



Identifying airline cost economies: An econometric analysis of the factors affecting aircraft operating costs



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ABSTRACT

This paper provides the results of an econometric analysis of the influences of airline characteristics on the average operating costs per aircraft movement. The analysis combines a comprehensive selection of airline-output variables, airline-fleet variables, and airline-market variables. The results confirm the existence of economies of density, economies of load factor, economies of aircraft utilisation and economies of aircraft size. The paper does not provide evidence of economies of scale, economies of stage length or economies of fleet commonality. Furthermore, airlines that additionally operate full freighters, airlines that are members of a worldwide alliance and airlines that operate a multi-hub system face higher average operating costs per aircraft movement. Surprisingly, the regression results demonstrate that airlines that use newer aircraft have higher average operating costs per aircraft movement, suggesting that ownership costs (depreciation and leasing costs) of new aircraft outweigh the increasing maintenance costs of old aircraft. Finally, the results show that airlines that have a dominant position at their hubs or bases have higher operating costs per aircraft movement, implying that the absence of serious competitive pressure enables airlines to charge higher ticket prices and, with that, leads to a limited focus on cost savings.

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1. Introduction

Today, the margins of most airlines are under constant pressure. Even in economic booms, many airlines scarcely make a profit. This mainly stems from the substantial increase in competition in the airline industry over the last decades. In particular, low-cost carriers have put considerable competitive pressure on the traditional network carriers. Indeed, they have gradually undermined network carriers' ability to practice the price discrimination necessary to recover their total costs (Tretheway, 2004). Morrison (2001) showed that the estimated savings due to actual, adjacent and potential competition from low-cost carrier Southwest Airlines were \$12.9 billion, which amounts to 20 per cent of the airline industry's domestic scheduled passenger revenue in the United States in 1998. This implies that the pressure on network carriers' operating costs in the United States increased considerably because of the abovementioned revenue reduction. In Europe, low-cost carriers also put additional pressure on network carriers' operating costs by offering flights at reduced fares. Franke (2004)

reported that Ryanair can offer cheap flights because of higher crew productivity, reduced cabin crew, high aircraft utilisation, new-generation aircraft, use of secondary airports, low ground handling charges and a higher average aircraft size. Furthermore, O'Connell (2007) stated that low-cost carriers' ability to offer 80 per cent of the service quality at less than 50 per cent of network carriers' cost jeopardises the future of network carriers in short-haul markets.

It is therefore important to have a clear view of the operating costs per aircraft movement and, perhaps even more relevant, the variables which have the most profound impact on those operating costs. Hence this paper investigates the key drivers of operating costs per aircraft movement using random- and fixed-effects regression techniques based on data from 2007 to 2010. The data used consist of financial and operational information from airlines' annual reports and detailed traffic figures from the Official Airline Guide (OAG). While other papers often focus on just a few factors, the results of this paper provide a comprehensive view of the impact on aircraft operating costs, combining airline-output variables, airline-fleet variables, and airline-market variables. This reduces the likelihood of spurious relationships. Moreover, the focus of this paper is operating costs per aircraft movement, rather than total operating costs as is the case in most existing literature. The

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results enable policy makers, airline managers and researchers to gain additional insight into the most important factors that affect operating costs per aircraft movement and, in turn, into the most profound airline cost economies.

2. Factors influencing airline operating costs

2.1. Existing literature

Early literature on cost economies often focused on the possible existence of economies of scale. Based on a meta-analysis, White (1979) concluded that economies of scale in the airline industry were negligible or non-existent at the overall firm level. This finding has been confirmed by several other scholars (see e.g. Braeutigam, 1999; Caves et al., 1984; Gillen and Morrison, 2005). Liu and Lynk (1999) deviated from this general finding by stating that significant economies of network size exist after the deregulation of the United States airline industry. In 1982, Bailey and Friedlaender (1982) mentioned the existence of economies of networking in the aviation industry as a form of economies of scope. In more recent years, different authors have demonstrated the existence of what is currently called economies of density (see e.g. Caves et al., 1984; Brueckner and Spiller, 1994). As a result of the emergence of hub-and-spoke networks, network carriers are able to use planes that are larger than would be the case in point-to-point networks: they concentrate their operation by channelling large passenger flows through their hub airports.

