

Ryanair's impact on airline market share from the London area airports: a time series analysis¹.

D.E.Pitfield
Transport Studies Group
Department of Civil and Building Engineering
Loughborough University
Loughborough
Leicestershire LE11 3TU
UK
E-mail: D.E.Pitfield@lboro.ac.uk

Ryanair tends to operate to destinations from its UK bases that are not the main airports in the country being served and in this it differs from many other European low cost carriers. For example, it flies from London Stansted (STN) to Venice Treviso (TSF), whereas the competition flies from other London area airports to Venice Marco Polo (VCE). Although direct competition is not provided in the way that rival services operate between identical pairs of airports, indirect competition is provided. This raises the question, when Ryanair commence services, what is the impact on the market share of the incumbent airlines at these other airports?

This can be established by examining UK Civil Aviation Authority (CAA) data on scheduled passengers carried, along with OAG data on flight frequency, airline and aircraft type on a number of selected routes. The impact on market share can be shown and the conclusion drawn that total traffic is stimulated on these sectors so that incumbent's traffic might fall, be constant or even increase, whilst their share, and probably their yield, falls, as Ryanair exploits latent demand. These findings echo previous work, for example, Barrett (2000).

These conclusions can be further supported by a time series analysis on monthly passenger data from 1991- 2003.

Keywords: Airline Competition, Market Share, Time Series Analysis

¹ I am grateful to my former colleague Ian Humphreys and to a recent graduate, Phillip Brown, for the inspiration to undertake this research. Howard Grubb of the University of Reading provided some technical advice.

1.0 Introduction

Low cost airlines in Europe have been particularly successful, experiencing a buoyant market with considerable growth in their traffic. One of the most successful is Ryanair, based in Dublin, Ireland, but operating from a variety of UK airports, especially London Stansted (STN).

In some instances, Ryanair operates to the same continental airport destination as other airlines offering competing service from other London area airports, in particular, London Heathrow (LHR) and London Gatwick (LGW), but mostly it operates to alternative airports in the destination country. For example, if British Airways from LHR serves Stockholm Arlanda (ARN), then Ryanair serves Stockholm Skavsta (NYO) and Vasteras (VST), airports that are some distance away from Stockholm city business district. Ryanair adopts this strategy, because apart from offering a low frills service at a low price, it often has achieved agreements with local airports, sometimes to the annoyance of domestic flag carriers, that are to its advantage, as well as, arguably, to the local region. There are a variety of cases in which Ryanair has inaugurated competitive services from STN and it is the objective of this paper to estimate the importance of and impact of this competition. This can be done in the first instance by examining the growth of traffic and market shares by route, an approach examined by CAA (1998) and Barrett (2000). However, this process can generate hypotheses rather than conclusive answers and so, in the main body of the paper, Autoregressive Integrated Moving Average (ARIMA) modelling with intervention analysis is used to identify the impact of Ryanair's presence on the combined market between the selected origins and destinations.

The next section briefly outlines the history, geography and economics of low cost airlines. Section 3 performs the analysis of market growth and market share and section 4 both outlines the time series methodology of intervention analysis and implements it by route. Conclusions are given in section 5.

2.0 Low Cost Airlines

South West was the first airline to operate a low cost model, starting in Texas in 1971 (Calder, 2002). After deregulation it has expanded and now stands sixth in the USA in terms of passenger-kms. A variety of other carriers have adopted this way of operating, including Jetblue, Airtran and Spirit (see Doganis, 2001). In Europe, after the liberalisation of air transport from 1993, Ryanair, easyJet and Virgin Express pioneered the South West approach in a European context. In 1998, British Airways set up a subsidiary, GO, to operate in this fashion as it was clearly convinced that this represented an opportunity and was a way of responding to a competitive threat. However, this airline was sold to easyJet in 2002.

In 2002, an established scheduled airline, BMI British Midland announced it was setting up bmibaby, initially at East Midlands airport, in competition with GO. This airport now has services from Ryanair, easyJet as well as bmibaby.

Recently, it has become apparent that carriers of this nature have been set up both in Europe and the rest of the world, for example, German Wings, Iceland Express, Virgin Blue, Freedom Air, Gol and Kulula.

Although the way these airlines operate is not absolutely identical (Williams, 2001), they do focus on cost reductions. As there are some elements of airline economics that they have little influence on, for example, fuel price, fuel burn and en-route navigation charges, there are others that will influence the costs per seat-km flown that they can influence. These include aircraft utilisation, aircraft turnaround times, seat pitch, the use of fewer crew and cheaper secondary airports along with direct selling and paperless ticketing. Yield management is also much simpler for these airlines as although the ticket price might vary by the hour as the departure date and time of departure are approached, these prices are for everywhere in the cabin. The other crucial characteristic of these carriers is how prices rise as the departure date approaches, representing a different approach to yield management than the traditional carriers. Some recent work has examined this aspect of their activity (Pitfield 2004) and compared this to the network carriers (Tretheway, 2004).

3.0 Market Share and Growth

This section examines the growth of the market for selected airports and the market shares achieved. This is compared to the frequency of service offered by the airlines participating on the route. The data on passengers carried is available from the UK CAA and the more recent information is accessible from the web (see CAA website). From this, monthly totals of scheduled passengers between the UK and countries worldwide can be obtained by cities and by airports. The OAG guide (2003) gives corresponding information for the scheduled airlines operating the route, the frequency of service offered and the aircraft type. The information for February 2003, for example, is given in OAG (2003) whereas earlier guides give information for earlier months and years. As airlines tend to operate summer and winter schedules, for historic data, it is important to have a summer month and a winter month guide for each of the years analysed.

