 2 show a good level of overall explanation with the competition dummy variable showing significance but the predicted traffic variable is insignificant.

4.2.5 London Heathrow – Los Angeles

On this route, the first individually examined here from London Heathrow, there is a high negative relationship between frequency and aircraft size at -0.750 .

There is a distinct difference here between 1990 and 1991 and the remaining period where post-Gulf War traffic is much higher. In these first two years, BA operates alongside Pan Am (PA) and T.W. In 1992 the two American carriers are replaced by AA and United Airlines (UA) and VS joins the British contingent. In 1995, DL also offers a code sharing service on VS aircraft and Air New Zealand (NZ) offers services using its fifth freedom rights. These airlines stay on the route until the end of the period by which time NZ is offering more flights than VS, with BA offering the most.

The models in Tables 1 and 2 show a good level of fit. Table 1 does not have a competition dummy variable as the number of airlines is always greater than two. The airline competition variable (AC) in Table 2 has the right sign but is not significant.

An attempt was made to improve the model of this route by omitting fifth-freedom carriers. If this is done then the variables measuring frequency, aircraft size and obviously, the number of airlines, all change but it is not possible to adjust the traffic variable as only total carryings on the route are known. However, we would still expect this total traffic variable to be of importance so it is possible to proceed.

Consequently, the relationship between aircraft size and frequency is stronger at $R = -0.817$ but in all other respects the two-stage model is weaker than that reported in Table 2 with a poorer level of explanation and less significant coefficients.

4.2.6 London Gatwick – New York (JFK)

For the first two years BA offered service along with VS, but then VS were allowed to move to London Heathrow. Traffic peaked when frequency was high in 1990.

For the remainder of the period there has been little change in frequency or traffic and aircraft size and frequency are strongly positively related at $R^2 = 0.815$.

As with the Los Angeles route above, but for reasons at the other end of the spectrum, there is no competition dummy variable in Table 1 because of the number of airlines. The level of explanation from the traffic variable alone, however, is good. This explanation is even better in Table 2 where the airline competition variable (*AC*) is the right sign and significant.

4.2.7 London Gatwick – Miami

The model in Table 1, with its specification of the competition dummy variable, shows a weak relationship between frequency and the traffic variable and as only in 1992 were there two carriers on the route so the model deems the rest of the period to be competitive. The model does not support this.

However, using the *AC* variable in Table 2 shows a significant impact of this variable on frequency. It suggests that an extra airline will result in 630 frequencies per annum which may well be a fair reflection of the mixed behaviour on this route.

In 1990, VS offered services along with CO and DL. In 1991 AA replaced CO and left the route the next year to leave the traffic with DL and VS. In 1993, CO returned and US Airways provided service for just this year. In 1995, BA joined the route for the first time and this was also to be CO's last year. It also appears that VS and DL began code sharing. Over the period traffic shows a steady decline from 1991 to 1994 and then a steady increase in the next two years.

4.2.8 London Heathrow – New York (JFK)

Of the routes examined here, this one has the greatest number of carriers, never falling below five and reaching seven in 1995 and 1996. Fifth-freedom carriers explain this regularly high number. Of these, there is a sharp contrast between Air India and El-Al where the first usually offers one service per day whereas the

second offers a very low and varying frequency per annum. As a result efforts have been made to deal with this route just focussing on US and British carriers.

However, taken as a whole, traffic falls from 1990 and then rises steadily from 1991, reaching a plateau in 1996 and then increasing again the next year. There is a strong correspondence with frequency offered where the traffic decline at the very beginning of the decade is matched by a less steep decline in frequency. Subsequent traffic growth is matched by frequency increases until frequency drops in 1996 whilst traffic holds steady.

At the beginning of the 1990.s, TW and PA offer the principal services along with BA. The first substantial change is in 1992 when UA and AA replace TW and PA and VS also enters the route offering two flights per day and increases this service frequency in subsequent years. DL joins the route in 1995 via a code sharing agreement with VS who by then is offering the equivalent of roughly three a day.

