UK Passenger Airlines: DEA

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Module: ECN3015

Assignment weight: 30%

2110 words

Assignment description

The second piece of work should focus upon an alternative modelling approach (although it may embody some econometric methodology). The choice of topic, collection of data and analysis should be made by the students. You may work in small groups but the work must be an individually written piece.

Students may choose to write either

- a technical report, that focuses upon the specifics of the chosen methodology
  - Data envelopment analysis
  - Monte Carlo simulation
- a **research report** which applies the modelling technique to a specific research problem **[Airlines]** (as per piece 1)
  - **Data envelopment analysis**
  - Monte Carlo simulation

In either case, the report should be around 2,500 - 3,000 words in length.

1 Introduction

The passenger air transport industry in the United Kingdom has recently experienced a period of rapid growth, mainly due to a long-term fall in crude oil prices. (MarketLine 2017)

This paper aims to inspect the extent of improvements in efficiency allowed by relaxation of the thin profit-margin constraint in result of the fuel price drop. The main hypothesis is that broader implementation of efficiency maximizing measures was enabled over this period, which should lead to an improvement. Furthermore, the effect is broken down to inspect constant between low-cost and legacy carriers.

Firstly, the literature review outlines existing research, focusing on identification of relevant inputs, outputs, and their prices to form a base for data envelopment analysis. Section 3 then relates these to the microeconomic framework of profit maximizing firm, while section 4 presents econometric technique building on top of it, the DEA. Section 5 conducts descriptive and exploratory analysis of collected data. Finally, section 6 provides output of the DEA itself. The conclusion then summarizes the findings, while identifying appropriate actions to be taken.

2 Literature review

In order to analyze efficiency of a set of firms using DEA[1], relevant inputs and outputs need to be identified. Gladovic (2012) provides a synthesis of previous literature on airline efficiency, critically assessing approaches taken therein. His most decisive indication is that "direct use of revenues as outputs and expenses as inputs is conceptually incorrect," hence physical inputs must be considered to characterize the technology of production properly. However, he further establishes that airlines do not "have clearly defined and quantifiable outputs and inputs," as in addition to the transport over distance, they provide other on-board services, may outsource or provide aircraft maintenance to other airline companies, and some of the LCCs[2] gain substantial amount of revenue from advertising.

The main equipment facilitating high-volume air travel in a short period of time is airplane. According to a report employing porter market forces conducted by MarketLine (2017), the most crucial production factor in the airline business is fuel. Furthermore, highly skilled labor is necessary to operate aircraft.

[1] Data envelopment analysis
[2] Low Cost Carriers

	Name	Price measure	Source	Quantity measure	Source
Inputs	Fuel	$Fuel\ price$	EIA (2018)	$\frac{Fuel\ spending}{fuel\ price} = Barels$	FAME (2018)
	Aircraft	$mean\left(\frac{Aircraft\ Lease\ price}{Aircraft\ seats}\right)$	FleetIntel (2018)	$Total\ seats$	CAA (2018)
	Labor	$\frac{Wage\ expenses}{Employees}$	FAME (2018)	$Employees$	FAME (2018)
Out	Transport	$\frac{Revenue}{Seat\ km\ used}$	CAA (2018)	$Seat\ km\ used$	CAA (2018)

Table 1: Inputs and outputs to be used in the DEA

3 Economic Theory

Because even the smaller airline companies tend to be quite large in terms of employees and economic costs of owned capital, positive effects such as division of labor are expected to be outweighed by diseconomies of scale. (Perloff 2013) For example, the seasonality of demand for air travel, which peaks in summer months, is expected to cause some aircraft of the largest firms to be idle outside of the peak period. Furthermore, with increasing number of employees, communication costs increase, while reactions to the current market climate slow down. For these reasons, the UK airline industry is expected to exhibit diminishing returns to scale.

While aiming to improve their performance, or efficiency, firms need to consider whether to focus on increasing output at given level of inputs or on reducing the level of inputs given their current output. Because of the varying nature of airline companies, both should be considered. Nevertheless, output orientation is more feasible, as aircraft generally have long idling periods and sales can be boosted using appropriate market insights and sales methods.

4 Methodology

In order to inspect whether there was a direct effect of decrease in fuel prices on efficiency of airline companies, two-step analysis shall be conducted. Firstly, Data Envelopment Analysis will be used to determine efficiency of individual airliners and their profit maximizing combinations of inputs and outputs, while taking aircraft fuel price at given time into account. This is going to be done both under assumption of constant returns to scale and variable returns to scale.