3.1 The Selected Airports

Airports were chosen where Ryanair operated services and where there was a sufficient time history of services on the route before Ryanair began operating, to allow time series to be developed for pre-Ryanair data. That means that Irish routes are not eligible and indeed, some of these were operated by Ryanair before it adopted the South-West model of operation. As a result, the routes to be examined are from London to Genoa, Hamburg, Pisa, Stockholm and Venice. The CAA data allows these totals by airport to be obtained from 1991 -2003 whereas the OAG source indicates the airline operating the route, the frequency and the aircraft type and its capacity.

3.1.1 Genoa

Genoa (GOA) is served throughout the period by British Airways from LGW and Ryanair commenced operations in May 1999 from STN. Unusually, this is one of the rare cases where Ryanair is serving the same destination airport as the competing airlines.

Analysing the growth of traffic, month by month, for 1991-2003 clearly shows the initial increasing trend in traffic from LGW, then the very rapid growth of Ryanair after its introduction of service to be the largest carrier to GOA. Scheduled traffic grew from an annual total of 41,379 in 1991 to 211,879 in 2003, an increase of 412.0 percent. On average, per annum, this is a growth of 15.8 percent. In the first full year of operation, Ryanair became the biggest carrier on the route and then modestly grew at 4.1 percent per annum.

The frequency of service data shows that by the end of the period the frequencies per week on offer from LGW had been halved and the equivalent of the service offerings at LGW in 1991, were, by the early 2000's being offered by Ryanair at STN instead.

Examining market shares by year shows that up to 1998, LGW provided most of the market capacity². However, by 1999 with operations from STN starting in May, this share fell to 57.2 percent. Since then the STN share has been dominant being just under 70 percent in 2003 which more than reflects adequately its share of frequency.

If a time series plot of the monthly data is examined it seems to portray a relatively simple case, that is, that around a rising trend in the overall market, that Ryanair became the dominant carrier to GOA at the expense of British Airways. However, the only definitive way in which to demonstrate this with rigour is to undertake an intervention analysis and this is done in section 4³.

3.1.2 Hamburg

Hamburg is served by Hamburg Airport (HAM), just north of the city centre and Hamburg Luebeck (LBC) some 40 miles north-east. HAM is served throughout the period from LHR by British Airways and Lufthansa. From the mid-1990's to early 2001 British Airways also offered service from LGW and Hamburg Airlines offered services in 1991 and 1994, carrying very small numbers. Services from STN were first offered in 1995 by AirUK, then by Gill Airways in 1998-9, then by Lufthansa and Buzz and in mid-2001, briefly, by BMI British Midland. At the end of 2002, Air

² In July and September 1994, the CAA data records scheduled passengers to GOA from LHR, however, the OAG records no scheduled carrier. This discrepancy is small and so it was ignored.

Berlin started to offer service. Service was briefly offered by Lufthansa from London City Airport (LCY) in the early 21st century. LBC has been served by Ryanair since June 2000.

Scheduled traffic grew from an annual total of 406,255 in 1991 to 774,586 in 2003, an increase of 90.7 percent. For Ryanair, traffic grew from 12,466 to 238,802 for complete years of operation, an increase of 91.5 percent. Examining the annual absolute and percentage change in traffic shows, on average, that traffic to Hamburg went up 5.8 percent per annum, whilst Ryanair's traffic grew at 39.0 percent per annum from 2001.

The frequencies on the route show the preponderance of offerings from LHR throughout the period and that frequencies from STN replaced LGW in 2001. It is interesting to note that on the cessation of the LCY service, Ryanair increased weekly frequency by one a day to bring the total to nineteen.

If annual market share is examined then it can be seen that LHR's percent share falls below 90 percent for the first time in 1996 and down to below 80 percent for the next three years as market share is taken by primarily LGW. The STN-HAM share increases dramatically in 2000 when Lufthansa and Buzz offer service but when the Ryanair service also starts from STN - LBC, the latter overshadows the others, growing to 30.8 percent in 2003, with LHR still dominant at 59.1 percent.

3.1.3 Pisa

Pisa is, of course, both a destination in its own right on the coast of Tuscany as well as a gateway to that region and Florence. Initially, it was served by British Airways and Alitalia from LHR. In March 1997, Alitalia moved its services to LGW and in April 1997, it was joined again by British Airways who withdrew from LHR. Ryanair commenced service in June 1998 and by the next year were taking nearly 50 percent of the market. They became the biggest carrier in 2000 after Alitalia withdrew from the route.

³ The tables and figures on which these comments are based are available on request from the author. An illustrative set of these tables and figures is shown for the London-Venice route in appendix 1.

Traffic grew from 162,678 in 1991 to 504,207 in 2003; an increase of 210 percent. In the first full year of operation, Ryanair had 165,902 passengers and this reached 318,916 by 2003. This is a growth of 92.2 percent in only four years. On average the overall market grew at 12.8 percent per annum, whilst the Ryanair market grew at 18.4 percent per annum. The weekly frequency shows that Ryanair either matches the frequency available from LGW or exceeds it. However, it is likely that the market share that results reflects pricing differentials rather than frequency, which is simply a reflection of capacity and not in this case a determinant of demand. In Ryanair's first full year of operation it took 45.4 percent of a 1999 market which had grown 23.5 percent in that year. It took 57.6 percent of the market the next year and since then it has exceeded a 60 percent share. It seems Ryanair has both encouraged a growth in the market and taken traffic away from incumbents, especially Alitalia.

3.1.4 Stockholm

Stockholm is served by four airports. ARN, the principal airport, is 24 miles north of the city centre and Bromma (BMA), which has seen service from LCY, is some nine miles from the centre. Considerably more distant are NYO at Nyköping and VST, both around 60 miles away⁴.