Today, extensive literature exists on the variables affecting airline costs. The majority of this literature focuses on the influence on total airline costs or unit costs. Papers aiming to identify factors that influence airline operating costs per aircraft movement are rather scarce. This section elaborates on the factors mentioned in the existing literature.

Most papers on the impact on airline costs have included variables measuring an airline's output in terms of traffic. Proxies often used to measure output are revenue passenger miles (RPM), number of seats offered, number of departing flights and number of carried passengers. All papers focussing on total cost function have found, not surprisingly, positive effects of airline output on airline total costs (Caves et al., 1984; Gillen et al., 1990; Windle, 1991; Banker and Johnston, 1993; Hansen et al., 2001). On the other hand, output has a negative effect on the average operating costs of an airline, as Baltagi et al. (1995) concluded. This implies that an increase in traffic density results in a decrease in unit costs and thus in a decrease in operating costs per aircraft movement, which signals the presence of economies of density. Additionally, studies have often concluded that the more points an airline serves, the higher the total costs of the airline (Caves et al., 1984; Windle, 1991; Hansen et al., 2001), which proves that a diverse network is more costly. The number of points an airline serves correlates positively with average costs (Baltagi et al., 1995), but also with the airline's operating margin (Gitto and Minervini, 2007).

The average stage length of an airline is often acknowledged as the most important cost driver (Hazedine, 2010) because with an increase in the average stage length, important variable costs concerning fuel, staff and maintenance increase. However, many authors have demonstrated that, keeping other (output) variables constant, the average stage length of an airline has a negative effect on the total costs of the airline (Caves et al., 1984; Gillen et al., 1990; Banker and Johnston, 1993), which is obvious evidence of the existence of economies of stage length. Moreover, other studies have pointed out that an increase in the average stage length correlates negatively with the average or unit costs and with the average air fare (Baltagi et al., 1995; Bitzan and Chi, 2006; Tsoukalas et al., 2008). Ryerson and Hanson (2013) found a slightly less than

proportional positive effect on an airline's direct operating costs per departure. Still, results are not unanimous: Chua et al. (2005) found no significant effect of stage length on total costs, while Brügggen and Klose (2010) found no evidence of a relationship between route length and an airline's operating performance. Furthermore, Mantin and Wang (2012) reported a negative relationship between stage length and operating profit margin.

The results of the analysis of the impact of the average load factor on airline costs are rather straightforward. Most studies have found a negative relationship between load factor and total airline costs (Caves et al., 1984; Windle, 1991; Hansen et al., 2001; Chua et al., 2005), implying that a higher load factor leads to lower total costs, which is evidence of the existence of substantial economies of load factor. In accordance with this, Bitzan and Chi (2006) found a negative effect of load factor on average air fares, Baltagi et al. (1995) found a negative effect on average airline costs and Antoniou (1992), Tsikriktsis (2007) and Mantin and Wang (2012) concluded that an airline's load factor has a positive impact on its operating margin. Only Gitto and Minervini (2007) found a deviating result: no effect of load factor on operating margin.

Previous literature has pointed to the influence of different fleet characteristics on an airline's cost performance. First, several scholars concluded that significant cost economies of aircraft size exist (Nicol, 1978; Banker and Johnston, 1993; Wei and Hansen, 2003; Ryerson and Hansen, 2013), implying that larger aircraft are more cost efficient. This is supported by Bitzan and Chi (2006), who found that aircraft size correlates negatively with average air fares. Second, several authors have studied the impact of aircraft age on operating performance and airline costs. While Antoniou (1992) found a negative relationship between aircraft age and operating margin and Ryerson and Hansen (2013) found that increasing aircraft age leads to higher direct operating costs per departure, Banker and Johnston (1993) found no evidence of any relationship. The notion that the normally higher maintenance costs of older aircraft are compensated by lower ownership costs (depreciation or leasing costs) (Swan and Adler, 2006; Berritella et al., 2009) supports the conclusion that there is no obvious effect of aircraft age on airline costs. Hazel et al. (2012) even concluded that aircraft older than 15 years have lower maintenance

Table 1
Descriptive statistics.

