Department for Transport

Re-estimating the National Air Passenger Demand Model Econometric Equations

August 2011

The Department for Transport has actively considered the needs of blind and partially sighted people in accessing this document. The text will be made available in full on the Department’s website in accordance with the W3C’s Web Content Accessibility Guidelines. The text may be freely downloaded and translated by individuals or organisations for conversion into other accessible formats. If you have other needs in this regard please contact the Department.

Department for Transport
Great Minster House
76 Marsham Street
London SW1P 4DR
Telephone 0300 330 3000
Website www.dft.gov.uk

Contents

1. INTRODUCTION

1.1 This paper provides a summary of the work to re-estimate the time series econometric equations underlying the National Air Passenger Demand Model. It provides background on the purpose and methodology of the work as well as including the full set of results for each market. The difficulties encountered, additional econometric analysis undertaken and possible further work are also considered.

1.2 The first stage in forecasting air passenger demand is to forecast national level demand, unconstrained by airport capacity. This is done using National Air Passenger Demand Model (NAPDM), which is based on the time series econometric. models of 19 aviation markets, split according to:

- The global region a passenger is travelling to or from;
- Whether the passenger is a UK or overseas resident;
- The passengers journey purpose (business or leisure);
- The type of flight the passenger is on (international or domestic); and
- Whether the passenger is making an international to international connection using a UK airport.

1.3 Each market is described by a typically three letter code.[1]

1.4 The econometric models used for the Department's last major forecasts are published in Annex A of Air Passenger Demand and CO2 Forecasts 2009 (APDCF 2009), which sets out the dependent variable used; the coefficients of the independent variables and the results of a range of diagnostic tests. This can be found at:

http://www.dft.gov.uk/pgr/aviation/atf/co2forecasts09/

1.5 The main reasons for re-estimating the models are.

---

[1] Journeys between the UK and foreign countries: First letter denotes UK resident (U), or Foreign resident (F). Second letter denotes Business (B), or Leisure (L). Third letter denotes foreign origin or destination: W: Western Europe; O: OECD excluding Western Europe; N: Newly Industrialised Countries (NICs); L: Less Developed Countries (LDCs).
Domestic journeys within the UK: DMB: Domestic business; DML: Domestic leisure. International to international (interliner) passengers: I-I.

a. to make use of the more recent data that is now available.
b. to test different specifications of the models, for example by changing the variables used or including lagged variables.
c. To review whether fare variables could be included in more models, given the expectation that aviation's entry into the EU Emmissions Trading System (ETS) will lead to increases in fares.

1.6 Ultimately the aim of the econometric analysis has been to estimate models which successfully explain past changes in UK passenger traffic, have parameter estimates in line with economic theory, and which pass the standard diagnostic tests. Particular emphasis has been placed on establishing the relationship between demand and income variables, and searching for fare effects where data permits.

1.7 A description of the data sources used in the econometric analysis can be found in a separate technical note entitled *Data Sources for the Econometrics in the National Air Passenger Demand Model*.[2]

[2] This note is available at www.dft.gov.uk

2. ECONOMETRIC ANALYSIS

2.1 Most of the markets display strongly trended variables. There are upward trends in traffic, but also in independent variables such as GDP, exports and imports. Similarly there is typically a downwards trend in air fares. And these trends are non stationary.[3]

2.2 Using standard regression techniques with non-stationary time series data can result in spurious regressions, because the standard errors on the estimated parameters are biased, leading to measures of parameter significance and model goodness of fit that are misleadingly high.

2.3 If the data series are non stationary but a linear combination of them is stationary (their time paths are linked) then the series are said to be cointegrated. To be cointegrated the variables must be integrated of the same order.[4] In the presence of cointegration there are a number of alternative time series techniques available.

2.4 Two of these techniques are a vector autoregression model and a vector error correction model. A multiple equation cointegration approach was considered in the early stages of the work. However there were problems in applying this method, related to the small data series. Following expert advice, this was abandoned and a single cointegration approach was adopted for this work.

2.5 Two single cointegration methodologies were considered, an Engle-Granger two-step model and an Unrestricted Error Correction Model (UECM). The advantage of both of these techniques is that they combine short run dynamic specification with desirable long run properties.

2.6 Both methods require cointegration and, as noted above, for this to exist all the variables must be integrated of the same order. This involves testing variables for unit roots by inspecting correlograms and conducting Dickey-Fuller tests on each variable to determine the order of integration. If the variables do all have unit roots (which is equivalent to being integrated to order one) the long run relationship can then be estimated in a simple Ordinary Least Squares (OLS) regression of the form:

[3] i.e. they are not following fixed, constant time trends.
[4] This is the minimum number of differences required to obtain a stationary series.

$$\boxed{Y_t = \alpha_0 + \alpha_1 X_t + u_t}$$

2.7 The residuals of this linear regression can then be tested for cointegration using a Dickey-Fuller test. If we can reject the null hypothesis of no cointegration then the residuals are stationary and we have a cointegrating relationship.

2.8 Estimating the long run relationship is the 1st step of the Engle-Granger method. The 2nd step of the Engle-Granger method is an error correction model (ECM). This is estimated as the first difference of traffic regressed against the differences of lagged traffic and lagged independent variables and also the lagged level residuals (ECM) from the long run model, as shown in the equation below. The lags of traffic and the independent variables determine the short run, dynamic relationship between these variables and traffic.

$$\boxed{\Delta Y_t = \beta_0 + \sum_{i=0}^{\infty} \beta_{1i} \Delta X_{t-1} + \sum_{i=1}^{\infty} \eta_i \Delta Y_{t-1} + \gamma ECM_{t-1} + u_t}$$

2.9 The lagged residuals are the error correction term, which reflects the deviation of traffic in the previous period from its long run equilibrium. The coefficient on the error correction term, γ, reflects the speed of adjustment: the larger it is the greater the response to the previous periods deviation from the long run trend.

2.10 A UECM is similar to an Engle-Granger ECM, but involves dropping the error correction term and regressing the lagged dependent and independent variables on traffic in differences and in levels. The levels term provides the error correction in this method. The UECM is more efficient, although it can be seen from these equations that the regressions are identical except for the expression of the error correction term (i.e. $\gamma ECM_{t-1} = (\gamma_1 Y_{t-1} + \gamma_2 X_{t-1})$) and as a result the change in the dependent variable should be equivalent under both methods. A full explanation of these methods can be found in Enders (2004).[5]

$$\boxed{\Delta Y_t = \alpha_0 + \sum_{i=0}^{\infty} \beta_i \Delta X_{t-1} + \sum_{i=1}^{\infty} \eta_i \Delta Y_{t-1} + \gamma_1 Y_{t-1} + \gamma_2 X_{t-1} + u_t}$$

2.11 We are using UECM outputs in our forecasting as this method is more efficient. In the initial stages of the work a number of different functional forms were tested but the log-log form, where all variables are expressed in natural logarithms, was chosen for all models as it yielded models best able to explain past movements in air passenger traffic. Therefore all the models take the following form:

---

5 *Applied Time Series Econometrics*, W.Enders, 2004, Wiley, 2nd ed. pp 335-339

$$\Delta Q_{it} = \alpha_i + \beta_i \Delta Z_{it} + \gamma_i Q_{it-1} + \delta_i Z_{it-1} + \varepsilon_{it}$$

where

Q_{it}	=	log of passenger demand in market i at time t
Z_{it}	=	log of explanatory variables in market i at time t
ε_{it}	=	error in prediction in market i at time t
$\alpha_i, \beta_i, \gamma_i, \delta_i$	=	parameters to be estimated.

2.12 Various diagnostic tests have been completed to check that our estimated equations are robust. Plots of fitted versus actual were studied as a first check of accuracy, followed by a test for omitted variables (Ramsay RESET), a test for heteroskedasticity (Breusch-Pagan), and a test for autocorrelation (Breusch-Godfrey). The results of these tests for each passenger market can be found in table 3.

Technical Peer Review

2.13 Expert academic advice was sought to ensure the methods used were fit for purpose. A team at the University of Westminster (UoW), led by Professor Austin Smyth, evaluated the techniques being used to update the econometric models to ensure they were fit for purpose. A short note prepared by the UoW team, describing the approach taken and limitations can be found in Annex A.

2.14 Ad hoc advice was also provided by Professor Joyce Dargay, Emeritus Professor of Transport Econometrics at the Institute of Transport Studies. Professor Dargay has very extensive experience in dealing with the problems that arise when working within the limitations of real world datasets. She examined all of the final models and endorsed the methods used, as well as making some useful suggestions as to how to interpret the findings.

2.15 All results have been shared and discussed with the Department's Aviation Forecasting and Appraisal Technical Working Group (AFATWG), which included external advisers.

Difficulties encountered

2.16 Problems arose from the extremely small sample sizes used in the estimation, with a maximum of 25 observations in a series. The time series datasets used contained annual data points. The main reason for this level of aggregation was that CAA passenger survey data is used to give the business, leisure and I-I split of traffic and these surveys are only conducted every 3 to 5 years at non London airports. It would therefore not be appropriate to impose monthly airport statistics for example as the journey purpose splits would not have been correct.

Divergence of the two step Engle-Granger and UECM

2.17 The regression outputs using a two step Engle-Granger and a UECM should in theory be identical. This was not always the case in practice, however, largely because of the size of the dataset. Only models in the UECM form have been used in the NAPDM.

Absence of cointegration

2.18 Dickey-Fuller tests, correlograms and data plots were used to establish each variables order of integration (they must be integrated of the same order for cointegration to exist). After running the 1st step Engle-Granger regression the residuals were tested for cointegration, using a Dickey-Fuller test. In some markets the Dickey-Fuller test indicated there was no cointegration, even though it was suspected there was.

2.19 For example, GDP appeared to be stationary in some Dickey-Fuller tests but the data plots clearly displayed a non stationary trend in every market. In the absence of cointegration there is an issue of unreliable critical values for the parameters' standard errors when using a UECM. However, where sample sizes are small, as in our modelling, less weight should be placed on Dickey-Fuller tests than with a larger dataset so where the results were borderline the UECM approach continued to be used, with correlograms and data plots assisting in confirming whether the variables were in fact stationary.

Additional econometric analysis

2.20 In addition to re-estimating and re-basing the models using the same market splits as the 2004 based models a number of more radical changes to the econometric models were explored. These met with varying degrees of success, but all the additional analysis undertaken is summarised below.

Inclusion of charter traffic with rest of the UK Leisure markets

2.21 Previously Charter traffic has been omitted from the econometric estimations of price and income elasticities, as it was assumed to be a quite different market from the scheduled and No Frill Carrier (NFC) markets which are aggregated for this stage in the modelling. After discussion at the AFATWG it was agreed that this distinction should now be abandoned as it seems sensible to assume that nowadays, when passengers book a flight, they largely view Scheduled, NFC and Charter flights as interchangeable. The combined markets are then split out in a sub-model prior to input into NAPAIM, in a similar way to that in which Scheduled and No Frills Carriers (NFCs) flights are currently split out. Therefore the UK Leisure to Western Europe market now includes Short Haul Charter passengers, while the UK Leisure to

OECD, NICs and LDCs includes the Long Haul Charter passengers, weighted by traffic.

Imposing elasticities in the models

2.22 There are a few markets where it was suspected that model or data limitations led to unexpected values for the income elasticities (YEDs) and price elasticities (PEDs). Professor Joyce Dargay advised that it is reasonable, for the purposes of forecasting, to impose YEDs or PEDs if there is a strong rationale for believing a certain relationship exists which, because of data limitations, has not been picked up in the estimated equations. This led to PEDs being imposed in four markets – ULW, DML, DMB and FLO – and a YED being imposed in the DML market. The justification for imposing PEDs and YEDs in these markets is given in the description of each model provided below.