Then, return to individual inputs in terms of output, and its change over time will also be examined. Positive tilt of function of returns to fuel over time would be an indicator of improvement in production technology and employment of other production factors. Such observation would therefore indicate whether individual airline companies invested in their efficiency improvement.

This will be conducted in R version 3.4.2, using R studio using Benchmarking package. (R Core Team, 2017, Peter Bogetoft 2010) The complete process is recorded at http://rpubs.com/mattved/348377.

5 Data

The dataset used for purposes of this analysis was collected from multiple sources, of which some were on the fringe of being credible. Because of the fact that a large proportion of data is proprietary and unavailable to academics, further assumptions had to be made in the process. The collection aimed to obtain annual data for years 2015 and 2016 relevant to themes introduced in the literature review.

Aircraft fuel prices were taken from EIA (2018), averages of monthly values calculated for each year, and then used as universal input price for each company. Even though this may not hold true due to factors such as long-term sourcing deals and backward integration, prices of commoditised securities are highly indicative of the current market situation.

Quantities of fuel used in the airline firms' production were calculated based on the composition of their fleet, fuel efficiency measures of individual aircraft models, and finally distance covered per aircraft. Age of fleet as well as take-off weight of loaded planes may be factors influencing the fuel consumption, which are not accounted for herein.

Information on total revenue, personnel expenses, and number of employees was collected using FAME (2018), which provides machine readable data from accounting and strategic reports. Even though the source is reliable, some distortion may be caused by the assumptions made. Firstly, revenue was considered to consist solely of boarding passes sold to customers and divided by total number of passenger kilometers produced to reveal price of output. Secondly, the price of labor was calculated as a division of personnel expenditure by total number of employees, which consists of office staff in addition to the more relevant cabin crew and pilots.

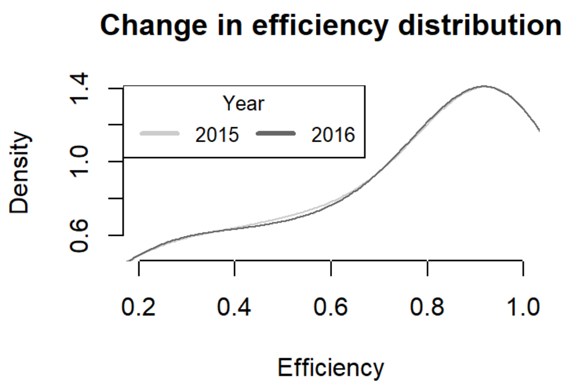
Finally, data on fleet composition and total available and used seat kilometers per aircraft type was obtained from CAA (2018) for both years, while economic cost of aircraft usage represented by dry lease prices per aircraft model were gathered in Fleet-Intel (2018).

6 Results

6.1 Constant returns to scale

Results of the data envelopment analysis under assumption of constant returns to scale, i.e. with linear production function, three companies are identified as fully efficient, while some exhibit very low efficiency of around 20%, as illustrated in figure 1a. The year on year change in the distribution shows slight improvement in the airlines with 2015 efficiency around 0.5. Otherwise, the distribution remains the same.

The peers, i.e. agents with efficiency of 1, which other firms are compared to include two legacy airlines specialized in long-distance travel, that is Thomas Cook, Virgin Atlantic, in addition to Titan Airways, a small carrier focused on sub-chartering and wet lease of large aircraft to firms. Whether an airline is LCC or legacy does not seem to make a difference, however, companies specialized in serving regional airports, such as Eastern Airways or BMI Regional, fall into the bottom of efficiency ranking.



(a) Efficiency distribution

CRS efficiency

	2015	2016
AIRTANKER SERVICES LTD	0.7123694	0.7223156
BA CITYFLYER LTD	0.5607607	0.5707885
BMI REGIONAL	0.2106617	0.2089287
BRITISH AIRWAYS PLC	0.7661813	0.7918410
EASTERN AIRWAYS	0.2069870	0.2215511
EASYJET AIRLINE COMPANY LTD	0.9364425	0.9456384
FLYBE LTD	0.5148123	0.5164462
JET2.COM LTD	0.8605237	0.8726538
LOGANAIR LTD	0.3898611	0.3787147
MONARCH AIRLINES	0.9333231	0.8676795
THOMAS COOK AIRLINES LTD	1.0000000	1.0000000
THOMSON AIRWAYS LTD	0.9553867	1.0000000
TITAN AIRWAYS LTD	1.0000000	1.0000000
VIRGIN ATLANTIC AIRWAYS LTD	1.0000000	1.0000000