Variable	Mean	Std deviation	Min value	Max value
Operating costs per aircraft movement (in USD)	24,100	20,476	3620	111,390
North America (share)	0.2227	0.4171	0.0000	1.0000
Asia (share)	0.2133	0.4106	0.0000	1.0000
Other regions (share)	0.2180	0.4139	0.0000	1.0000
Europe (share)	0.3460	0.4768	0.0000	1.0000
Average stage length (in km)	1595	880	295	4640
Number of operations	296,185	373,920	8819	2,134,024
Number of points served	95	73	10	387
Average load factor	0.7518	0.0672	0.5970	0.8750
Average aircraft size	164	46	42	334
Aircraft utilization (×1000 km)	2610	877	712	5161
Fleet commonality	0.4762	0.2643	0.1332	1.0000
Share of turboprop	0.0962	0.1916	0.0000	1.0000
Share of full freighter	0.0156	0.0354	0.0000	0.1722
Average aircraft age	8.5	3.6	2.0	21.4
Oil price (in USD per barrel)	79	12	57	107
Staff costs/employee (×1000 USD)	64.5	30.7	5.4	146.8
Number of hubs	1.8	1.6	0.0	7.0
Route dominance	0.5327	0.1882	0.1304	1.0000
Hub dominance	0.4126	0.2047	0.0566	0.9336
Alliance membership	0.4550	0.4992	0.0000	1.0000
Private ownership	0.7109	0.4544	0.0000	1.0000

Table 2
Correlations.

	Operating costs per operation (ln)	Average stage length (ln)	Operations (ln)	Points served (ln)	Load factor (ln)	Aircraft size	Aircraft utilization (ln)	Fleet commonality (ln)	Dummy turboprop	Dummy full freighter	Aircraft age ² (ln)	Oil price	Staff costs/employee
Operating costs per operation (ln)	1.000												
Average stage length (ln)	0.802	1.000											
Operations (ln)	-0.086	-0.062	1.000										
Points served (ln)	0.193	0.171	0.812	1.000									
Load factor (ln)	0.150	0.334	0.316	0.394	1.000								
Aircraft size	0.737	0.697	0.034	0.170	0.291	1.000							
Aircraft utilization (ln)	0.359	0.627	0.335	0.289	0.250	0.508	1.000						
Fleet commonality (ln)	-0.548	-0.494	-0.287	-0.419	-0.052	-0.225	-0.395	1.000					
Dummy turboprop	0.093	-0.025	-0.011	0.028	-0.279	-0.214	-0.146	-0.502	1.000				
Dummy full freighter	0.549	0.436	0.163	0.254	-0.009	0.342	0.237	-0.464	0.177	1.000			
Aircraft age ² (ln)	0.148	0.066	0.058	0.090	-0.044	-0.093	0.069	-0.370	0.185	0.101	1.000		
Oil price	0.131	0.035	-0.020	-0.037	-0.019	0.025	0.067	-0.040	0.048	0.057	0.001	1.000	
Staff costs/employee	-0.083	-0.328	0.323	0.278	0.219	-0.090	-0.160	0.105	-0.143	-0.072	0.162	0.021	1.000
Dummy no hubs	-0.506	-0.401	-0.022	-0.155	0.183	-0.251	-0.422	0.707	-0.343	-0.335	-0.366	-0.026	0.260
Dummy one hub	0.355	0.376	-0.471	-0.257	-0.196	0.214	0.232	-0.249	0.057	0.201	0.117	0.041	-0.257
Route dominance ⁴ (ln)	-0.054	-0.039	0.094	0.208	-0.055	-0.269	-0.026	-0.215	0.211	0.025	0.384	-0.020	0.057
Hub dominance ⁴ (ln)	0.286	0.314	0.222	0.257	-0.129	0.074	0.468	-0.640	0.307	0.290	0.245	0.016	-0.195
Alliance membership	0.333	0.224	0.279	0.408	0.078	0.122	0.304	-0.604	0.115	0.216	0.382	-0.010	0.215
Private ownership	-0.294	-0.278	0.378	0.252	0.319	-0.088	-0.085	0.292	-0.245	-0.169	-0.110	-0.035	0.459
Dummy 2007	-0.043	-0.039	0.003	-0.034	0.049	-0.025	-0.001	-0.020	-0.042	-0.001	-0.013	-0.119	-0.019
Dummy 2008	0.089	0.005	-0.003	-0.028	-0.118	0.012	0.074	-0.012	0.001	0.016	0.004	0.697	-0.020
Dummy 2009	-0.058	0.002	0.015	0.043	-0.040	-0.002	-0.033	0.014	-0.017	-0.021	-0.007	-0.696	-0.002
Dummy 2010	0.013	0.032	-0.015	0.019	0.115	0.015	-0.042	0.018	0.058	0.006	0.016	0.128	0.042
Dummy Europe	-0.129	-0.469	-0.037	0.173	-0.133	-0.184	-0.423	0.143	-0.029	-0.160	-0.107	-0.037	0.439
Dummy North America	-0.291	-0.040	0.390	0.217	0.427	-0.233	0.107	0.124	-0.176	-0.214	0.195	-0.048	0.163
Dummy Asia	0.264	0.281	-0.104	-0.102	-0.170	0.360	0.098	-0.170	0.146	0.218	-0.061	0.018	-0.371
Dummy other	0.180	0.303	-0.247	-0.317	-0.109	0.089	0.283	-0.121	0.066	0.183	-0.014	0.074	-0.302