Because of the number of carriers on the route, the **C** variable is not utilised but the **AC** variable in Table 2 is not significant. If this and other variables are changed to represent just US and British carriers then, unfortunately, the results do not improve and even leaving out just EI-Al when its offerings are very low does not improve the results either.

4.2.9 London Heathrow – San Francisco

For the whole of the period, traffic has been increasing and this is matched by frequency except for a slight decline in 1991 and a more considerable one in 1997. There is a negative relationship of $R = -0.401$ between frequency and aircraft size over the whole period.

In 1990 and 1991 BA and TW and PA were on the route, the two US carriers being replaced by UA in 1992. In 1993 AA joined the route and then was replaced by VS in 1994. In 1995, AA returned and DL was a new entrant, again code sharing with VS, and this combination served the market until the end of the period.

Using the C variable in Table 1 makes little sense as the only period taken as being uncompetitive is 1992. The AC variable is a better representation of competition but it has the wrong sign in Table 2 and it is insignificant.

4.2.10 London Heathrow – Washington

PA, TW and BA offered services in 1990 and 1991 with, notably, BA offering supersonic services by Concorde. In 1992, only UA offered service and was joined by BA in 1993 as well as for the next three years. In 1996 VS also entered the market. Aircraft size has grown over the period but there is only a weak relationship with frequency. Indeed, as Tables 1 and 2 both show, there is also a weak relationship between frequency and traffic and inspecting the scatters over time shows that although traffic has increased consistently and at a relatively faster rate in the early and later parts of the period, frequency has little discernible pattern other than perhaps a cyclical one with the peaks in 1991, 1994 and 1996 and the troughs in 1992 and 1995. The representation of competition by the **AC** variable appears to be significant.

Table 1: Route by Route results: Competition Dummy Variable

ROUTE	COEFFICIENT	T STATISTIC	R ²	F
LGW - Atlanta	Constant = 2372.580		0.440	1.570
	$\hat{T} = -0.000912$	-0.413		
	C = 296.345	1.641		
LGW - Boston	Constant = 1012.562		0.141	0.328
	$\hat{T} = 0.001800$	0.282		
	C = 356.425	0.400		
Manchester - Chicago	Constant = 1226.443		0.055	0.289
	$\hat{T} = -0.00314$	0.538		
LGW - Dallas	Constant = 421.483		0.738	5.644
	$\hat{T} = 0.003511$	0.845		
	C = 1106.501	2.705		
LHR - Los Angeles	Constant = -1925.258		0.770	16.730
	$\hat{T} = 0.006619$	4.090		
LGW - New York	Constant = -108.269		0.768	16.547
	$\hat{T} = 0.006648$	4.068		
LGW - Miami	Constant = -1465.597		0.225	0.579
	$\hat{T} = 0.008523$	0.743		
	C = 597.221	0.984		
LHR - New York	Constant = 1332.687		0.616	8.006
	$\hat{T} = 0.005299$	2.830		
LHR - San Francisco	Constant = 596.115		0.833	9.978
	$\hat{T} = 0.004137$	3.911		
	C = 118.220	0.198		
LHR - Washington	Constant = 1976.452		0.275	0.759
	$\hat{T} = 0.0005125$	0.231		
	C = 650.351	1.190		