2.23 In addition it proved impossible to derive a satisfactory model for the UBL market. Therefore, for forecasting, the elasticities estimated for the UBN market have been used, on the basis that this is expected to be the most similar of the other sectors for which models were estimated to the UBL sector. Given that the UBL sector is one of the smallest (accounting for 1% of total UK terminal passengers in 2008), the imposition of the model for UBN will not significantly affect the overall forecasts.

2.24 It has also been agreed that sensitivity tests should be performed in which YEDs different to those estimated are imposed in some markets, to reflect the possibility that the elasticities estimated in the econometric analysis are biased by the omission from the model of factors representing market liberalisation. For forecasting purposes, it is also assumed that the YEDs and PEDs in each market will fall through time, to reflect the likelihood that, as the market for air travel matures, the responsiveness of air travel to changes in its key drivers reduces. The adjustments made to YEDs and PEDs to reflect potential bias in the estimated elasticities and the impact of market maturity are described in more detail in a separate technical note entitled Reflecting changes in the relationship between UK air travel and its key drivers in the National Air Passenger Demand Model.

Including a surface mode variable in domestic markets

2.25 In the domestic markets, we expected the cost of surface mode alternatives to air to be a significant factor in explaining changes in passenger numbers. Therefore we worked with DfT's rail forecasting team to create rail generalised cost time series for both the business and leisure markets.

2.26 In deriving the rail generalised cost time series we used the times and costs on the London to Glasgow route as a proxy for a typical journey where rail and air are close substitutes, with data available from 1991-

2008. The generalised cost variable was significant in some domestic leisure market models but in all cases it had an intuitively incorrect sign (implying a negative relationship between rail fares and air traffic). This may have been because of the poor quality of the rail ticket sales data. The final set of models therefore did not include a surface mode variable. The chosen models passed all diagnostic tests and so did not suffer from an omitted variable problem

Splitting up the LDC market

2.27 As the LDCs market encompasses such a wide range of countries it was difficult to find a model to fit at the aggregate level. An attempt was made to separate out the 'high growth' LDCs from the rest. The countries chosen were Brazil, the Middle Eastern countries and India. These countries are immature markets with high growth potential and are distinct from the more mature leisure markets which are also included in LDCs e.g. Caribbean, where the market includes the visiting friends and relatives (VFR) passenger market. However this separation did not prove successful and a model could not be fitted for this sub group of LDCs.

Including alternative fares variables in the models

2.28 A limited amount of analysis took place to test whether fares to destinations other than the market in question were significant explanatory variables. Due to time constraints only the ULL market was looked at and fares to other destinations were not found to be significant. However it seems possible that in some markets there could be fare effects which are not being picked up in the current models.

Testing for maturity in the historic relationship between income and traffic

2.29 It may be expected that between 1984 and 2008 the relationship between income and traffic would have changed in some markets as they have become more mature. To test for falling income elasticities alternative model forms were tried and the Chow test for structural breaks was used. Two fairly mature markets were tested, UBW and UBO. No evidence was found that income elasticities had fallen over the period, however this could well be because the time series were too short, so when a significantly longer time series is available later in this decade this may be worth testing again.

Potential future further work

2.30 In addition to the additional analysis outlined above there, a number of other potential work streams were identified in the process of re-estimating the econometric models but were not taken forward as part of this analysis. These are:

- Various anomalies in the way countries were allocated to the four geographical regions have been spotted. For example, Chile joined the OECD in 2010 but is currently included in the LDC category. Though, as noted above, a limited amount of analysis of splitting up the LDC market was undertaken as part of this work this is now a longer term development issue as it would require re-estimation of all the models. A possible improvement to the modelling would be to include a sixth world zone, made up of middle income countries, rather than grouping a large number of heterogeneous countries together as LDCs. However this will depend on the availability of data on individual LDCs, which is currently patchy. More generally, the geographical zoning in NAPDM should in any case be reviewed as part of any future exercise to re-estimate the econometric models underpinning the forecasts.

- An issue which became apparent once income elasticities were obtained for each market was the difficulty in deciding which variables to include in quoting income elasticities. For example, UK air traffic could rise very quickly to NICs (dominated by China) to take advantage of the opportunities there in the future, almost irrespective of what is happening to UK GDP. Indeed in the econometric model for UK Business to NICs foreign GDP is a key driver of UK business traffic to that region. This is also true of other business models. In such cases, the income elasticity has been defined as the combined impact of all income variables in the model.

- Intercept dummy variables have been used in a number of markets. In most cases we have been able to identify a specific event to justify the need for each dummy variable. However this has not always been the case. We might expect to find that the same dummy variables would feature in the models for UK and foreign residents for a given geographical market. This is not the case – for example, whilst a dummy variable of 1996 has been used in the ULW market, two dummies, for 1991 and 2001, have been used for the FLW market. Whilst this should not significantly affect the parameters used in forecasting, we would have liked to spend more time examining the reasons why certain dummy variables proved to be significant in one market and not others.

- Finally, further work is required to develop a better understanding of the fares data used to estimate the models. At the moment it is understood the fares data is often poor but there is not a detailed understanding of exactly what the limitations of the data are, which could then potentially lead to an improvement in the fare series.

3. RESULTS OF RE-ESTIMATING THE NAPDM ECONOMETRIC EQUATIONS

3.1 The following pages present the outputs from the econometric analysis of each of the 19 passenger markets. The notation is as follows.

lntra	Natural logarithm of Traffic levels
lngdp	Natural logarithm of UK GDP
lncon	Natural logarithm of UK Consumption
lnfgp	Natural logarithm of Foreign GDP
lnips	Natural logarithm of UK Passenger Fares
lnpfr	Natural logarithm of Foreign Passenger Fares
lnexr	Natural logarithm of UK Nominal Exchange Rate
lnimp	Natural logarithm of UK Imports
lnexp	Natural logarithm of UK Exports
d.[variable]	Differenced variable
l.[variable] or L1	Lagged variable (one year)
d.l.[variable] or DL	Differenced lagged (one year) variable
D[year]	Dummy
PED	Price elasticity of demand
YED	Income elasticity of demand

3.2 In estimating the econometric models a constant was initially included in every model. The constant was only excluded if it was found to be insignificant.

3.3 The estimated coefficients for each of the independent variables for each market are shown in Table 1 below. The associated t-statistics are shown in Table 2. Table 3 shows the results of the econometric diagnostic tests. Tables 3 also shows the 2008 share of total modelled passenger traffic to and from the UK.

3.4 Tables 1 to 3 show that:

- in all markets an R2 value[6] exceeding 0.6 is obtained;
- the income variables are significant at the 5% level or higher in all but the FBN and I-I models, where the foreign GDP variable is significant at the 10% level in I-I and insignificant in the FBN model. The fare level variables are significant at the 5% level, with two exceptions (FLN and FBO), where the variable is retained because the variables are jointly significant, the parameter is of the correct sign and plausible magnitude, and therefore likely to be useful in forecasting[7]; and
- there is no evidence of autocorrelation or heteroscedasticity at the 5% level except in the UK Business to Western Europe market – which suffers from autocorrelation.

---

[6] R^2 is a measure of the goodness of fit of a model. It measures the proportion of variability of the dependent variable (the number of air passengers) in the past that is explained by the model.

[7] The critical values for the t-stats, given the 24 observations in the UK and foreign market models (excluding domestic and I-I markets), are 1.71 at the 10% level, 2.06 at the 5% level and 2.80 at the 1% level. Given that there are 19 observations in the domestic models the critical values for the t-stats are 1.73 at the 10% level, 2.09 at the 5% level and 2.86 at the 1% level. The critical values for the t-stat in the I-I model, given 12 observations, are 1.78 at the 10% level, 2.18 at the 5% level and 3.05 at the 1% level.

Table 1: Parameter Estimates

Sector	Dep Variable	Const	d.lngdp	d.lncon	d.lnfgp	d.lnips	d.lnpfr	d.lnexr	d.lnexp	d.lnimp	l.lntra	l.lngdp	l.lncon	l.lnfgp	l.lnips	l.lnpfr	l.lnexp	l.lnimp	l.lnexr	d91	d93	d96	d00	d01	d02	d03	d04	d05	d08
		Variable																											
UBW	D-Lnt-Tra	0		1.27		-0.35			0.47		-0.78		0.57		-0.21		0.42												
UBO	D-Lnt-Tra	0			2.40					0.02	-0.41			0.18				0.21											
UBN	D-Lnt-Tra	0	4.98		0.54						-0.86	0.41		0.46										0.26					
UBL	D-Lnt-Tra	0	4.98		0.54						-0.86	0.41		0.46										0.26					
ULW	D-Lnt-Tra	0		2.82							-0.47		0.62		-0.16							0.13							
ULO	D-Lnt-Tra	0				-0.85			0.81		-0.73		0.56		-0.25		0.43												
ULN	D-Lnt-Tra	0		1.88		-0.16					-0.84		1.34		-0.46														
ULL	D-Lnt-Tra	0	2.60			-0.49					-0.51	0.95			-0.44													0.18	
FBW	D-Lnt-Tra	0.79		1.87					0.52		-1.21		0.75			-0.30	0.60									-0.15			
FBO	D-Lnt-Tra	2.95					-0.45		0.67		-1.02					-0.17	0.57												
FBN	D-Lnt-Tra	0.49			0.53						-0.30			0.23											0.64				-0.60
FBL	D-Lnt-Tra	0.54								0.18	-0.39							0.27			0.52								
FLW	D-Lnt-Tra	0.94					-0.67				-0.36		0.44			-0.27				-0.08				-0.21					
FLO	D-Lnt-Tra	8.90			0.94			-0.20			-0.75			0.41					-1.58						-0.20				
FLN	D-Lnt-Tra	3.74			0.20		-0.18				-1.02			0.53		-0.22								-0.28					-0.45
FLL	D-Lnt-Tra	2.10			0.08		0.003				-0.53			0.25		-0.18					0.44				-0.24				
DMB	D-Lnt-Tra	0	2.96								-0.41	0.41															0.12		
DML	D-Lnt-Tra	-2.42		2.41							-0.42		0.95										-0.08						
I to I	D-Lnt-Tra	5.82			0.06		-0.24				-1.06			0.50		-0.70								-0.15					

Table 2: Parameter t-statistics

Sector	Dep Variable	Const	d.lngdp	d.lncon	d.lnfgp	d.lnips	d.lnpfr	d.lnexr	d.lnexp	d.lnimp	l.lntra	l.lngdp	l.lncon	l.lnfgp	l.lnips	l.lnpfr	l.lnexp	l.lnimp	l.lnexr	d91	d93	d96	d00	d01	d02	d03	d04	d05	d08
UBW	D-Lnt-Tra	0		2.05		-1.93			4.14		-3.65		3.23		-3.17		3.39												
UBO	D-Lnt-Tra	0			6.26					0.19	-6.89			3.52				3.92											
UBN	D-Lnt-Tra	0	3.31		2.32						-5.09	4.63		4.42										3.76					
UBL	D-Lnt-Tra		3.31		2.32						-5.09	4.63		4.42										3.76					
ULW	D-Lnt-Tra	0		4.29							-2.90		2.91		-2.79							-2.56							
ULO	D-Lnt-Tra	0				-2.26			3.88		-3.35		2.78		-2.84		2.51												
ULN	D-Lnt-Tra	0		2.02		-0.79					-3.46		3.29		-2.98														
ULL	D-Lnt-Tra	0	2.62			-2.33					-2.44	2.37			-2.28													2.86	
FBW	D-Lnt-Tra	1.10		3.70					3.70		-8.60		5.00			-3.50	6.90									-3.35			
FBO	D-Lnt-Tra	2.30					-1.50		3.60		-4.10					-0.90	3.60												
FBN	D-Lnt-Tra	2.00			2.20						-1.90			1.60											5.21				-4.98
FBL	D-Lnt-Tra	2.40								1.60	-3.80							4.30			7.71								
FLW	D-Lnt-Tra	1.10					-3.70				-5.50		2.70			-2.80				-1.61				-4.45					
FLO	D-Lnt-Tra	2.80			2.40			-0.20			-4.40			2.50					-2.50						-3.02				
FLN	D-Lnt-Tra	2.70			0.50		-0.40				-4.50			3.60		-1.10								-2.18					-3.07
FLL	D-Lnt-Tra	2.30			0.80						-4.30			3.20		-2.20					6.00				-3.53				
DMB	D-Lnt-Tra	0	4.50								-3.48	3.42															3.39		
DML	D-Lnt-Tra	-2.42		4.86							-2.34		2.27										-2.2						
I to I	D-Lnt-Tra	3.40			0.10		-1.00				-5.80			2.00		-3.40								-4.73					