ARN is served throughout the period by British Airways and Scandinavian Airline System (SAS) from LHR. From 1998 to early 2001, SAS also provided a service from STN and LGW offered service to ARN, first by Transwede, then by British Airways and Finnair and lastly by British Airways alone, although all service offerings from LGW were terminated in 2001. Malmo Aviation offered sporadic service from LCY to BMA in 1992-3 and 1998-9. Ryanair provides the remaining services to NYO and VST from STN. NYO services started in 1997 and VST in 2001. Scheduled traffic grew from an annual total of 520,312 in 1991 to 1,279,587 in 2003, an increase of 145.9 percent. Within these totals Ryanair traffic grew from 89,776, when service was only offered to NYO, to 429,599 in 2003, an increase of some 378.5 percent. Traffic

⁴ This may matter less than at first seems likely as Barrett (2000) quotes Nielsen (1999) that "half of the route's passengers are Stockholm citizens, proving the local catchment area's acceptance of this fledgling airport."

from STN soon surpassed the LGW totals. Overall, on average, traffic to Stockholm went up 8.3 percent per annum, whilst Ryanair's traffic grew at 18.0 percent per annum on average from 1998 when service was first offered for a full calendar year. The rival SAS service from STN to ARN never achieved significant passenger numbers and was discontinued in 2001.

The pattern of frequencies on the routes varies but by winter 2003, there were thirty four flights per week from STN compared to seventy two from LHR.

Whereas, LHR and LGW dominate the sector in the early 1990's in terms of market share, by 2002 and 2003, although LHR still captures 71.6 and 66.4 percent of the market respectively, Ryanair's share is 28.6 and 33.5 percent, in line with its relative frequency offerings.

3.1.5 Venice

Venice Marco Polo Airport (VCE) is the principal airport of the city but service is also offered to Treviso (TSF), about twenty miles away. In the early 1990's, British Airways and Alitalia offered service to VCE from LHR, but Alitalia moved to LGW in late 1994. British Airways discontinued its service in mid-2000 and switched to LGW. There was no service at all from LHR from then, until BMI British Midland commenced services in 2003. When British Airways switched to LGW, for a year Alitalia offered service, but it withdrew leaving British Airways on its own. For a year in 2002-2003, British Airways was joined by Volare, before operating alone again at LGW.

Ryanair started services to TSF in 1998 and in December of the same year, GO, a low cost subsidiary of British Airways, began operating from STN to VCE. This service became an easyJet service on its take-over of GO in 2002. Scheduled traffic grew from a total of 147,803 in 1991 to 846,526 in 2003, an increase of 472.7 percent⁵. Within these totals, the Ryanair traffic grew from 77,873 to 365,785 in 2003, an increase of 369.7 percent. On average, traffic to Venice went up 16.3 percent per

⁵ This increase, by comparison to the growth in traffic to Stockholm, probably reflects the relative suitability of the low cost carriers to the leisure market traffic that is more important at VCE than STO.

annum, whilst the Ryanair route averaged 37.8 percent growth per annum. Indeed, the large overall percentage increase in traffic in the two years up to 2000 is largely accounted for by the low cost carriers and whilst Ryanair's growth continues in the 21st century, the GO/easyJet service steadied around the 160,000 passengers carried mark, some 200,000 behind Ryanair.

The frequencies on the routes show the dominant position of Ryanair by 2003 and the fluctuations in service offerings before that as airlines changed their service offerings and the airports at which they were based.

If market share is examined, the early dominance of LHR is shown, followed by the joint dominance of LHR and LGW. By 1998, however, the Ryanair service accounts for 18.8 percent of the traffic. By 2003, this share has grown to 43.2 percent, with LGW at 30.8 percent and the easyJet service at 19.6 percent. The low cost carriers are taking well over half the market and some of this may be at the expense of LGW share but again, to demonstrate this with some certainty, rather than generating hypotheses, requires intervention analysis.

3.2 Relative Performance

Table 3.1 shows the growth on each route before the involvement of Ryanair and the growth rate afterwards. The three Italian leisure destinations display a different pattern to the other two, STO and HAM, more business-like, destinations. In the first group of cases, growth is considerably raised by Ryanair's market entry, whereas it isn't in the others.

Table 3.2 shows market share achieved by Ryanair in the first month of operation, in the first year of operation and in 2003. Again there seems to be a difference between the Italian destinations and the other two. However, the Venice route also looks closer in character to the other northern European destinations in that although the initial market penetration is good, it does not grow as rapidly as GOA or PSA. This is almost certainly because of the competition offered by easyJet from STN- VCE. So it seems that where competition is less and a dominant market role is achieved, so large market shares can be achieved whereas the share is less if there is more competition.

The final Table in this section (Table 3.3) shows the total passengers on the route from the time that Ryanair started its service and Ryanair's traffic. This shows the proportion of the market growth taken by Ryanair since it offered service. In two cases it dominates the market; in another it seems to be restrained by another low-cost carrier and in the remainder, it is dealing with a less vibrant and more business orientated market. It seems likely that latent demand is being exploited and that competitor's traffic has also been affected, especially where these proportions are high. More definitive results on the impact on the market must await the intervention analysis as the discussion in this section can at best generate hypotheses, but not test them.

4.0. ARIMA Models and Intervention Analysis

ARIMA modelling is usually concerned with producing models that replicate the typical behaviour of a time series⁶. However, it is important to be able to explain any disruption to normal behaviour and so intervention analysis is used to analyse the introduction of Ryanair services on these routes. To this end, first an ARIMA model is found that replicates the time series before the intervention. This is identified in the usual manner using Autocorrelation Function (ACF) and Partial Autocorrelation Function (PACF) plots accompanied by a tendency to be parsimonious in the number of parameters specified. The residuals of this model must be white noise.

The model form is then re-estimated on the whole time series, including the intervention, with this taking the characteristics of a binary dummy variable representing a step function⁷. The coefficient can be interpreted as showing the impact of the intervention on the whole time series.