(b) Individual efficiencies

Figure 1: Efficiency under CRS

The most frequent peer the inefficient airlines should aim to mimic in use of inputs is Thomas Cook, which has some weight in case of all of the other airlines. Reason for this is that unlike the other two firms at full efficiency, Thomas Cook Airlines do have the optimal combination of outputs in addition.

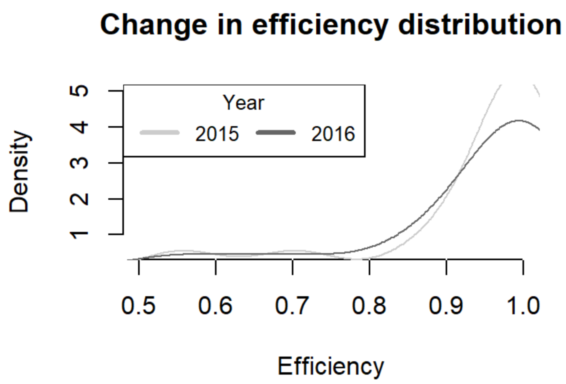
Calculating values of input through input oriented optimization suggests Virgin Atlantic to substitute fuel usage and number of workers with more aircraft, perhaps with lower fuel consumption per kilometer. Titan Airways is on the other hand advised to increase their employee base, while selling part of their fleet. In reality, however, these suggestions cannot be applied due to the nature of the respective firms' strategy. Further reductions of input quantities that could realistically sustain the same output do not occur in the IOO results.

Considering output oriented optimization in 2015 however, Thomson Airways would need to increase their output by 5%, while both EasyJet and Monarch Airlines by 7% to reach full efficiency, which may be facilitated by increasing seat occupancy on flights or increasing number of seats on an airplane. The first of the three has indeed managed to reach full efficiency by 2015. On the other end, the already mentioned Eastern has no way of increasing output to the efficient level, which is almost 5 times greater than the current.

6.2 Variable returns to scale

Should the assumption of returns to scale be changed to state that they are variable, expected to be diminishing due to effect of diseconomies of scale. More companies are considered fully efficient, as firms at subefficient state under the CRS assumption greater in scale become breaking points of the sector production function, removing the effect.

Inspecting the difference between years 2015 and 2016, only the firms with initial efficiency below 75% seem to deteriorate by a margin, the subefficient firms nearing value of 1 improve, with BMI Regional reaching the production possibility frontier.



(a) Efficiency distribution

VRS efficiency

	2015	2016
AIRTANKER SERVICES LTD	1.0000000	1.0000000
BA CITYFLYER LTD	0.7044482	0.6956541
BMI REGIONAL	0.9306952	1.0000000
BRITISH AIRWAYS PLC	1.0000000	1.0000000
EASTERN AIRWAYS	1.0000000	1.0000000
EASYJET AIRLINE COMPANY LTD	1.0000000	1.0000000
FLYBE LTD	0.5552871	0.5466052
JET2.COM LTD	0.8717434	0.8792292
LOGANAIR LTD	1.0000000	1.0000000
MONARCH AIRLINES	0.9452628	0.8791598
THOMAS COOK AIRLINES LTD	1.0000000	1.0000000
THOMSON AIRWAYS LTD	1.0000000	1.0000000
TITAN AIRWAYS LTD	1.0000000	1.0000000
VIRGIN ATLANTIC AIRWAYS LTD	1.0000000	1.0000000

(b) Individual efficiencies

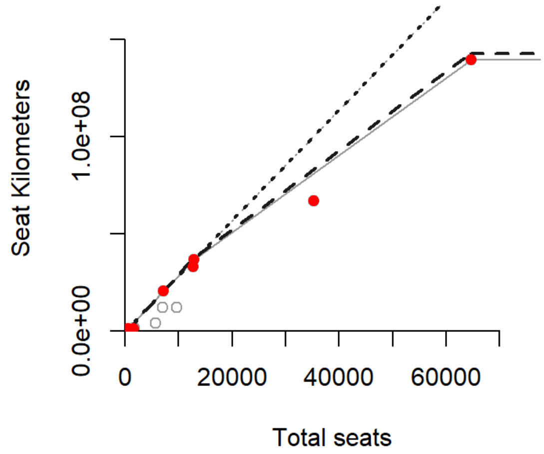
Figure 2: Efficiency under VRS

Based on output oriented optimization results, Monarch Airlines had opportunity to reach full efficiency under VRS if they were to increase output by 6% between the years while keeping the levels of input. Unfortunately, they did not manage to achieve this and dropped significantly. Jet2.com needed 15% growth given inputs, which they did not achieve fully, but they managed to improve to some extent.