Table A3: Results of diagnostic tests

Sector	2008 share of modelled traffic	R2	F	F sig	Breusch-Godfrey autocorrelation	Breusch-Godfrey significance	Ramsey RESET	RESET significance	Breusch-Pagan heteroskedasticity	Breusch-Pagan significance
UBW	6%	0.78	8.6	0	5.94	0.01	5	0.02	0.05	0.82
UBO	1%	0.89	30.22	0	0.76	0.38	1.04	0.4	0.23	0.63
UBN	0%	0.79	11.01	0	0.36	0.55	0.4	0.75	0.14	0.71
UBL	1%	0.79	11.01	0	0.36	0.55	0.4	0.75	0.14	0.71
ULW	33%	0.73	10.06	0	0.11	0.74	1.7	0.21	0.23	0.64
ULO	5%	0.7	6.89	0.001	0.5	0.48	0.88	0.47	0.04	0.85
ULN	1%	0.7	8.66	0	0.89	0.35	3.15	0.06	1.35	0.25
ULL	6%	0.79	10.95	0	0.14	0.7	0.33	0.81	0.22	0.64
FBW	5%	0.87	14.85	0	1.14	0.29	3.53	0.05	0.75	0.39
FBO	1%	0.6	5.4	0.003	0.14	0.71	0.66	0.59	1.28	0.26
FBN	0%	0.84	18.44	0	2.41	0.12	0.35	0.71	0.29	0.59
FBL	1%	0.83	23.1	0	3.11	0.08	0.52	0.68	0.33	0.56
FLW	10%	0.82	12.84	0	2.5	0.11	0.88	0.48	1.58	0.21
FLO	3%	0.63	4.91	0.004	4.02	0.05	0.5	0.69	0.66	0.41
FLN	0%	0.7	5.28	0.003	3.04	0.08	1.25	0.33	1.46	0.23
FLL	1%	0.85	13.44	0	0.02	0.89	2.14	0.14	0.96	0.33
DMB	7%	0.75	11.19	0	1.19	0.28	0.74	0.55	0.18	0.67
DML	8%	0.66	6.88	0.003	2.09	0.15	1.58	0.25	0.29	0.59
I to I	10%	0.96	22.8	0.002	0.11	0.74	0.61	0.67	0.02	0.9

Long run air fare and income elasticities

3.5 Price and income elasticities have been calculated (where possible) using the method in Figure 1. This method differs in some cases from that used in Air Passenger Demand and CO_2 Forecasts (APDCF) 2009. All of the re-estimated models contain logged variables so only point elasticities are calculated, while in APDCF 09 some arc elasticities were used as the model forms varied between markets.

Figure 1: Finding Point Elasticities from Error Correction Models (ECMs)

Given an ECM equation with *traffic* and *fares* (simplified):

$$d \ln tra = \alpha \ln tra_{t-1} + \beta \ln fare_{t-1} + \gamma (d \ln fare)$$

Fare elasticity of demand with respect to traffic can be derived. Assuming that in the long run equilibrium, *d lntra* and *d lnfare* are zero:

$$0 = \alpha \ln tra_{t-1} + \beta \ln fare_{t-1}$$

$$\alpha \ln tra_{t-1} = -\beta \ln fare_{t-1}$$

$$\ln tra_{t-1} = \frac{-\beta}{\alpha} \ln fare_{t-1}$$

Now each side can be differentiated and rearranged to find that the fare elasticity of demand is given by ($-\beta/\alpha$):

$$\frac{1}{tra_{t-1}} dtra_{t-1} = \frac{-\beta/\alpha}{fare_{t-1}} dfare_{t-1}$$

$$\frac{dtra_{t-1}}{dfare_{t-1}} \frac{fare_{t-1}}{tra_{t-1}} = \frac{-\beta}{\alpha}$$

3.6 The measurement of income elasticities was complicated in some markets by the presence of more than one income variable. This was primarily an issue in business markets where it was found, not unexpectedly, that demand was driven by economic activity in the UK and in the overseas market. This was dealt with by taking the sum of the coefficients on these components and dividing through by the (negative of the) coefficient on lagged traffic (α in figure 1) to find the income elasticity.

3.7 Another complication in calculating income elasticities concerned the foreign leisure market to Western Europe which contained UK consumer spending as its only income variable. In this market the coefficient on UK consumer spending was used to calculate the income elasticity on the basis that UK consumer spending is treated as operating as a proxy for consumer spending in the rest of Europe.

3.8 As explained in section 2, there are a few markets where we suspected that model or data limitations led to unexpected values for the income elasticities (YEDs) and price elasticities (PEDs). This led us to impose PEDs in four markets – ULW, DML, DMB and FLO – and a YED in the DML market. Justifications for imposing elasticities in each case are provided in the description of the individual models at the end of this section.

3.9 In addition, it proved impossible to derive a satisfactory model for the UBL market. Therefore, for forecasting, the elasticities estimated for the UBN market have been used, on the basis that this is expected to be the most similar of the other sectors for which models were estimated to the UBL sector. Given that the UBL sector is one of the smallest (accounting for 1% of total UK terminal passengers in 2008), the imposition of the model for UBN will not significantly affect the overall forecasts.

3.10 Table 4 below summarises the resulting long run income and air fare elasticities.

Table 4: Long run price and income elasticities of UK air passenger demand

Sector	2008 share of passenger traffic	Sector PED	Market PED	Sector YED	Market YED
UBW	6%	-0.3	-0.2	1.3	1.2
UBO	1%	0.0		1.0	
UBN	0%	0.0		1.0	
UBL	1%	0.0		1.0	
ULW	33%	-0.7	-0.7	1.3	1.4
ULO	5%	-0.3		1.3	
ULN	1%	-0.6		1.6	
ULL	6%	-0.9		1.9	
FBW	5%	-0.2	-0.2	1.1	1.0
FBO	1%	-0.2		0.6	
FBN	0%	0.0		0.8	
FBL	1%	0.0		0.7	
FLW	10%	-0.8	-0.6	1.2	1.0
FLO	3%	-0.3		0.5	
FLN	0%	-0.2		0.5	
FLL	1%	-0.3		0.5	
DMB	7%	-0.3	-0.5	1.0	1.7
DML	8%	-0.7		1.5	
I to I	10%	-0.7	-0.7	0.5	0.5
Overall	100%		-0.6		1.3

Notes:

Income variable depends on sector

Price and income elasticities are point estimates

Results are elasticity of terminal passengers to income or fares

PEDs in ULW, FLO, DMB and DML and YED in DML have been entered manually for reasons stated in section 2, p10.

3.11 The average PED across all markets is -0.6 and the overall YED is 1.3. The overall YED is the same as in APDCF 09. This is in line with estimates found in the literature. The overall PED has increased slightly from -0.5 to -0.6 since APDCF 09.

Updated Econometric Models

3.12 This section presents the detailed outputs of the econometric analysis for the preferred models for each of the 19 passenger market sectors. The notation used for each of the variables is as set out on page 13.

UK Business Western Europe (UBW)

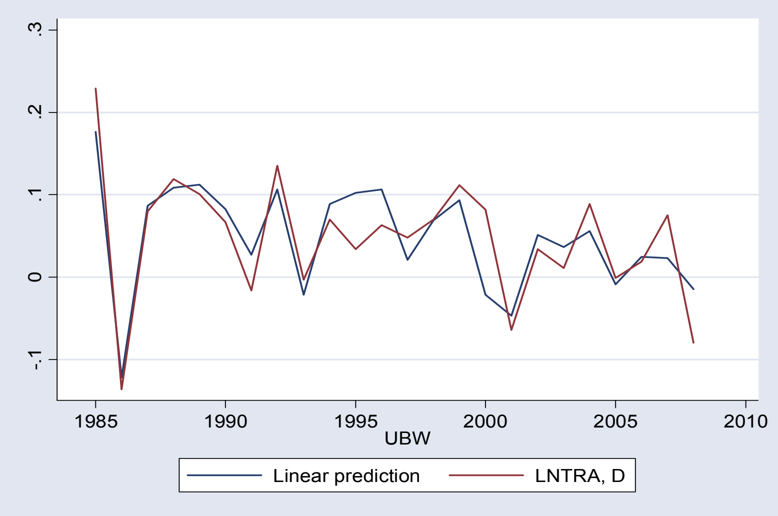
Stata Output

```
regress d.lntra d.lnexp d.lncon d.lnips l.lntra l.lncon l.lnexp l.lnips, noconstant

      Source |       SS       df       MS              Number of obs =      24
-------------+------------------------------           F(  7,    17) =    8.60
       Model |  .145718435     7  .020816919           Prob > F      =  0.0002
    Residual |  .041137542    17  .002419855           R-squared     =  0.7798
-------------+------------------------------           Adj R-squared =  0.6892
       Total |  .186855977    24  .007785666           Root MSE      =  .04919

------------------------------------------------------------------------------
D.lntra      |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
lnexp        |
          D1 |   .4727284   .1143193     4.14   0.001     .2315357     .713921
lncon        |
          D1 |    1.27207   .6212659     2.05   0.056    -.0386863    2.582827
lnips        |
          D1 |  -.3502224   .1817938    -1.93   0.071    -.7337737    .0333289
lntra        |
          L1 |   -.778166   .2129866    -3.65   0.002    -1.227528   -.3288035
lncon        |
          L1 |   .5736985    .177451     3.23   0.005     .1993097    .9480873
lnexp        |
          L1 |   .4192475   .1237042     3.39   0.003     .1582544    .6802406
lnips        |
          L1 |  -.2125258   .0670274    -3.17   0.006    -.3539413   -.0711104
```

Plot of Fitted vs Actual



Interpretation of model

3.13 This model fits well but the Ramsey RESET test suggests a potential problem with omitted variables. The PED is -0.3, indicating that demand is fairly price inelastic, which is in line with expectations for a business market, where the passenger is often not paying for their travel and their plans are less flexible than leisure passengers. The UBW market is more price elastic than many other business markets, this is most likely due to the greater availability of viable alternative modes of travel on these short haul routes, for example by Eurostar. No price elasticity was found in APDCF 09 for this market.

3.14 There are two variables reflecting levels of economic activity – UK exports to the region and UK consumption. These two variables are likely to be picking up different effects, with the exports term picking up the impact of greater demand for UK products and services overseas, whilst the consumption term is picking up the impact of greater demand from within the UK. The YED calculated by summing across the two income variables of 1.3 indicates that a 1% rise in the income variables will lead to a rise in traffic of 1.3%. This is the most income elastic of the business markets, though this value is lower than in APDCF 09. This relatively high elasticity could potentially overstate the relationship between the income drivers and traffic if European deregulation of the airline market has driven up traffic over this period. This deregulation will be reflected somewhat in falling fares but there may be a small additional effect incorrectly attributed to income.