Although in essence the above describes the procedure followed, as the data is monthly over a 12 year period, so it is subject to seasonal variations and an inspection of a simple time series plot of traffic illustrates that. Consequently, an ARIMA model will have a seasonal component which is a little harder to estimate than a non-seasonal model. In outline, the procedure is to first make the variance of the series a

⁶ For a good reference source, see Wei(1994).

⁷ If the series is subsequently differenced, so this becomes a pulse function. A permanent step in the level of the market shows up as a one time pulse in a differenced series.

constant by taking a logarithmic transformation. ACF and PACF plots are then investigated at suitable lags, which in this case is in multiples of 12. If the autocorrelations do not die out rapidly at these lags, then the series needs to be seasonally differenced and, as usual, if the ACF of this differenced series shows a single spike and the PACF attenuates from the first seasonal lag, then a Moving Average model with one parameter, MA(1), is suggested as the seasonal model component. If the ACF had a pair of spikes, the model would be a MA(2). Conversely, if the PACF shows a single spike, and the ACF attenuates, then an Autoregressive model with one parameter, AR(1), is suggested, whereas if the PACF has two spikes, it should be AR(2).

The residuals of this model can then be investigated to determine the non-seasonal component and the same rules then apply on the interpretation of the ACF and the PACF on these residuals in suggesting the model form.

After estimating both components of this model and checking that the resulting residuals are white noise, this model can be re-estimated for the whole of the data series, including binary intervention variable(s).

4.1 ARIMA Models

ARIMA models are normally described by three parameters, (p,d,q). p refers to the order of a vector of autoregressive parameters AR(p), d refers to the degree of differencing and q to the order of a vector of moving average parameters, MA(q). So a ARIMA(1,0,0) or AR(1) model can be written as

$$Y_t = \phi_1 Y_{t-1} + a_t \quad (2.1.1)$$

and using the backshift operator, $B Y_t = Y_{t-1}$

$$(1 - \phi_1 B) Y_t = a_t \quad (2.1.2)$$

where Y_t is the time series data and a_t is the disturbance or random shock at time t .

There is a tendency to favour parsimonious models as well as to avoid some mixed models which may suffer from parameter redundancy (McDowell et al, 1980).

If the data, Y_t is differenced before the application of the model so as to ensure stationarity, then a (1,1,0) model results and Y_t is replaced by $z_t = Y_t - Y_{t-1}$ and the backshift operator now is in terms of z_t as $B z_t = z_{t-1}$

If the model has a seasonal component, for example, if the data is gathered over a long period of time and is recorded for short intervals within this period, then it will be necessary to specify a seasonal ARIMA model. These are also described by three parameters (P,D,Q)S where P refers to the order of a seasonal autoregressive vector, D refers to the degree of seasonal differencing and Q is the order of a vector of moving average parameters. S is equal to 12 as the data is monthly with an annual periodicity. So a SAR(1) or Seasonal ARIMA(1,0,0)12 model can be written as

$$Y_t = \Phi_{12} Y_{t-12} + a_t \quad (2.1.3)$$

and using the backshift operator, B^{12} , which as it is raised to a power involves repeating it,

$$(I - \Phi_{12} B^{12}) Y_t = a_t \quad (2.1.4)$$

If seasonal differencing is required, then this model is applied to the seasonal differences, $w_t = Y_t - Y_{t-12}$.

Combining the two model components multiplicatively, gives an ARIMA(p,d,q)(P,D,Q)S model which can be generally represented as

$$\phi_p(B^S) \Phi_P(B)(I-B)^d(I-B^S)^D z_t = \theta_q(B) \Theta_Q(B^S) a_t \quad (2.1.5)$$

Variations can be derived from (2.1.5), for example an ARIMA (1,1,0)(1,1,0)12 is applied to the regularly and seasonally differenced data where

$$w_t = z_t - z_{t-12} = (Y_t - Y_{t-1}) - (Y_{t-12} - Y_{t-13})$$

and is given by

$$w_t = \phi_1 w_{t-1} + \Phi_{12} w_{t-12} - \phi_1 \Phi_{12} w_{t-13} + a_t \quad (2.1.6)$$

and using the backshift operators, B and B^{12} now applied to w_t

$$(I - \phi_1 B)(I - \phi_{12} B^{12}) w_t = a_t \quad (2.1.7)$$

Inspection of the ACF and PACF determine p,d,q and P,D,Q as indicated above, although it is the consensus that this process is as much art as science.

4.1.1 Assessing Model Fit.

It is common in time series modelling to not only require the residuals of the model to be white noise (as shown by the Box-Ljung Q statistics) but for the model to replicate the cycles in the data and to generally mimic the data adequately. The first of these requirements can be undertaken through visual inspection but the latter requires some additional calculations. An obvious statistic to invoke here is the root mean square error which is

$$\text{RMS} = \sqrt{1/T \sum_{t=1}^T (Y_t^s - Y_t^a)^2} \quad (2.1.8)$$

where Y_t^s = forecast value of Y_t

Y_t^a = the actual values and T = time periods

However, this statistic is influenced by the absolute scale of the errors, so comparison between model fits is difficult. This difficulty can be overcome if Theil's inequality coefficient, U , is used as the denominator of the coefficient corrects for differences in scale.

$$U = \sqrt{1/T \sum_{t=1}^T (Y_t^s - Y_t^a)^2} / \sqrt{1/T \sum_{t=1}^T (Y_t^s)^2 + 1/T \sum_{t=1}^T (Y_t^a)^2} \quad (2.1.9)$$