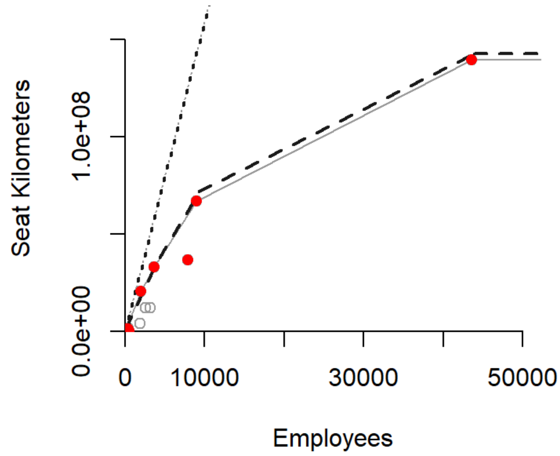
6.2.1 Returns to Inputs

As figure 3 shows, all single-input 2016 production functions shown by in dashed black lines are positively tilted in comparison to the 2015. The reason for this, in case of both labor and capital may be associated with the drop in price of fuel or an improvement in technology utilizing the third input.

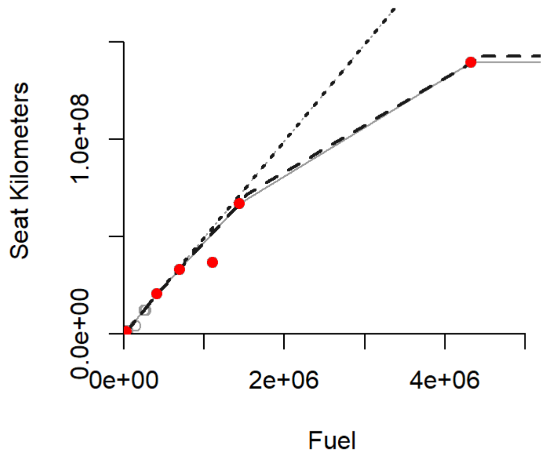
In figure 3c, the marginal effects of increase in fuel used in production are characterized in the same manner. In this case, the increase is not substantial for the smaller airline companies, however there is a positive tilt among the largest, which shows that apart from the relaxation of fuel prices causing increase in productivity of the complement production factors, there has been some increase in efficiency of their utilization. This fuel may alternatively be related to the fact that, on average, annual cost per worker has decreased, which is however likely outweighed by the increase of economic cost of aircraft between the years.



(a) Aircraft seats



(b) Labor



(c) Fuel

Figure 3: Returns to individual outputs

7 Conclusions and recommendations

In conclusion, this study has attempted an efficiency analysis of UK airline companies, using the DEA method, considering aircraft fleet, fuel, and labor as inputs and total number of kilometers traveled per passenger as the only output. While the data collection has been a cause of complexities, the analysis has shown that there has been slight increase in efficiency under assumption of constant returns to scale and reduction of number of firms in the lowest quartile of efficiency distribution in case of variable returns to scale.

Return to fuel has increased slightly in case of large airlines, namely British Airways and Easy Jet, suggesting improvement in utilization of other production factors. Same scenario has occurred with the remaining two inputs, suggesting that while there has been some technological improvement, the airlines have also focused on increasing their output, owing to increased profit margin at given price.

A pitfall to the airline industry is general availability of data related to operation of its firms. Although there is an element of confidentiality to some information, for purposes of publicly available data analysis that would enable worthy feedback to the firms and benefit public, more specific resources should be provided by aviation authorities or airlines themselves, mainly regarding fuel consumption. This is not only important for transparency of the oligopolistic structure, but also the environment, as air travel and transport is one of the larger causes of air pollution.

2110 words

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Software used

- RStudio
- LyX