UK Business OECD (UBO)

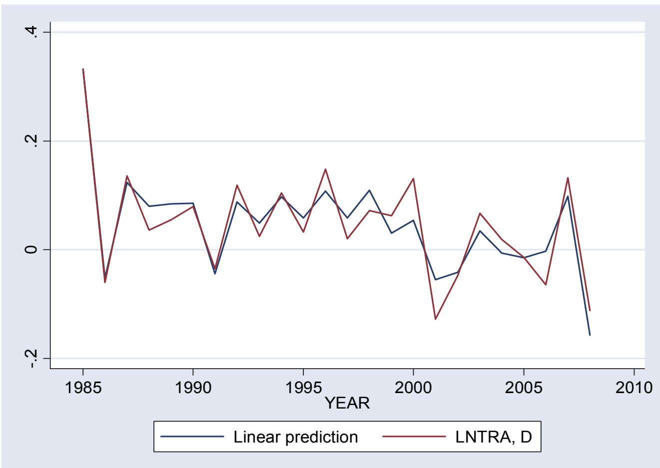
Stata Output

regress d.lntra d.lnfgp d.lnimp l.lntra l.lnimp l.lnfgp, noconstant

Source	SS	df	MS		
Model	.246224312	5	.049244862	Number of obs =	24
Residual	.03096035	19	.001629492	F(5, 19) =	30.22
				Prob > F =	0.0000
				R-squared =	0.8883
				Adj R-squared =	0.8589
Total	.277184663	24	.011549361	Root MSE =	.04037

D.lntra	Coef.	Std. Err.	t	P>|t|	[95% Conf. Interval]	
lnfgp D1	2.401879	.3835695	6.26	0.000	1.599059	3.204699
lnimp D1	.0159503	.0844774	0.19	0.852	-.1608629	.1927635
lntra L1	-.4081078	.0592119	-6.89	0.000	-.5320397	-.284176
lnimp L1	.2114398	.0540005	3.92	0.001	.0984155	.3244641
lnfgp L1	.1848799	.0524865	3.52	0.002	.0750244	.2947353

Fitted vs Actual



Interpretation of model

3.15 This model for UBO fits very well and passes all the diagnostic tests. As for the UBW market there are two economic activity-related variables. In this case a foreign GDP variable reflects the role of foreign demand in influencing the demand for business travel, whilst an imports variable reflects the role of demand in the UK for overseas products. The YED is 1.0 when calculated as the aggregate across both income-related variables. No price elasticity was found in UBO, though it is likely to be close to zero as long haul business travel is expected to be one of the most inelastic markets. The short run YED of 2.4 is significantly larger than the long run YED, which whilst not wholly intuitive will not have a significant affect on our forecast.

UK Business NICs (UBN)

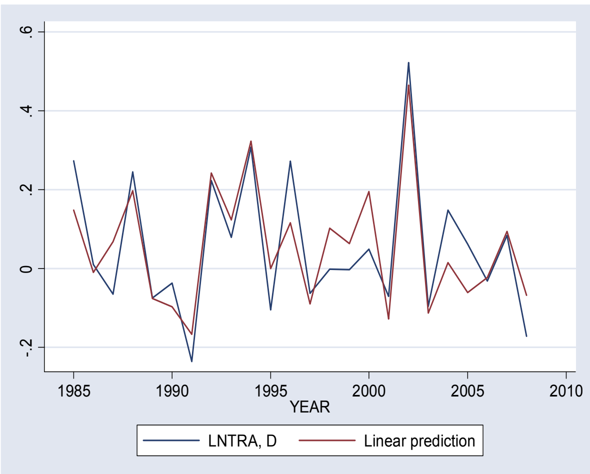
Stata Output

```
regress d.lntra d.lngdp d.lnfgp l.lntra l.lnfgp l.lngdp d0102,noconstant

      Source |       SS       df       MS              Number of obs =      24
-------------+------------------------------           F(  6,    18) =   11.01
       Model |  .624798972     6  .104133162           Prob > F      =  0.0000
    Residual |  .170283312    18  .009460184           R-squared     =  0.7858
-------------+------------------------------           Adj R-squared =  0.7144
       Total |  .795082283    24  .033128428           Root MSE      =  .09726

------------------------------------------------------------------------------
D.lntra      |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
lngdp        |
          D1 |   4.981037   1.505113     3.31   0.004     1.818913    8.143162
lnfgp        |
          D1 |   .5380331   .2318605     2.32   0.032     .0509122    1.025154
lntra        |
          L1 |  -.8624065   .1692943    -5.09   0.000    -1.218081   -.5067323
lnfgp        |
          L1 |    .462733   .1048001     4.42   0.000      .242556    .6829099
lngdp        |
          L1 |   .4093243   .0884056     4.63   0.000      .223591    .5950577
d0102        |   .2623965   .0698289     3.76   0.001     .1156914    .4091017
```

Fitted vs Actual



Interpretation of model

3.16 The UBN model has a good fit and passes all diagnostic tests. An intercept dummy was included with value -1 in 2001 and 1 in 2002 to reflect the impact of 9/11 on aviation demand. The UBN model contains both UK and foreign GDP variables, to reflect the role of domestic and foreign economic activity in driving demand for business travel. These variables were highly correlated during the historic period over which the models have been estimated and so it is difficult to isolate the relative contribution of each variable to changes in traffic. However, the models perform much better with both variables included than just one, and we would expect economic activity both in the UK and overseas to affect the demand for business travel (as we have found in other business markets) The YED calculated by summing across these variables is equal to just over 1. This is slightly higher than that found in APDCF 09, but the model used in APDCF 09 only included a foreign GDP term and so the YEDs are not strictly comparable.

3.17 As in previous estimation work, no price elasticity was found for this market. This is not a surprising result as we would not expect demand in long haul business markets to be elastic (because fare changes represent a very small proportion of total travel costs and because there are few travel alternatives to air).

UK Business LDCs (UBL)

3.18 It has proven impossible to derive a satisfactory model for this market. We have therefore decided to use the long run elasticities estimated for UBN in producing forecasts for the UBL market on the basis that the drivers of demand in each market are likely to be broadly similar.

UK Leisure Western Europe (ULW)

Stata Output

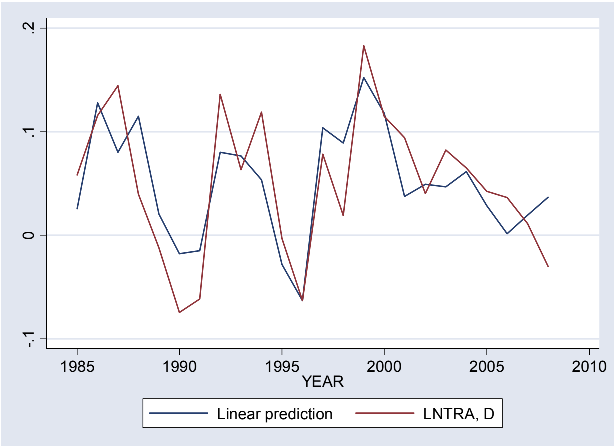
```
regress d.lntra d.lncon l.lntra l.lncon l.lnips d96, noconstant

      Source |       SS       df       MS              Number of obs =      24
-------------+------------------------------           F(  5,    19)  =   10.06
       Model |  .12222892      5  .024445784           Prob > F       =  0.0001
    Residual |  .046152844    19  .002429097           R-squared      =  0.7259
-------------+------------------------------           Adj R-squared  =  0.6538
       Total |  .168381765    24  .007015907           Root MSE       =  .04929

------------------------------------------------------------------------------
D.lntra      |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
lncon     D1 |   2.824325   .6581559     4.29   0.000     1.446789    4.201861
lntra     L1 |  -.4656605    .160422    -2.90   0.009    -.8014276   -.1298934
lncon     L1 |   .6216995   .2137186     2.91   0.009     .1743814    1.069018
```

```
lnips     L1 |  -.1553494    .0555998  -2.79   0.012    -.2717212  -.0389776
d96          |  -.1293396    .0506007  -2.56   0.019    -.235248   -.0234311
------------------------------------------------------------------------------
```

Fitted vs Actual



Interpretation of model

3.19 This is by far the largest of the markets, with 33% of modelled traffic in 2008 once short haul charter is included. The model fits well and passes all diagnostic tests. A negative intercept dummy is included for 1996. A long run PED of -0.33 has been estimated. However, this is likely to be biased downwards because the fare series used reflects scheduled fares only. Indeed when we estimate a model for the scheduled market only we find a long run PED of -0.7, which is more in line with our prior expectations that this would be one of the more price elastic markets. This is likely because 1) traffic in this segment is dominated by holiday traffic and 2) passengers in this segment are more likely to have alternative modes of transport available to them (e.g. Eurostar) than other long haul markets. The value of -0.7 is also more consistent with the literature on price elasticities which finds short haul leisure is a very price elastic market. For the purposes of forecasting we have therefore decided to impose a long run PED of -0.7. We estimated a model including a SR fare variable but this yielded a coefficient that was almost exactly equal to zero (and therefore statistically insignificant) so we have chosen to use a model with this term omitted for forecasting.

3.20 The long run YED of 1.3 fits within the range of elasticities included in the literature review. It is possible that this elasticity is biased upwards because some of the effects of market liberalisation could be attributed to income effects. This possibility is explored in further detail in a separate technical note[8]. The short run YED (2.82) is very high in this market, and

---

[8] See *Reflecting changes in the relationship between UK air travel and its key drivers in the National Air Passenger Demand Model, Department for Transport, 2011*

significantly greater than the long run YED. This is difficult to explain and therefore a cause of concern, but as it will not significantly affect our forecasts is retained.

UK Leisure OECD (ULO)

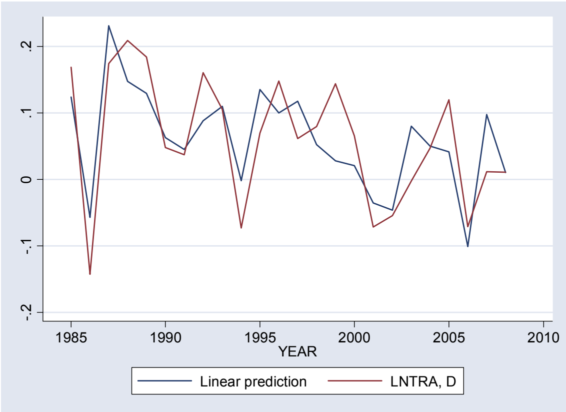
Stata Output

```
. regress d.lntra d.lnips d.lnexp l.lntra l.lncon l.lnips l.lnexp,noconstant

     Source |       SS       df       MS              Number of obs =      24
-------------+------------------------------           F(  6,    18) =
6.89
      Model |  .204782318     6  .034130386           Prob > F      =  0.0006
   Residual |  .089158658    18  .004953259           R-squared     =  0.6967
-------------+------------------------------           Adj R-squared
=  0.5956
      Total |  .293940976    24  .012247541           Root MSE      =  .07038

------------------------------------------------------------------------------
-----------
D.lntra      |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+------------------------------------------------------------------
----
lnips        |
         D1 |   -.852307   .3765917    -2.26   0.036    -1.643497   -.0611172
lnexp        |
         D1 |   .8060737    .207581     3.88   0.001     .3699622    1.242185
lntra        |
         L1 |  -.7345812   .2191856    -3.35   0.004    -1.195073   -.2740894
lncon        |
         L1 |   .5604629   .2013606     2.78   0.012     .1374199     .9835059
lnips        |
         L1 |  -.2456357   .0863874    -2.84   0.011    -.4271289   -.0641425
lnexp        |
         L1 |   .4277829    .170462     2.51   0.022     .0696555    .7859104
------------------------------------------------------------------------------
------------
```

Fitted vs Actual



Interpretation of model

3.21 This model fits well and passes all diagnostic tests. The constant has been omitted because it was statistically insignificant and because the implied PED and YED are more intuitive without it. The model has two income related variables – UK consumer spending and UK exports to the OECD. The latter is a less obvious driver and could reflect the impact of greater trade links between OECD countries leading to more UK residents emigrating overseas and therefore an increase in visiting friends and relatives (VFR) travel. However, this explanation might also be relevant to other leisure markets and so the fact that it has found to be significant only in this market does lead us to question it. The exclusion of the constant increased the YED (calculated by summing across both income-related variables) from 0.8 to 1.4 and reduced the PED from -0.69 to -0.33. We expected the YED of ULO to be similar to ULW, indicating a similar level of maturity, but expected the ULW market to have a higher PED, given the existence of alternative means of travel and cheaper overall holiday costs (such that fare changes represent a higher proportion of total costs).