costs than aircraft between 10 and 15 years old. Third, various papers have elaborated on the positive effect of fleet commonality on the operating margin of an airline (Seristö and Vepsäläinen, 1997; Gitto and Minervini, 2007; Brüggén and Klose, 2010), suggesting that airlines with a more uniform fleet are more cost efficient. In addition, Brüggén and Klose (2010) concluded that a larger fleet size leads to a higher operating margin, while Gillen and Morrison (2005) mentioned the existence of economies of aircraft utilisation. Tsikriktsis (2007) and Mantin and Wang (2012) found a positive relationship between aircraft utilisation and profitability. Finally, operating a turboprop aircraft is less expensive than operating a jet aircraft of the same size (Bitzan and Chi, 2006).

Obvious effects of fuel and labour price on airline costs exist as well. This is not surprising because the data from the airlines' annual reports show that, on average, fuel and labour costs form approximately 50 per cent of an airline's total costs. Multiple studies have concluded that the higher the fuel price and/or labour price, the higher the total costs of the airline (Windle, 1991; Seristö and Vepsäläinen, 1997; Hansen et al., 2001) or the higher the direct operating costs per departure (Ryerson and Hansen, 2013), which means that lower fuel and/or labour costs can lead to substantial cost savings (Anbil et al., 1991). In contrast, Gitto and Minervini (2007) found no relationship between the number of employees and an airline's operating margin.

Finally, previous studies have pointed to the effects of airlines' specific characteristics on their cost performance. Several studies concluded that hubbing leads to significant cost savings (Banker and Johnston, 1993; Baltagi et al., 1995; Berry et al., 1997) as a result of economies of density. However, Bootsma (1997) and Düdden (2006) found that operating multiple hubs leads to increased complexity costs. Banker and Johnston (1993) added that carriers that dominate their hubs, and therefore may have some

monopoly power, can achieve relatively greater economies from hub concentration than carriers operating at competitive hubs. Additionally, Chua et al. (2005) found a negative relationship between having large code share alliance partners and total costs; however, Goh and Yong (2006) did not find any significant effects of code share alliance partners. The final factor mentioned in the existing literature is that government-owned airlines have higher total costs than privately owned airlines (Windle, 1991).

While most of the studies above focus on just a few of the factors mentioned, this paper examines the effect of all factors, including the effect on aircraft operating costs of route and hub dominance, alliance membership and governmental ownership. The data and variables used for this exercise will be discussed in Section 3 of this paper.

2.2. Hypotheses

Based on the existing literature as presented above, the following hypotheses have been constructed:

- The number of operations leads to lower operating costs per aircraft movement due to economies of density.
- The number of points served leads to higher operating costs per aircraft movement.
- The average stage length leads to higher operating costs per aircraft movement.
- A higher load factor leads to lower operating costs per aircraft movement.
- An increase in aircraft size leads to a relatively smaller increase in operating costs per aircraft movement because of economies of aircraft size.