In addition, it can be broken down into the bias, the variance and the covariance proportions of U where U^M is an indication of systematic error, U^S indicates the ability of the model to replicate the degree of variability in the data and U^C shows the

$$U^M = (\bar{Y}^s - \bar{Y}^a)^2 / (1/T) \sum (Y_t^s - Y_t^a)^2 \quad (2.1.10)$$

$$U^S = (\sigma_s - \sigma_a)^2 / (1/T) \sum (Y_t^s - Y_t^a)^2 \quad (2.1.11)$$

$$U^C = 2(1 - \rho) \sigma_s \sigma_a / (1/T) \sum (Y_t^s - Y_t^a)^2 \quad (2.1.12)$$

unsystematic error. U^M , U^S and U^M sum to 1 and ideally, U^M , $U^S = 0$ and $U^M = 1$. (Pindyck and Rubinfeld, 1998)

4.2 Route by Route Analysis

4.2.1 Genoa

First the Genoa data series of total traffic⁸ before the intervention of Ryanair is transformed into logarithms to ensure the variance is constant and the ACF inspected over seasonal peaks at lags of 12, 24, 36 months etc. The peaks revealed here suggest that the series is seasonally differenced. Inspecting the ACF and PACF of this transformed series suggests a seasonal AR(1) model. An analysis of the residuals from this model, in turn, suggests a non-seasonal autoregressive model with either one or two parameters. Both of these models when applied produce white noise residuals with the standard error of the two parameter model being slightly lower although the one parameter model might be preferred for parsimonious reasons and because of its goodness of fit.

If the whole total series from 1991 to 2003 is then modelled using the model forms identified above, plus an intervention variable, then the impact of Ryanair's start-up from Stansted can be calculated on the British Airways' traffic from Gatwick. The details of these models are shown in Appendix 2⁹. The standard error of the two parameter model is slightly lower and the coefficient of the intervention variable suggests that the market grew by 44 percent because of the participation of Ryanair. By 2003, Ryanair's share of the market was 70 percent, as shown in section 3.1.1, so not only did it result in the growth of the market, it also took about 25 percent of British Airways' traffic. The relative change in frequencies offered reflects this statistical finding. If the other model is examined, which has superior RMS and U values, then Ryanair had a 48 percent impact suggesting it took slightly less traffic from British Airways.

⁸ This is largely British Airways from LGW as traffic from LHR only occurs for two months over the whole period.

⁹ Available on request from the author.

4.2.2 Hamburg

Hamburg initially proved the most difficult data series to model. Although it seems clear that the summed series for all the airports except Ryanair's traffic to LBC requires a logarithmic transformation and seasonal differencing, which, in turn, suggests a seasonal AR(1) model, the prescription for model building from then on is not very clear. These residuals suggest an AR(1) non-seasonal model, but applying this results in an insignificant seasonal parameter and the residuals are not white noise. A careful examination of the sequence of the modelling process, plus some experimentation, resulted in a model with two seasonal and non-seasonal autoregressive coefficients that removes any significant spike in the ACF of the residuals except at a lag of four which can be regarded as a product of chance as it is not at a seasonal point and plots have been obtained for a large number of lags. However, McDowall et al (1980) state that a greater than one parameter seasonal autoregressive model, although possible, is rare. Consequently, the model form was revisited and a model form that gives good results is shown in Appendix 2. However, there is some doubt whether these yield white noise residuals as there is a spike in the ACF at lag 24.

Re-applying the original model to all the data, now including the post Ryanair start-up traffic represented by an intervention variable, gives a coefficient of 0.087 with $t=1.550$ and $SE=0.072$ and the results are also shown in Appendix 2. Although this is not a significant as we might like, it is difficult to interpret the coefficient that suggests Ryanair expanded the total market by 9 percent and this may be a product of the fact that this total series includes not only traffic from LHR, LGW and LCY, but also other traffic from STN. The U and RMS statistics favour the first model from Appendix 2 and on this basis the impact on total traffic was 12 percent.

If the traffic from LHR is isolated and a similar procedure invoked, so, not surprisingly, a similar difficulty in model identification results. However, an identical model form to that used above suffices, with the same caveats, and applying this to Ryanair's traffic plus the total for 12 years from LHR gives a significant intervention coefficient at 0.18. If Ryanair's impact on the LHR plus its own market was plus 18 percent, so by 2003, it was taking 34 percent of the total market.

A similar analysis was conducted for traffic from LHR plus LGW. This results in a significant estimate of intervention at 11 percent. These intervention results are shown in Appendix 2.

It is gratifying that the suggested expansion of the market, irrespective of which set of models is used, has a gradation that is logical in that, the whole market has the smallest suggested expansion, whilst the LHR market plus Ryanair has the largest suggested expansion. In addition, unlike Genoa, Ryanair is flying to a different airport in the destination country so we might expect its impact to be smaller. We might also expect this as there is also more competition on the sector. It seems Ryanair expanded the market and took about the same volume of traffic again from its competitors.

4.2.3 Pisa

To replicate the time series before the intervention of Ryanair, it is necessary to take logarithms of the data and then to seasonally difference it with a periodicity of 12. Examination of the ACF and PACF plots at periodic lags suggests an AR(1) seasonal model and an investigation of the residuals from this gives a non-seasonal autoregressive model with one parameter. The residuals of this model are white noise.

Re-estimating this model form for the whole data series along with the intervention, gives the coefficients and goodness-of-fit recorded in Appendix 2. These results can be interpreted as showing that Ryanair resulted in a 30 percent increase in the traffic on the route. Compared to the analysis in section 3.1.3, this in turn suggests that Ryanair grew the market and also took about the same percentage share from its competitors, especially Alitalia¹⁰. This is statistical proof for the hypotheses suggested in section 3.1.3, that Ryanair is responsible for both increasing the size of the market and taking traffic from incumbents.