UK Leisure NICs (ULN)

Stata Output

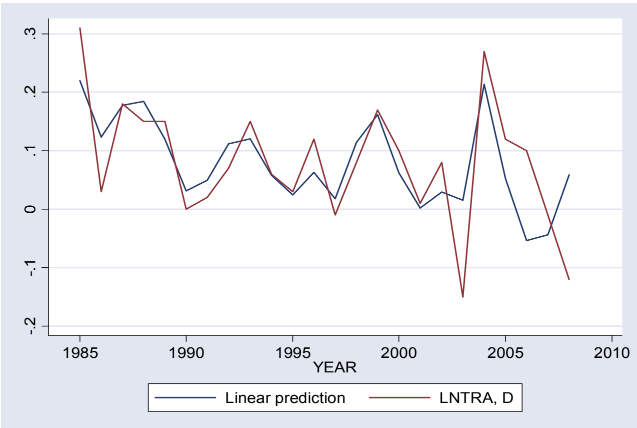
```
regress d.lntra d.lncon d.lnips l.lntra l.lncon l.lnips, noconstant

      Source |       SS       df       MS              Number of obs =      24
-------------+------------------------------           F(  5,    19) =    8.66
       Model |  .283074855     5  .056614971           Prob > F      =  0.0002
    Residual |  .124225083    19  .006538162           R-squared     =  0.6950
-------------+------------------------------           Adj R-squared =  0.6147
       Total |  .407299938    24  .016970831           Root MSE      =  .08086

------------------------------------------------------------------------------
D.lntra      |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
```

Incon						
D1	1.877894	.9293138	2.02	0.058	-.0671817	3.82297
lnips						
D1	-.161632	.2048446	-0.79	0.440	-.5903767	.2671127
lntra						
L1	-.8403024	.2426101	-3.46	0.003	-1.348091	-.3325135
lncon						
L1	1.335059	.4062185	3.29	0.004	.4848336	2.185284
lnips						
L1	-.4633205	.1553022	-2.98	0.008	-.7883717	-.1382693

Fitted vs Actual



Interpretation of model

3.22 The model fits well and passes all diagnostic tests. The YED, calculated on UK consumer spending, is high at 1.6, indicating that this is a relatively immature market, although this is lower than in APDCF 09. There has been very rapid growth in traffic between the UK and NICs over the period, though it is still a very small market overall making up 1% of total traffic in 2008. The long run PED is quite high for a long haul market at -0.55, although almost identical to that found in APDCF 09.

3.23 The high PED may in part be because of high correlation between the UK consumer spending series and fare series, leading to biasing of the coefficients on each variable (i.e. the YED may be biased downwards and the PED may be biased upwards). However, it may also reflect the possibility that those travelling to NICs on leisure trips are more responsive to fare changes, perhaps because they regard destinations in other regions (LDCs or OECD countries) as close substitutes.

UK Leisure LDCs (ULL)

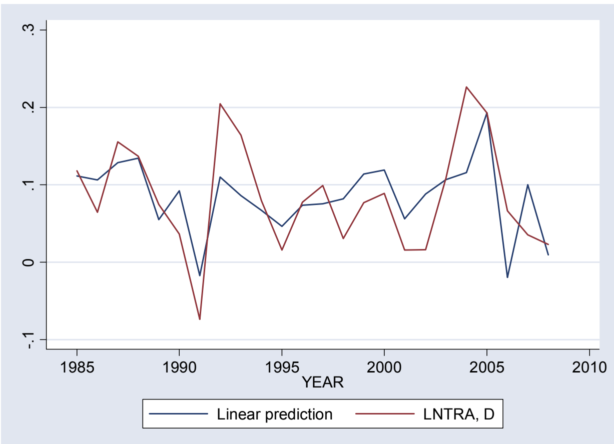
Stata Output

```
regress d.lntra d.lngdp d.lnips l.lntra l.lngdp l.lnips d05, noconstant

     Source |       SS       df       MS              Number of obs =      24
-------------+------------------------------           F(  6,    18) =   10.95
       Model |   .2248517     6  .037475283           Prob > F      =  0.0000
    Residual |  .061590814    18  .003421712           R-squared     =  0.7850
-------------+------------------------------           Adj R-squared =  0.7133
       Total |  .286442514    24  .011935105           Root MSE      =   .0585

------------------------------------------------------------------------------
D.lntra      |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
lngdp        |
          D1 |   2.601635   .9935056     2.62   0.017     .5143569    4.688912
lnips        |
          D1 |  -.4891942   .2097512    -2.33   0.031    -.9298652   -.0485232
lntra        |
          L1 |  -.5104355   .2093508    -2.44   0.025    -.9502651   -.0706058
lngdp        |
          L1 |   .9454913   .3982612     2.37   0.029     .1087757    1.782207
lnips        |
          L1 |  -.4374939   .1916732    -2.28   0.035    -.8401844   -.0348034
d05          |    .183645   .0641797     2.86   0.010     .0488084    .3184817
```

Fitted vs Actual



Interpretation of model

3.24 It proved difficult to fit a model in this market. This is probably because of the highly heterogeneous markets included in the LDC grouping. As explained earlier, attempts were made to disaggregate this market but none were successful. The model chosen fits well despite this and passes all diagnostic tests.

3.25 The long run YED of 1.85, calculated on UK GDP, is the second highest of any of our markets. This is likely due to the fact that this market has seen rapid traffic growth over the period the models were estimated (1984 to 2008), far outstripping GDP growth. There are a number of key LDCs which are driving the results as data is more readily available for them, such as Brazil, South Africa, India and Pakistan. The short run YED is of slight concern, in that it exceeds the long run value, indicating that passengers' initial response overshoots the long run response. We might have expected UK consumer spending to be the key economic variable for this market, given its role in the other UK leisure markets. In practice, UK GDP and consumer spending were very highly correlated over the estimation period and are assumed to be perfectly correlated in forecasting, so this will make no difference to the forecasts.

3.26 The long run PED of 0.85 is very high for a long haul market. However, as for the ULN market, this result may in part be because of high correlation between UK GDP and leisure fares to LDCs during the estimation period, leading to biasing of the coefficients on each variable (i.e. the YED may be biased downwards and the PED may be biased upwards). However, as before, it may also reflect the possibility that those travelling to LDCs on leisure trips are more responsive to fare changes, perhaps because they regard destinations in other regions as close substitutes.

3.27 A negative intercept dummy for 2005 has been added to account for particularly fast growth resulting from liberalisation of the Indian and African markets in that and previous years.

Foreign Business Western Europe (FBW)

Stata outputs

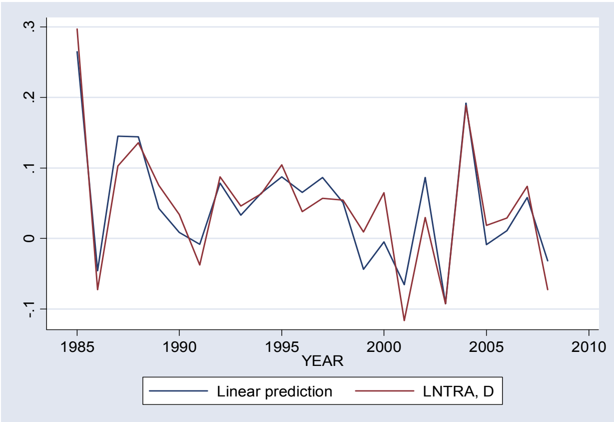
```
regress d.lntra d.lnexp d.lncon l.lntra l.lncon l.lnpfr l.lnexp d03

    Source |       SS       df       MS              Number of obs =      24
-------------+------------------------------           F(  7,    16) =   14.85
     Model |  .161126644     7  .023018092           Prob > F      =  0.0000
  Residual |  .024799335    16  .001549958           R-squared     =  0.8666
-------------+------------------------------           Adj R-squared =  0.8083
     Total |  .185925978    23  .008083738           Root MSE      =  .03937

------------------------------------------------------------------------------
D.lntra      |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
lnexp        |
         D1 |   .5191115   .1388418     3.74   0.002     .2247799     .813443
lncon        |
```

D1	1.873869	.5014314	3.74	0.002	.8108817	2.936856
lntra						
L1	-1.208862	.139183	-8.69	0.000	-1.503917	-.9138073
lncon						
L1	.7515206	.1486083	5.06	0.000	.4364851	1.066556
lnpfr						
L1	-.2965149	.0837844	-3.54	0.003	-.47413	-.1188999
lnexp						
L1	.595515	.0862744	6.90	0.000	.4126215	.7784085
d03	-.1477594	.0440557	-3.35	0.004	-.2411533	-.0543655
_cons	.786328	.7052318	1.11	0.281	-.7086965	2.281353

Fitted vs Actual



Interpretation of model

3.28 The model fits very well and passes all diagnostic tests. A negative intercept dummy is included for 2003 which could be accounting for the effects of the Iraq War or the SARS outbreak on air travel demand. However, if this were the case we would also expect to require a dummy in other markets. The FBW market contains two income variables (consumption and exports) reflecting the role of economic activity in the UK and in European markets in driving traffic. In particular, it is likely that the UK exports to Western Europe variable is highly correlated with consumer spending in Western Europe. The long run YED on the two income variables is 1.1, the highest of the foreign business markets. The long run PED is -0.25, similar to that for UBW, and suggesting demand is price inelastic, as we would expect in a business market.

Foreign Business OECD (FBO)

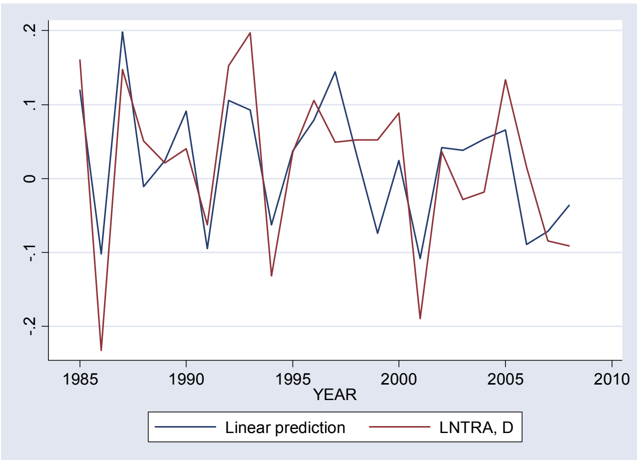
Stata Output

regress d.lntra d.lnexp d.lnpfr l.lntra l.lnexp l.lnpfr

```
      Source |       SS       df       MS              Number of obs =      24
-------------+------------------------------           F(  5,    18) =    5.40
       Model |  .167357607     5  .033471521           Prob > F      =  0.0033
    Residual |  .111520272    18  .006195571           R-squared     =  0.6001
-------------+------------------------------           Adj R-squared =  0.4890
       Total |  .278877879    23  .012125125           Root MSE      =  .07871

------------------------------------------------------------------------------
D.lntra      |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
lnexp        |
          D1 |   .6742651   .1861917     3.62   0.002     .2830908    1.065439
lnpfr        |
          D1 |  -.4535616   .3027785    -1.50   0.151    -1.089676    .1825523
lntra        |
          L1 |  -1.022461   .2467695    -4.14   0.001    -1.540905   -.5040178
lnexp        |
          L1 |    .567222   .1553421     3.65   0.002     .2408604    .8935837
lnpfr        |
          L1 |  -.1686098   .1820763    -0.93   0.367    -.5511379    .2139183
_cons        |   2.947437   1.232916     2.39   0.028      .357177    5.537696
```

Fitted vs Actual



Interpretation of model

3.29 The model fits reasonably well and passes all diagnostic tests. Although it is a foreign market the only significant income variable is UK exports. UK exports to OECD countries were highly correlated with UK imports over the estimation period and the analysis indicates that the UK exports term is proxying for overall trade between the UK and OECD countries. Taking the elasticity on the exports variable gives a value of 0.6, which is fairly low but not entirely surprising for a mature market such as this. The

PED of -0.2 indicates demand is inelastic, which is expected in a long haul business market.