Table 2: Route by Route results: No. of Airlines Variable

ROUTE	COEFFICIENT	T STATISTIC	R ²	F
LGW - Atlanta	Constant = 1779.890		0.440	1.570
	$\hat{T} = -0.000912$	-0.413		
	AC = 296.345	1.641		
LGW - Boston	Constant = 577.252		0.107	0.240
	$\hat{T} = 0.003590$	0.628		
	AC = -24.598	-0.052		
Manchester - Chicago	Constant = 1226.443		0.055	0.289
	$\hat{T} = -0.00314$	0.538		
LGW - Dallas	Constant = -749.853		0.547	2.419
	$\hat{T} = 0.004942$	0.922		
	AC = 550.547	1.594		
LHR - Los Angeles	Constant = -1793.618		0.858	12.053
	$\hat{T} = 0.003131$	1.187		
	AC = 767.567	1.571		
LGW - New York	Constant = -12.861		0.991	218.868
	$\hat{T} = 0.0006562$	0.933		
	AC = 639.569	9.925		
LGW - Miami	Constant = -2959.521		0.798	7.916
	$\hat{T} = 0.008601$	1.537		
	AC = 630.174	3.886		
LHR - New York	Constant = -2524.153		0.671	4.082
	$\hat{T} = 0.004873$	2.431		
	AC = 713.920	0.822		
LHR -San Francisco	Constant = 677.120		0.832	9.879
	$\hat{T} = 0.004358$	2.281		
	AC = -41.464	-0.077		
LHR - Washington	Constant = 1375.562		0.525	2.208
	$\hat{T} = -0.000465$	-0.247		
	AC = 675.571	2.064		

5. Interpretation

The regressions show the relation between frequency and traffic to be the dominant one, and that frequency is relatively little influenced by other factors that change over time. At first sight this is counter-intuitive, because it is expected that airlines will compete on frequency, that competition has been encouraged, and that therefore there will have been changes in the way that frequency varies with traffic. These changes will have been driven by competition between existing carriers and also by competition between them and new entrants.

The analysis shows that these changes did not happen to the extent expected, at least in the period 1990 to 1997 on the routes examined. There are, in fact, many reasons why this might be so. The most obvious is that incumbent airlines will not compete in ways that will increase their costs or reduce their revenues per seat unless they are forced into it. The shortage of runway slots at Heathrow definitely reduces this possibility.

It seems, from the greater evidence of competition in the pooled data, that the airlines were making their aircraft size/frequency decisions more on a system basis than on a route-by-route basis, although the route by route results are statistically less robust. This will clearly be so when an airline is strengthening its hub operation and bypassing the traditional gateways. Most airlines are looking for economies from fleet commonality when they purchase aircraft (such as in crew training and maintenance costs), which gives them a range of sizes within a generic aircraft type. However, there will be some routes where they would prefer either a larger or a smaller aircraft, and in these cases the frequency will be dictated by aircraft availability. Such decisions may be constrained by wider network strategies and an inability to change aircraft types at short notice.

As alliances develop, airlines will be able to control market share more easily without increasing frequency. The experience on the Vancouver/California routes shows clearly that, following a period of classic frequency-based competition when the US and Canada

adopted open skies, the markets consolidated with code sharing in 1998. The routes are now dominated by only two alliances, often only one to a route (Aircraft Commerce, May-June 1999, pp 27-33).

6. Conclusions

The weight of existing evidence is that the greater opportunities to enter the UK North Atlantic market have had a small impact on competition. One way that this can be measured is through the number of carriers on a route and their impact on frequency.

This paper has examined data on the routes from available UK departure points to a variety of US destinations, some of which are major hubs, using a regression model with a specification designed to avoid simultaneous equation bias. Analysis of individual routes allowed alternative specifications of a dummy variable representing competition to be experimented with. This showed that the only sensible specification was related to the number of carriers on the route and this was significant overall in the pooled data. There is some influence on the frequency offered from the number of competing airlines and this influence appears to be stronger than in the case of short haul routes in Europe. Nevertheless, the major influence on frequency remains traffic; the other identified influences are relatively minor.

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ⁱ This data was collected by a former Loughborough University student, Robin Kirk, to whom the authors are grateful.

ⁱⁱ ⁱⁱ The direction of causation can be examined following Granger (1969).

ⁱⁱⁱ With the exception of Manchester-Chicago where AA is the only operator.

^{iv} It is well known that collinearity affects both the estimates of the parameters and the size of the standard errors and that to deal with collinearity by the omission of collinear variables introduces specification bias that also affects the parameter estimates.

^v Specifying Miami as a hub for South America did not give such good results.