4.2.4 Stockholm

First of all the impact of Ryanair's service to NYO was investigated. This involved modelling the total traffic, without any Ryanair services, up to 1997, and then modelling the total series from 1991 to 2003, including Ryanair's service to NYO, but

¹⁰ However, analysing Alitalia's withdrawal as a second binary intervention variable does not yield significant results.

excluding the service later offered to VST. The model coefficients are shown in Appendix 2 where it can be seen that the model that gives white noise residuals has a seasonally autoregressive term and two autoregressive non-seasonal terms. As usual this is fitted to the seasonally differenced logarithms of the data. The intervention coefficient is significant and suggests the start up of Ryanair at STN expanded the total market by 10 percent. By 2003, the share of the traffic to NYO was 25 percent of the total being examined.

An attempt to similarly investigate the impact of the start up to VST was undertaken, however, a separate significant intervention could not be determined, perhaps because the time series post-intervention is quite short. Nevertheless, if Ryanair's total traffic from STN is taken as the intervention, then another model in Appendix 2 is derived with a significant intervention also at 10 percent. If the impact on just the LHR traffic is examined, the intervention is 15 percent. Both of these models are applied to both seasonally and regularly differenced data.

Again the relative size of these coefficients is intuitively correct and it seems that Ryanair has taken 10-15 percent of British Airways and SAS's traffic. This magnitude of impact is again feasible as Ryanair serves two different airports to ARN and the traffic may well be somewhat more business orientated, where fares matter less.

4.2.5 Venice

In this case it is possible to investigate both the intervention of Ryanair and the subsequent intervention of GO. Following the usual procedures gives white noise residuals for a model with a moving average parameter and a seasonal autoregressive parameter, all applied to seasonally and regularly differenced logarithms of the data before the interventions. Re-estimating this model with two binary intervention variables gives the results in Appendix 1. It can be seen that Ryanair increased the market by 26 percent whilst GO/easyJet added a further 24 percent. By 2003 the two low cost carriers accounted for nearly 63 percent of the market. Of this total Ryanair is carrying over 43 percent of the traffic so it seems clear that it took share away from its competitors, including the LGW based services and this is reflected in a change in the relative frequencies offered. It also took traffic from easyJet as by 2003 easyJet had a market share less than its initial impact on the market. As easyJet's traffic also

stagnates relatively after its first year it can be suggested that Ryanair has been considerably more successful than its low cost competitor.

5.0 Conclusions

By using ARIMA modelling with intervention analysis it has been possible to improve on the hypothesis generation of section 3 where it appears that Ryanair, on joining the route, established market share for itself and had an impact on incumbents. It has been possible to show the actual impact on the market. These estimates are quite robust, as even if the underlying ARIMA modelled is changed, the intervention coefficients change little. Such estimates of impact are superior to the percentage analysis undertaken in section 3 where it is only possible to generate hypotheses. The intervention analysis allows the impact of Ryanair to be judged on the whole time series, including the period of intervention, so not only can their impact on the sector be shown, but when this is compared to achieved market shares, much more definite inferences can be drawn on the competitive impact of the airline. It is clear that its actual impact has been considerable.

First, the Italian, mostly leisure, destinations, GOA, PSA and VCE. For the first two of these, the interventions are large. Ryanair serves the same airport as its competitors and they are flag carriers. In the case of VCE, Ryanair serves a different airport and it also has competition from another low cost carrier at the principal airport. The intervention effect is less. For the two more business orientated destinations (although leisure activities are easily possible in both STO and HAM), the competitors are traditional scheduled carriers and there are more than one per route for much of the time and Ryanair serves an alternative airport. The size of the intervention is less. This hierarchy of impacts is completely consistent with the analysis of section 3 as it correlates with both the growth of the market and the market share held by Ryanair. The intervention, the growth and the ultimate share will all be bigger if there is little competition; if it is of a traditional type; the destination is primarily leisure and Ryanair serves the same airport as the competition.

This reinforces the tentative and preliminary conclusions of Barrett (2000) who focussed on airport competition but did examine Ryanair's services from STN as one case study. The share of new entrants by 2002 is shown in Barrett (2004) and

updated for some of those cases here. However, this paper has moved beyond the simple analysis of shares to analytically establishing the degree of impact of Ryanair and, given its actual market share, its substantial impact on the incumbents; they lost market share or abandoned their services.

It is likely that the impact on charter services has also been considerable and a similar methodology could be applied to a more limited number of destinations than are analysed here. This is a task for further work.

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Table 3.1: Growth by Route before and after Ryanair

Destination	Before Ryanair	After Ryanair
	Annual average % growth	Annual average % growth
GOA	14.2	18.1
HAM	6.0	5.5
PSA	6.8	18.8
STO	9.4	7.6
VCE	12.1	20.6

Table 3.2: Market Share, Month one, first year and 2003

Destination	First month	Full year	2003
	%	%	%
GOA	16.1	62.5	68.4
HAM	13.7	18.7	25.9
PSA	26.7	45.4	63.3
STO - NYO	6.6	15.3	22.1
- VST	5.1	7.9	11.5
VCE	17.3	21.9	21.8

Table 3.3: Proportion of Market since Ryanair start-up

Destination	Ryanair pax	Total pax	Ryanair percent
GOA	649146	986327	65.8
HAM	620848	2895188	214
PSA	1377894	2467321	55.8
STO - NYO	1556480	8879907	17.5
- VST	321999	3899533	8.3
VCE	1353178	3932951	34.4