Foreign Business NICs (FBN)

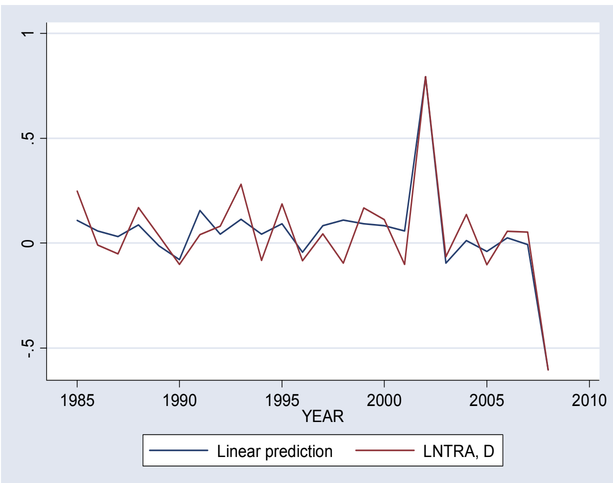
Stata Output

```
regress d.lntra d.lnfgp l.lntra l.lnfgp d02 d08

      Source |       SS       df       MS              Number of obs =      24
-------------+------------------------------           F(  5,    18) =   18.44
       Model |  1.07436787     5  .214873574           Prob > F      =  0.0000
    Residual |  .209702103    18  .011650117           R-squared     =  0.8367
-------------+------------------------------           Adj R-squared =  0.7913
       Total |  1.28406998    23  .055829129           Root MSE      =  .10794

------------------------------------------------------------------------------
 D.lntra     |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
lnfgp        |
          D1 |   .5322897   .2404845     2.21   0.040     .0270505    1.037529
lntra        |
          L1 |  -.3025074   .1523214    -1.99   0.062    -.6225228     .017508
lnfgp        |
          L1 |   .2293246   .1372701     1.67   0.112    -.0590692    .5177183
d02          |   .6440657   .1235738     5.21   0.000     .3844467    .9036847
d08          |  -.5926217   .1189742    -4.98   0.000    -.8425773   -.3426661
_cons        |    .494895   .2372236     2.09   0.051    -.0034933    .9932833
```

Fitted vs Actual



Interpretation of model

3.30 The model fits very well and passes all diagnostic tests. A positive dummy was included for 2002 to reflect the recovery in demand after 9/11. A negative dummy is included for 2008, perhaps to reflect the early effects of the financial crisis on businesses. No PED was found and the only income variable is foreign GDP. It might be expected that a variable reflecting economic activity in the UK would also be a significant driver of business travel from NICs. Inspection of the data reveals that the foreign GDP series for this market is highly correlated with the UK income terms, so it is likely that the FGP elasticity also reflects the role of UK income growth. The long run YED implied by the model is 0.8, similar to the YED in APDCF 09.

Foreign Business LDCs (FBL)

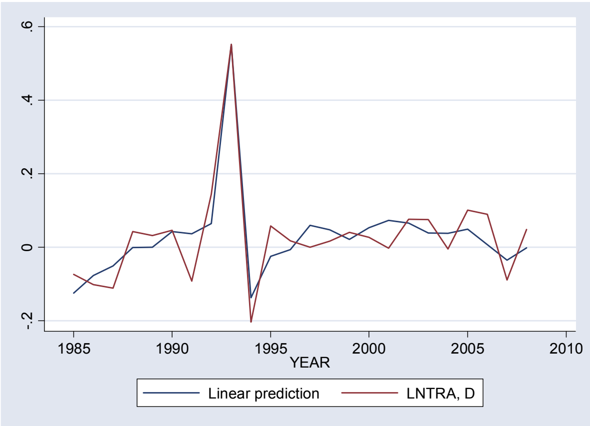
Stata Output

```
regress d.lntra d.lnimp l.lntra l.lnimp d93

      Source |       SS       df       MS              Number of obs =      24
-------------+------------------------------           F(  4,    19) =   23.10
       Model |  .361454178     4  .090363545           Prob > F      =  0.0000
    Residual |  .07433916    19  .003912587            R-squared     =  0.8294
-------------+------------------------------           Adj R-squared =  0.7935
       Total |  .435793339    23  .018947536           Root MSE      =  .06255

------------------------------------------------------------------------------
D.lntra      |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
lnimp        |
          D1 |   .1795923   .1110364     1.62   0.122    -.0528096    .4119942
lntra        |
          L1 |  -.3912117   .1018892    -3.84   0.001    -.6044682   -.1779551
lnimp        |
          L1 |   .2686161   .0613954     4.38   0.000      .140114    .3971182
d93          |   .5152102   .0668542     7.71   0.000     .3752829    .6551376
_cons        |   .5440505   .2198829     2.47   0.023     .0838303    1.004271
```

Fitted vs Actual



Interpretation of model

3.31 This model fits very well and passes all diagnostic tests. A positive intercept dummy has been included for 1993 to reflect the strong growth in this market following the Gulf War. No PED was found, possibly due to poor fare data in LDCs, though traffic in a long haul business market would not be expected to be very price sensitive anyway.

3.32 The only income variable is a UK imports term, which reflects the relative importance of the UK market in driving traffic in this market relative to foreign markets. The long run YED of 0.7 is similar to that estimated for the FBN market, but is significantly lower than the YED used in APDCF09 (1.4, though based on foreign GDP and UK Imports).

Foreign Leisure Western Europe (FLW)

Stata Output

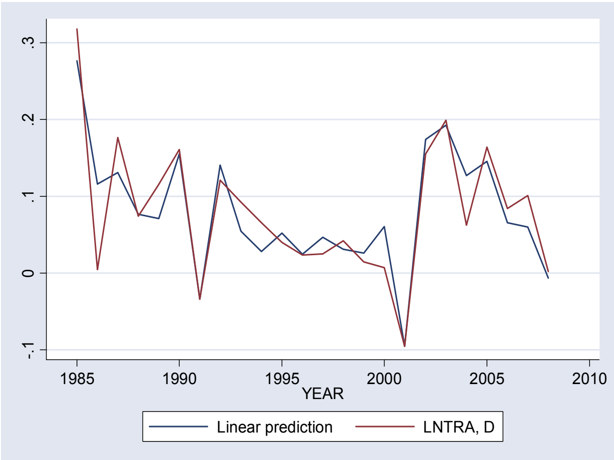
```
regress d.lntra d.lnpfr l.lntra l.lncon l.lnpfr d01 d91

     Source |       SS       df       MS              Number of obs =      24
-------------+------------------------------           F(  6,     17) =   12.84
       Model |  .145696295     6  .024282716           Prob > F      =  0.0000
    Residual |  .032158837    17  .001891696           R-squared     =  0.8192
-------------+------------------------------           Adj R-squared =  0.7554
       Total |  .177855133    23  .007732832           Root MSE      =  .04349

------------------------------------------------------------------------------
D.lntra      |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
lnpfr        |
          D1 |  -.6676445   .1799073    -3.71   0.002    -1.047216   -.2880734
lntra        |
          L1 |  -.3619449   .0657906    -5.50   0.000    -.5007509   -.2231388
lncon        |
```

L1	.4366079	.158965	2.75	0.014	.101221	.7719948
lnpfr						
L1	-.2746815	.0956513	-2.87	0.011	-.4764882	-.0728748
d01	-.2089532	.0469048	-4.45	0.000	-.3079135	-.1099928
d91	-.0754285	.0467434	-1.61	0.125	-.1740485	.0231916
_cons	.9354573	.8505774	1.10	0.287	-.8591042	2.730019

Fitted vs Actual



Interpretation of model

3.33 This is the second largest market, with 10% of modelled traffic in 2008. The model fits very well and passes all diagnostic tests. Dummies have been included for 1991 and 2001 to reflect the impact of the gulf war and 9/11 respectively on worldwide demand for aviation. The PED of -0.76 is one of the highest, and similar to ULW, as expected. Like ULW this is a relatively price elastic market because of the availability of close substitutes in short haul travel and the elastic nature of leisure travel compared to business. The only income variable is UK consumer spending, which is quite surprising for a foreign leisure market. However, we think this is acting as a proxy for consumer spending in Western Europe, which is likely to be highly correlated with UK consumer spending. As might be expected the long run YED of 1.2 is very similar to that estimated for ULW. As previously mentioned, there is a chance that the YED has been biased upwards due to the impact of deregulation of air markets in Europe over the estimation period.

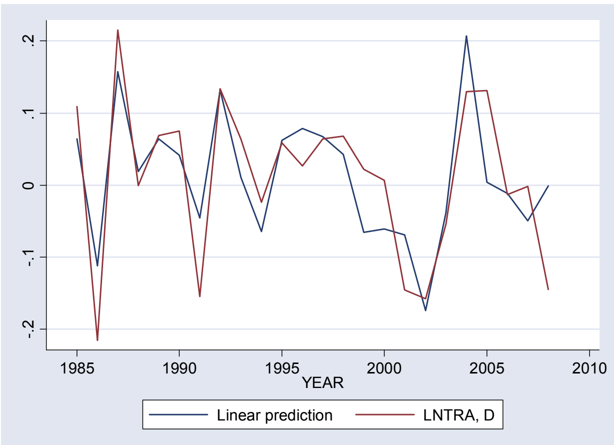
Foreign Leisure OECD (FLO)

Stata Output

```
regress d.lntra d.lnexr d.lnfgp l.lntra l.lnfgp l.lnexr d0203
      Source |       SS       df       MS              Number of obs =      24
-------------+------------------------------           F(  6,    17) =    4.91
       Model |  .174761459     6  .02912691            Prob > F      =  0.0044
```

```
   Residual |  .100921217    17  .005936542          R-squared     =  0.6339
-------------+------------------------------          Adj R-squared =  0.5047
      Total |  .275682675    23  .011986203          Root MSE      =  .07705
------------------------------------------------------------------------------
D.lntra      |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
lnexr        |
         D1  |  -.1965016   .6908481    -0.28   0.780    -1.654064     1.26106
lnfgp        |
         D1  |   .9363921    .389011     2.41   0.028     .1156507    1.757133
lntra        |
         L1  |  -.7500755   .1697916    -4.42   0.000    -1.108304   -.3918465
lnfgp        |
         L1  |   .4110086   .1622347     2.53   0.021     .0687233     .753294
lnexr        |
         L1  |  -1.580155   .6235959    -2.53   0.021    -2.895827   -.2644825
d0203        |  -.1964886   .0650071    -3.02   0.008    -.3336416   -.0593355
_cons        |   8.900231   3.118474     2.85   0.011     2.320827    15.47964
```

Fitted vs Actual



Interpretation of model

3.34 The model fits reasonably well and passes all diagnostic tests. An intercept dummy taking the value 1 in 2002 and 2003 is included to reflect the impact of 9/11 and the Iraq war and SARS on the worldwide demand for aviation. The only income variable is foreign GDP. This yields a YED of 0.55, one of the lowest of all markets. This might suggest that this relatively mature long haul leisure market has experienced its rapid growth phase due to rapidly rising incomes and deregulation.

3.35 We were unable to estimate a PED for this model. However, based on our expectation that the PED for this market should be of the same order of magnitude as that for ULO (because traveller incomes are broadly similar, there are no realistic alternative travel modes, and if anything foreign residents from the FLO have more alternative travel destinations than ULO), for forecasting purposes we have decided to impose the PED estimated for the ULO market (-0.33).

Foreign Leisure NICs (FLN)

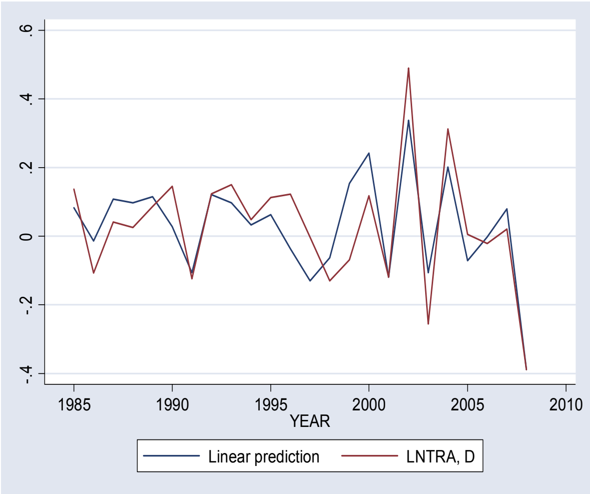
Stata Output

```
regress d.lntra d.lnfgp d.lnpfr l.lntra l.lnfgp l.lnpfr d01 d08

    Source |       SS       df       MS              Number of obs =      24
-------------+------------------------------           F(  7,    16) =    5.28
     Model |  .507792164     7  .072541738           Prob > F      =  0.0028
  Residual |  .219701695    16  .013731356           R-squared     =  0.6980
-------------+------------------------------           Adj R-squared =  0.5659
     Total |  .727493859    23  .031630168           Root MSE      =  .11718

------------------------------------------------------------------------------
D.lntra      |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
lnfgp        |
          D1 |   .1988643   .3683492     0.54   0.597    -.5820011    .9797297
lnpfr        |
          D1 |  -.1830743   .3725302    -0.49   0.630     -.972803    .6066545
lntra        |
          L1 |  -1.023922   .2266766    -4.52   0.000    -1.504455   -.5433892
lnfgp        |
          L1 |   .5251871   .1424839     3.69   0.002     .2231347    .8272395
lnpfr        |
          L1 |  -.2217348   .1956492    -1.13   0.274    -.6364926    .1930231
d01          |  -.2809591   .1285934    -2.18   0.044     -.553565   -.0083533
d08          |  -.4511605    .147058    -3.07   0.007    -.7629096   -.1394115
_cons        |   3.743524    1.38524     2.70   0.016     .8069463    6.680102
```

Fitted vs Actual



Interpretation of model

3.36 The model fits well and passes all diagnostic tests. An intercept dummy was included for 2001 to reflect the impact of 9/11 on worldwide demand for aviation. A further intercept dummy was also included for 2008 to improve the fit of the model though it has proved difficult to identify the real world driver. The only income variable found to be significant was foreign GDP. The implied long run YED of 0.5 is relatively low. We suspect that the the low elasticities in both the NICs and LDCs market, which are not expected to be showing signs of maturity, actually indicate these markets are very immature and are yet to reach the 'growth' stage in their product life cycle. The long run PED of -0.2 indicates highly inelastic demand, which is not surprising in a long haul market, though is a lot lower than that estimated for the ULN market, which is surprising. One possible explanation is that foreign residents travelling to the UK face significantly higher overall holiday costs than UK residents travelling to NICs and so any change in fares will represent a smaller change in their total trip costs.

Foreign Leisure LDCs (FLL)

Stata Output

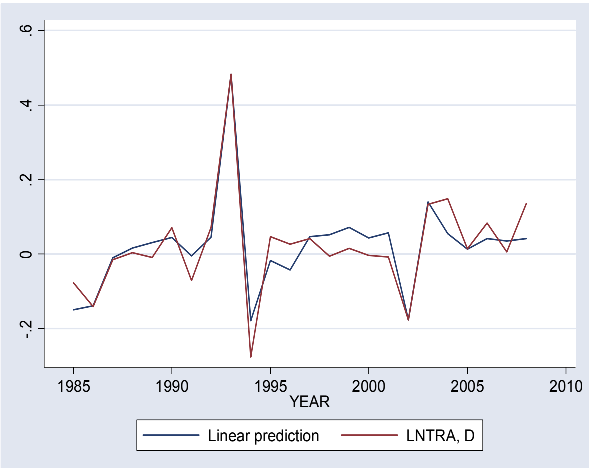
```
regress d.lntra d.lnpfr d.lnfgp l.lntra l.lnpfr l.lnfgp d93 d02

      Source |       SS       df       MS              Number of obs =      24
-------------+------------------------------           F(  7,    16) =   13.44
       Model |  .377775684     7  .053967955           Prob > F      =  0.0000
    Residual |  .064256084    16  .004016005           R-squared     =  0.8546
-------------+------------------------------           Adj R-squared =  0.7910
       Total |  .442031768    23  .019218773           Root MSE      =  .06337

------------------------------------------------------------------------------
```

D.lntra		Coef.	Std. Err.	t	P>|t|	[95% Conf. Interval]	
lnpfr							
	D1	.003332	.1194797	0.03	0.978	-.2499538	.2566177
lnfgp							
	D1	.0797175	.0945805	0.84	0.412	-.1207843	.2802192
lntra							
	L1	-.5297774	.1217053	-4.35	0.000	-.7877811	-.2717737
lnpfr							
	L1	-.1809865	.0813945	-2.22	0.041	-.3535351	-.008438
lnfgp							
	L1	.2460304	.0749638	3.28	0.005	.0871142	.4049466
d93		.4351798	.0725235	6.00	0.000	.2814367	.5889229
d02		-.2419264	.0685187	-3.53	0.003	-.3871796	-.0966732
_cons		2.100695	.8867785	2.37	0.031	.2208083	3.980581

Fitted vs Actual



Interpretation of model

3.37 The model fits very well and passes all diagnostic tests. Intercept dummies are included for 1993 to reflect the recovery from the Gulf War and 2002 to reflect the long term downward impact of 9/11 on demand for aviation in this market. The long run YED of 0.5 (calculated using the only income variable – foreign GDP) would normally indicate a mature market but as mentioned above is likely to be in this case an indication of a very immature market, yet to reach a rapid growth phase. The PED of -0.3, is similar in magnitude to that for FLN, indicating that demand is relatively price inelastic. Why this is so much lower than the PED estimated for the ULL market is not entirely clear. However the explanation offered above for the difference between the PED estimated for the FLN and ULN markets is also applicable here.

Domestic Business (DMB)

Stata Output

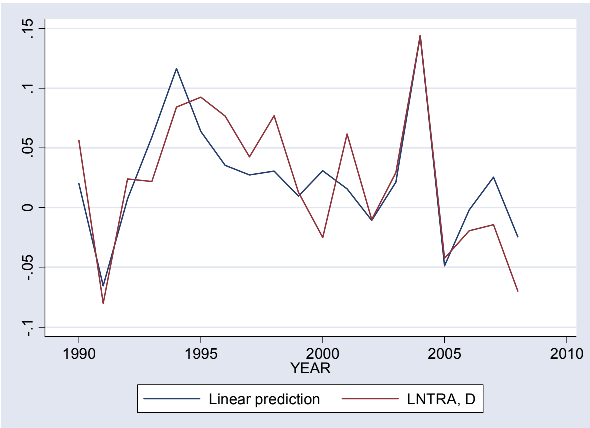
regress d.lntra d.lngdp l.lntra l.lngdp d04, noconstant

Source	SS	df	MS
Model	.055176361	4	.01379409
Residual	.018497537	15	.001233169
Total	.073673897	19	.003877574

Number of obs	=	19
F(4, 15)	=	11.19
Prob > F	=	0.0002
R-squared	=	0.7489
Adj R-squared	=	0.6820
Root MSE	=	.03512

D.lntra	Coef.	Std. Err.	t	P>|t|	[95% Conf. Interval]	
lngdp D1	2.960709	.6578797	4.50	0.000	1.558472	4.362947
lntra L1	-.411132	.1180907	-3.48	0.003	-.6628363	-.1594277
lngdp L1	.408132	.1193344	3.42	0.004	.1537768	.6624873
d04	.1229065	.036226	3.39	0.004	.0456927	.2001203

Fitted vs Actual



Interpretation of model

3.38 The domestic business model fits fairly well and passes all diagnostic tests. A positive intercept dummy was included for 2004 to improve the model's fit. This could be attributed to a recovery in confidence after the SARS outbreak. The long run YED, calculated on UK GDP, of 1.0 is much lower than in APDCF 09 (2) but probably better reflects the maturity of this market. However the short run YED of 2.96 is very high and significantly greater than the long run elasticity, which is difficult to explain.

3.39 Surprisingly, given the availability of alternative modes, we have been unable to estimate any fare elasticity for this market. For forecasting purposes we intend to impose a long run price elasticity of demand equal to that estimated for the UBW market (-0.3) on the basis that we would expect the PED in this market to be broadly similar, if not higher. There are various factors that might influence the relative size of the PED in these two markets. The income levels of business passengers travelling to Europe and domestically are broadly similar. However the range of alternatives open to people travelling domestically should if anything be greater than those travelling to and from Europe (they should certainly have a greater range of viable transport modes to choose from) suggesting an even higher level of PED than for UBW. Given that the value of -0.3 is consistent with the literature on price elasticities we have reviewed, we think imposing the PED estimated for the UBW market is justified.

Domestic Leisure (DML)

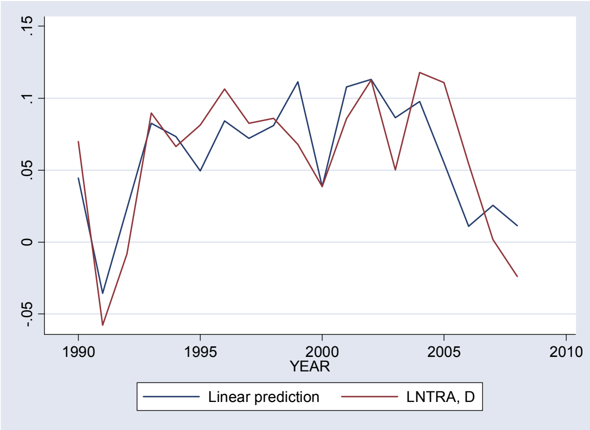
Stata Output

```
regress d.lntra d.lncon l.lntra l.lncon d00

    Source |       SS       df       MS              Number of obs =      19
-------------+------------------------------           F(  4,    14)  =    6.88
     Model |  .028981642     4  .00724541            Prob > F      =  0.0028
  Residual |  .014742941    14  .001053067           R-squared     =  0.6628
-------------+------------------------------           Adj R-squared =  0.5665
     Total |  .043724583    18  .002429143           Root MSE      =  .03245

------------------------------------------------------------------------------
D.lntra      |      Coef.     Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
lncon     D1 |    2.41427    .4963358    4.86   0.000     1.349736    3.478804
lntra     L1 |  -.4191478    .1787454   -2.34   0.034    -.8025185   -.0357771
lncon     L1 |   .9463332    .4170656    2.27   0.040     .0518164     1.84085
d00          |  -.0747107    .0348844   -2.14   0.050    -.1495303    .0001089
cons         |  -2.419941    1.098814   -2.20   0.045    -4.776662   -.0632195
------------------------------------------------------------------------------
```

Fitted vs Actual



Interpretation of model

3.40 The model for the domestic leisure market fits fairly well and passes all diagnostic tests. An intercept dummy is included in 2000, in part reflecting a decline in demand after the plane crash at Stansted in December 1999.