Appendix 1

London-Venice

Figure 1.1.1: Passenger Numbers. London-Venice, 1991-2003

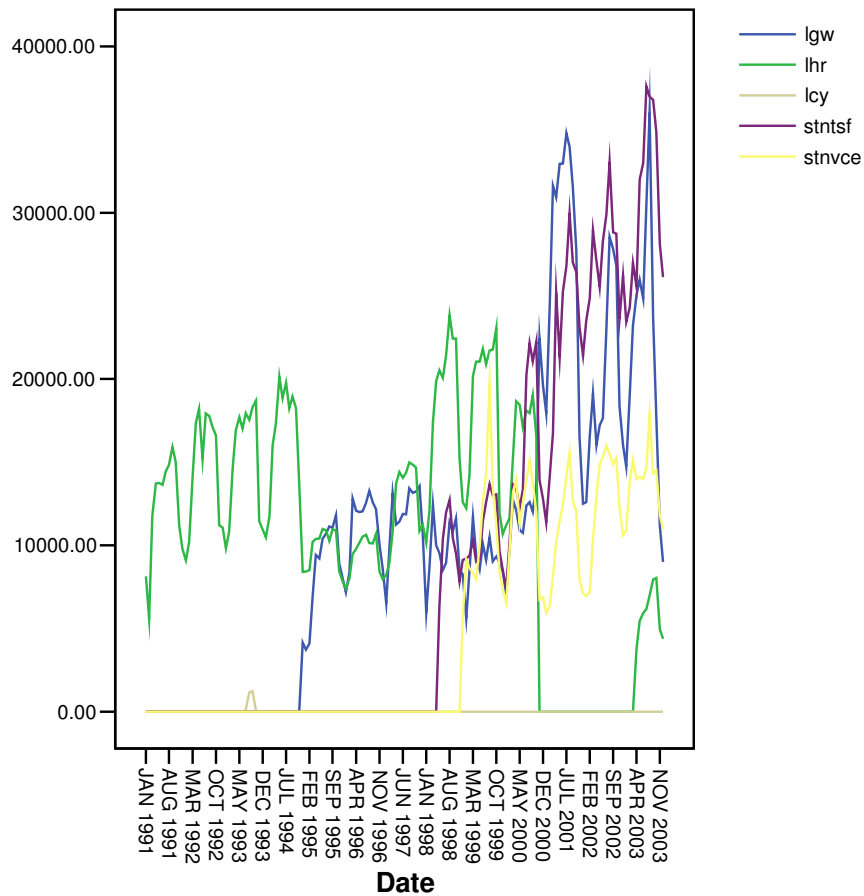


Table 1.1.1 Annual Traffic Growth London-Venice, 1991-2003

Year	Route										Total	
	LGW		LHR-		LCY-		STN		STN-			
	No	%	No	%	No	%	No	%	No	%	No	%
1991	0	-	147803	-	0	-	0	-	0	-	147803	-
1992	0	-	175862	19.0	0	-	0	-	0	-	175862	19.0
1993	0	-	181813	3.4	2536	-	0	-	0	-	184349	4.8
1994	4150	-	191889	5.5	0	-	0	-	0	-	196039	6.3
1995	105474	n.c	118233	-38.4	0	-	0	-	0	-	223707	14.1
1996	133702	26.8	113355	-4.1	0	-	0	-	0	-	247057	10.4
1997	140068	4.8	151202	33.4	0	-	0	-	0	-	291270	17.9
1998	114657	-18.1	218131	44.3	0	-	78323	-	5653	-	416764	43.1
1999	109262	-4.7	220619	1.1	0	-	129086	64.8	131269	2222.1	590236	41.6
2000	156065	42.8	163960	-25.7	0	-	182597	41.5	135509	3.2	638131	8.1
2001	327931	110.1	0	-	0	-	268800	47.2	124073	-8.4	720804	13.0
2002	239747	-26.9	0	-	0	-	328587	22.2	152156	22.6	720490	-0.0
2003	261044	8.9	53577	-	0	-	365785	11.3	166120	9.2	846526	17.5

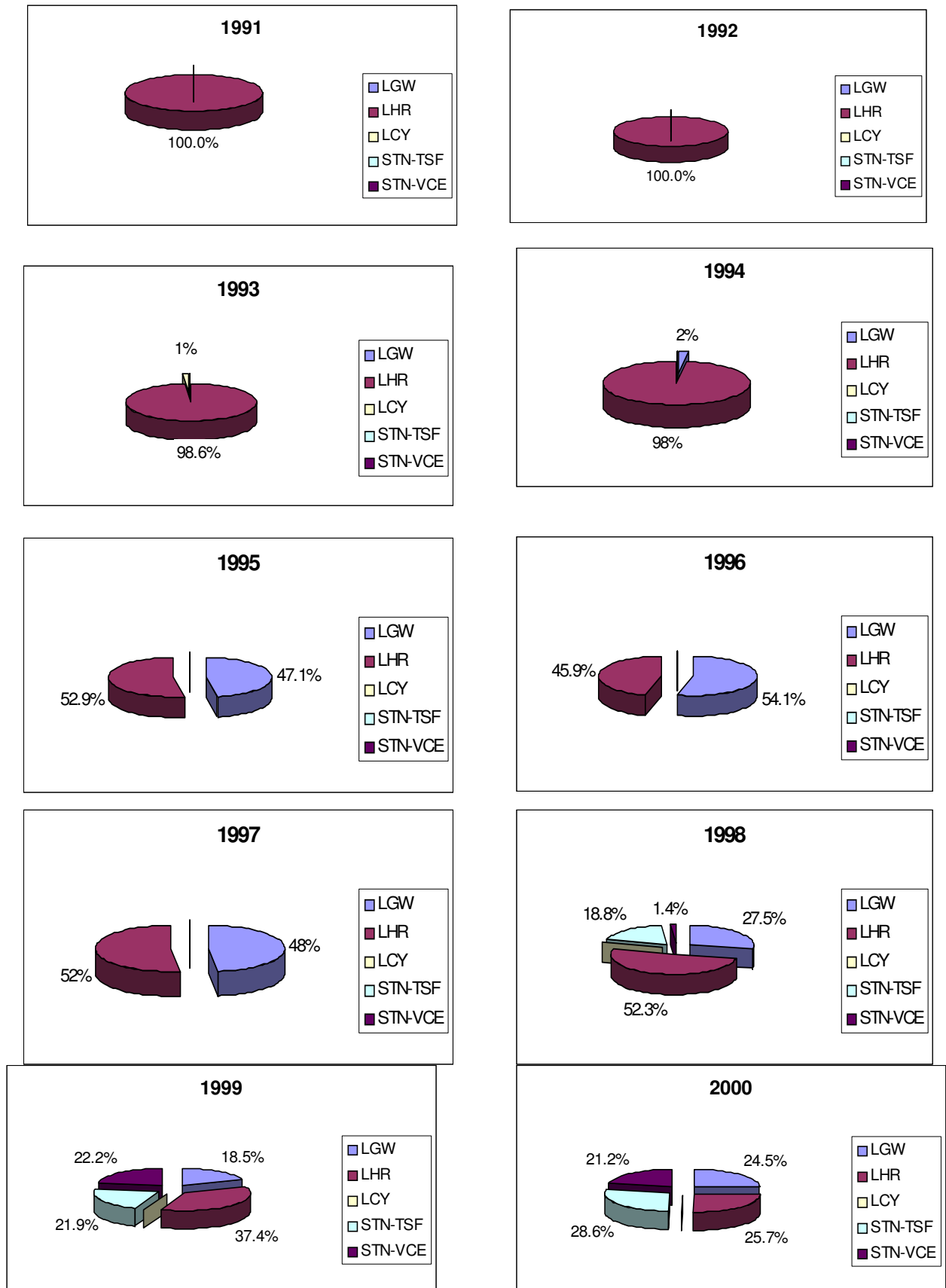
n.c. not calculated

Table 1.1.2: Frequency of Service.

London-Venice Weekly flight frequencies 1991-2003

	STN- TSF	STN- VCE	LHR- VCE	LGW- VCE
March 91 - Oct 91	0	0	14	0
Oct 91 - March 92	0	0	14	0
March 92-Oct 92	0	0	14	0
Oct 92 - March 93	0	0	14	0
March 93-Oct 93	0	0	14	0
Oct 93 - March 94	0	0	14	0
March 94-Oct 94	0	0	15	0
Oct 94 - March 95	0	0	14	7
March 95-Oct 95	0	0	7	14
Oct 95 - March 96	0	0	7	14
March 96-Oct 96	0	0	8	14
Oct 96 - March 97	0	0	8	14
March 97-Oct 97	0	0	9	14
Oct 97 - March 98	0	0	7	7
March 98-Oct 98	14	0	15	14
Oct 98 - March 99	14	7	14	7
March 99-Oct 99	14	9	15	14
Oct 99 - March 00	14	7	14	7
March 00-Oct 00	20	9	15	21
Oct 00 - March 01	12	7	0	42
March 01-Oct 01	20	14	0	35
Oct 01 - March 02	20	7	0	21
March 02-Oct 02	20	14	0	34
Oct 02 - March 03	20	14	0	35
March 03-Oct 03	28	14	7	14
Oct 03 - March 04	21	13	7	14

Figure 1.1.2: London to Venice Market Share



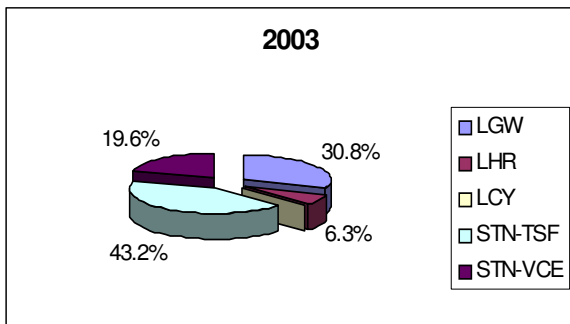
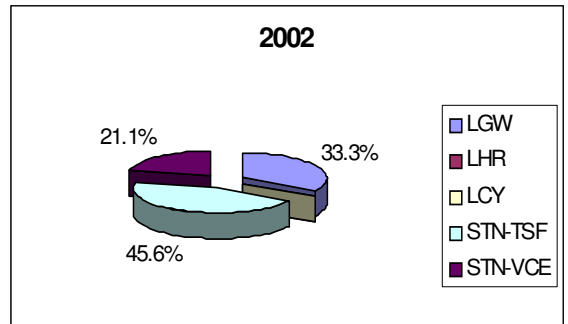
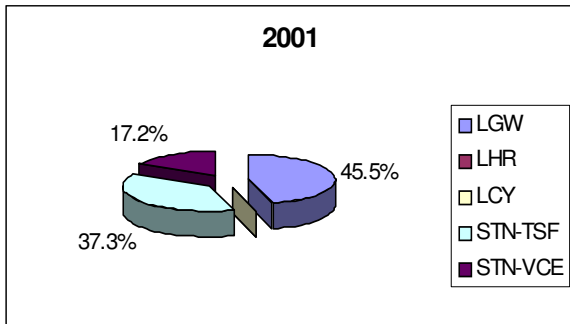


Table 1.1.3: Venice Intervention Model - with regular differencing

	Parameters	t tests	Goodness of Fit
MA1	0.565	8.019	SE = 0.084
SAR1	-0.458	-5.981	Log Likelihood = 151.540
Intervention -Ryanair	0.258	4.548	AIC = -295.081
Intervention - GO	0.236	4.165	SBC = -283.229
RMS = 3156.129	U = 0.037	U _m = 0.003,	U _s = 0.001, U _c = 0.995