3.41 Surprisingly, as for the domestic business market and given the availability of alternative modes, we have been unable to estimate any fare elasticity for this market. For forecasting purposes we intend to impose a long run price elasticity of demand equal to that estimated for the ULW market (-0.7) on the basis that we would expect the PED in this market to be broadly similar. There are various factors that might influence the relative size of the PED in these two markets. The income levels of leisure passengers travelling to Europe and domestically are broadly similar. However the range of alternatives open to people travelling domestically should, if anything, be greater than those travelling to and from Europe (they should certainty have a great range of transport modes to choose from) suggesting an even higher level of PED than for ULW. On the other hand CAA statistics suggest that a higher proportion of UK residents travelling domestically for leisure are going to visit friends and relatives, whilst a higher proportion of passengers to Europe are going on holiday. If holidays are perceived to be more of a luxury than visiting friends and family, this might suggest a lower PED is warranted for the DML market. On balance, and given that the value of -0.7 is consistent with the literature on price elasticities we have reviewed, we think imposing a PED equal to that in the ULW market is justified.

3.42 The YED of 2.3, calculated on UK consumer spending is one of the highest, in line with the value found in APDCF 09 of 2.5. However, following discussion with independent experts, we believe the estimated YED is biased upwards as a result of the omission of a fares variable. Therefore, a YED of 1.5 in 2010 has been imposed in this market, in forecasting.

International to International Interliners (I-I)

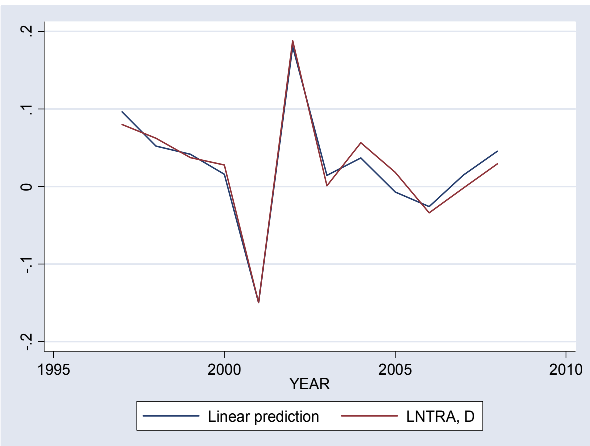
Stata Output

```
regress d.lntra d.lnpfr d.lnfgp l.lntra l.lnpfr l.lnfgp d01

     Source |       SS       df       MS              Number of obs =      12
-------------+------------------------------           F(  6,      5) =   22.80
       Model |  .065297811     6  .010882968           Prob > F      =  0.0017
    Residual |  .002386132     5  .000477226           R-squared     =  0.9647
-------------+------------------------------           Adj R-squared =  0.9224
       Total |  .067683943    11  .006153086           Root MSE      =  .02185

------------------------------------------------------------------------------
D.lntra      |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
lnpfr        |
          D1 |  -.2426329   .2246329    -1.08   0.329    -.8200701    .3348043
lnfgp        |
          D1 |   .0606082   .3950295     0.15   0.884    -.9548476    1.076064
lntra        |
          L1 |  -1.063258   .1830757    -5.81   0.002     -1.53387   -.5926474
lnpfr        |
          L1 |  -.6975238   .2052302    -3.40   0.019    -1.225085   -.1699628
lnfgp        |
          L1 |   .4981752   .2484371     2.01   0.101    -.1404527    1.136803
d01          |  -.1480762   .0313078    -4.73   0.005    -.2285554   -.0675971
_cons        |   5.822439   1.676128     3.47   0.018     1.513816    10.13106
```

Fitted vs Actual



Interpretation of model

3.43 The I-I model passes all diagnostic tests and has the highest explanatory power of all the econometric models. A negative intercept dummy was included for 2001 to reflect the impact of 9/11 on worldwide demand for aviation. The YED of 0.5, calculated on foreign GDP, seems quite low and may reflect the rising prominence of alternative hub airports in Europe and elsewhere over the forecasting period. The PED of -0.7 describes the responsiveness of UK I-I passengers to changes in fares that are generally not UK specific (e.g. to changes in oil prices that also affect the fares faced by passengers for using alternative hub airports). If fares via UK and foreign hubs have been moving together the model is not capturing the impacts of changes in the relative prices of travelling via the UK or foreign hubs. If the fares faced by passengers to interline via the UK were to increase by 1% in the absence of increases to fares to alternative hubs, the impact on interlining traffic to the UK could be expected to be significantly greater than implied by the PED of -0.7, as passengers switch to alternative interlining routes avoiding the UK.

3.44 To reflect the issues mentioned above we intend to impose a higher PED on this market when we are looking at UK specific changes in fares. Unfortunately evidence on an appropriate value is limited. A PED of -2.0, for Schipol airport in the Netherlands has been suggested in a recent paper produced for the Dutch Ministry of Transport, Public Works and Water Management. The value of -0.7 will continue to be used in standard model runs where the major driver of fare changes tends to be changes in oil prices and carbon allowance prices that will affect all EU interlining routes equally. The change in the I-I PED in the updated model has been relatively large, moving from -0.3 in APDCF 09 to -0.7.

4. Annex A University of Westminster Econometric Study

Introduction

A.1 The objective of this commission was for the Department for Transport (DfT) to obtain econometrics advice during the process of updating the econometrics equations of its suite of forecasting models. In addition, an expert was required to provide a review of the Department's work, to ensure the methodology employed was 'fit for purpose'.

A.2 A number of issues require consideration when modelling time-series data including tests for stationarity, whether some relationships are spurious or co-integrated, model specification including possible omission of significant variables, heteroscedasticity and autocorrelation, in addition to establishing an appropriate shape to the functions selected.

A.3 The key deliverable required was a short note describing the approach the Department had taken and any limitations identified. This note summarises the observations made and advice offered by the Department of Transport Studies, the University of Westminster (UoW) to the Department for Transport (DfT) in relation to the issues of concern raised by DfT. These observations and advice encompass:

- Observations on the Engle-Granger procedures and the Johansen Method
- Selection of Lags and Dickey-Fuller test (DF)
- Error correction models
- Omission of variables
- Other possible tests
- Areas of Concern including:
- Data issues
- The sufficiency of descriptive variables
- The implications of modelling travel segments separately or in aggregate

- Critical Values

Econometric Methods and Associated Tests: UoW's Observations

A.4 Given various constraints under which the Department is advancing this work University of Westminster (UoW) would endorse the comprehensive procedure that DfT have adopted to estimate the parameters for the demand forecasting model, such as:

- Checking all variables are stationary in the same order;
- Regressing to obtain residuals;
- Testing to see if residuals are stationary, therefore indicating co-integration and obtaining long-run elasticities if the time series is in log form;
- Using an Error Correction Model (ECM) to obtain short-run elasticities when using differenced time series.

Observations on the Engle-Granger procedures and the Johansen Method

A.5 The Department employs the Engle-Granger methodology for co-integrated variables as its method for estimating long run elasticities. This test is acknowledged to have its limitations and concerns were raised on the appropriateness of the technique given a number of limitations in its application. These concerns include the implied distribution properties of the parameters of the lag polynomials, the efficiency of the parameter estimations in co-integrating relationships and the implications .of that for the estimated elasticities.

A.6 The Johansen method was initially identified as an alternative preferred approach assuming the data set was suitable for its use. However, due to limitations of the package STATA that the Department currently employs and the size of the dataset currently available this method could not be implemented. To counter the above issues UoW recommended that the Johansen technique should be applied. In addition it identifies if there is more than one co-integrating relationship. The drawback is that it does not indicate the direction of causation.

Selection of Lags and Dickey-Fuller test (DF)

A.7 The Department has applied a range of standard techniques to address the issue of lags and stationarity. These include graphical plots, correlograms and the Augmented Dickey-Fuller test to test for normality and to determine stationarity. Overall, the Dickey-Fuller test is being used correctly. Although within STATA the DF is currently being run, with a check for time trend, therefore checking for both unit roots and time trend, this adds unnecessary complication to the analysis. To simplify the methodology and check for 'pure' unit root DF should be tested without the time trend option. Including a trend and a constant in the auxiliary regression of the ADF test accounts for non-stationary arising from both time trends and a unit root.

Error correction models

A.8 The application of the Engle-Granger identifies whether two variables are cointegrated thereby establishing long-run dynamics of the relationship. In log form it the model yields long-run elasticities for the variables. Having established that the residuals are stationary application of the Error Correction Model gives short-run elasticities. The ECM with all the differenced variables included and residual for 't-1' is the correct model to obtain elasticities. Independent advice suggests that the remaining outputs (that were given directly after the EG ECM) are not necessary given that the Department had already identified the optimum combination of variables in the tests already performed. It also appears that the number of variables incorporated in the outputs could be increased. When developing a model it is always better to include all relevant explanatory variables.

Omission of variables

A.9 To address the whether or not relevant variables have been omitted the Department applied the RESET test. It is emphasised that although the tests (RESET) indicate that the model is correct with regard to the variables used this does not mean that this it cannot be improved upon by inclusion of other variables, This requires further consideration of the range of potentially significant level of service variables, demographic and lifestyle features, economic factors, as well as geo political considerations and supply side trends and innovations. Having reviewed the potential role of such factors the next stage is to identify the availability and review the quality of data to represent trends in such features.

Other possible tests

A.10 The Department has applied a wide range of tests to establish the appropriateness and robustness of the data, parameters estimated and model specification. The Breusch-Godfrey LM test for autocorrelation and Durbin-Watson d-statistic are however unnecessary because the variables are stationary. In general, the RESET test is used to assess if all the variables used in the model are relevant but this should be used jointly with the R2 value. If the null hypothesis of RESET is accepted then tests for heteroscedasticity and normality become redundant. It is best practise to use RESET as guidance and to test individually for normality, heteroscedasticity, autocorrelation and collinearity.

Other Areas of Concern Raised by the Department and UoW's Responses

Data

A.11 With regard to concerns raised by the Department on the outputs of the techniques applied UoW suggested that these could be mainly be due to the limited number of observations in the data set, which had an approximate range of between 20 and 25 observations. Some of the techniques used are sensitive to sample size or are only suitable for large sample sizes, i.e. ADF appropriate for large samples sizes

A.12 Therefore, UoW recommends that DfT, where possible, obtain a larger data set on a smaller selection of variable and rerun the tests. Do the same procedure on the original observations of these variables and do a comparison of the results. This will indicate whether the problem lies with sample sizes. Overall it is recommended that variables that can be disaggregated to quarterly time periods should be exploited to their maximum potential. This would also facilitate application of alternative potentially more powerful statistical tests, such as the Johansen ML test which will give better elasticities for the variables themselves (cointegration), and arguably yield more robust findings.

Sufficient descriptive variables

A.13 It is felt that for the expected future use of the forecasting model there should be more explanatory variables, e.g. the extent of and fares offered by competitor carriers, population ratio (size of population in relation to the size of the region or catchment area).

Modelling travel segments separately or in aggregate

A.14 Decisions to model travel segments separately or in aggregate should generally be determined by evidence concerning variations in the behaviour of individual market and/or the extent to which data available to measure the variables chosen are 'market specific'. The 21 markets can be assessed in two ways, firstly, individually as the Department have done and secondly, combining the 21 markets. The advantage of combining all 21 markets is the inclusion of all variables that impact the movement of those markets. However, it may be appropriate to undertake more disaggregated analysis of more limited sets of variables where these are available at a more disaggregated level (temporal basis) and/or where they are considered relevant to selected market segments.

Critical Values

A.15 The Engle-Granger test is highly dependent on the critical values that are used to assess the model; therefore it is necessary to ensure that the correct values have been used. It has been recommended that the MacKinnon 2010 critical values be used.