Dummy no hubs	Dummy one hub	Route dominance ⁴ (ln)	Hub dominance ⁴ (ln)	Alliance membership	Private ownership	Dummy 2007	Dummy 2008	Dummy 2009	Dummy 2010	Dummy Europe	Dummy North America	Dummy Asia	Dummy other
1.000													
-0.398	1.000												
-0.199	0.184	1.000											
-0.698	0.380	0.575	1.000										
-0.516	0.306	0.204	0.473	1.000									
0.360	-0.594	-0.215	-0.387	-0.110	1.000								
-0.002	-0.014	-0.020	-0.026	-0.017	0.011	1.000							
-0.033	0.017	-0.005	0.017	-0.001	-0.026	-0.331	1.000						
0.006	-0.021	0.030	0.028	0.023	0.011	-0.339	-0.361	1.000					
0.030	0.018	-0.007	-0.021	-0.007	0.004	-0.307	-0.327	-0.335	1.000				
0.010	0.038	0.170	-0.072	0.156	0.112	-0.007	-0.023	0.006	0.025	1.000			
0.230	-0.377	0.146	-0.147	-0.055	0.341	0.023	-0.007	0.008	-0.025	-0.389	1.000		
-0.132	0.026	-0.423	-0.058	-0.081	-0.281	-0.018	0.007	-0.004	0.015	-0.379	-0.279	1.000	
-0.218	0.311	0.076	0.288	-0.045	-0.195	0.003	0.026	-0.011	-0.019	-0.384	-0.283	-0.275	1.000

- Higher aircraft utilisation leads to lower operating costs per aircraft movement.
- Higher fleet commonality leads to lower operating costs per aircraft movement.
- Older aircraft are more expensive to operate because of increasing maintenance costs.
- Operating turboprop aircraft leads to lower operating costs per aircraft movement.
- Lower route dominance forces airlines to be more efficient, which results in lower operating costs per aircraft movement.
- Hub dominance results in lower operating costs per aircraft movement because of the probable increased airline buyer power and the possibility of more optimal aircraft and/or crew utilisation.
- Membership in a major alliance enables an airline to closely cooperate with alliance partners, which goes hand in hand with substantial cost savings.
- Privately owned airlines are more profit-driven and, accordingly, are more eager to limit operating costs.

3. Research method

3.1. Parametric approach

In this paper, a parametric approach is used to estimate the effects of airline operating costs. In earlier literature, scholars also used nonparametric techniques to estimate airline cost functions. The main advantage of parametric methods is that they are more efficient and therefore the conclusions drawn tend to be more powerful. On the other hand, as parametric techniques make more assumptions regarding the population distribution and sample size,

nonparametric methods are generally more flexible, more robust and more applicable to non-quantitative data. Due to the availability of a sizable sample of 59 airlines over a period of four years, parametric methods are used for the estimations.

The paper presents the results of a random effects and fixed effects estimation for 2007–2010. Using fixed effects techniques allows for the control of airline-specific effects that do not or hardly differ over time (such as business strategy, image and region). In a second step, an ordinary least squares (OLS) regression is used to estimate the effects of time invariant variables on the fixed effect term. Adding the results of the OLS regression makes it possible to examine the influence of variables that are fixed over time, but measurable, such as the number of hubs and private ownership. The econometric model is as follows:

$$\ln(\text{OCA}) = (\alpha + \delta_i) + \beta_1\chi_{1it} + \beta_2\chi_{2it} + \dots + \beta_n\chi_{nit} + \epsilon_{it} \tag{1}$$

$\ln(\text{OCA})$ is the natural logarithm of the airline operating costs per aircraft movement,¹ while $\alpha + \delta$ forms the fixed part of the equation, consisting of a constant (α) and an individual airline fixed effect (δ) (in the case of the fixed effects model). The explanatory variables χ form the set of factors that have a significant effect (β) on the operating costs per aircraft movement. The paper distinguishes between variables concerning airline-output characteristics, airline-fleet characteristics and airline-market characteristics.

¹ Note that only flights operated by the respective carrier are taken into account. Hence, code share flights are only considered as an “operation” for the airline that actually operates the flight.

3.2. Data

This research analyses the effects of an extensive set of airline characteristics on the operating costs per aircraft movement (see Table 1 for descriptive statistics and Table 2 for correlations). Annual reports of 59 airlines for 2007–2010 (see Appendix A) have been analysed to map the operating costs, the output variables and the fleet variables for each airline for each year. Variables that are not distributed normally have been log transformed. Additional information on how the variables are constructed is provided below.

The dependent variable is the total operating costs per aircraft movement, which is calculated as follows:

Operating costs per aircraft movement

$$= \frac{\text{Total operating costs}}{N \text{ of aircraft movements}} \quad (2)$$

The total operating costs have been taken from the airline's annual report, while the total number of aircraft movements is from the OAG database.

The airline-output variable load factor has been taken from the airline's annual report for the respective year, while the number of

well. Using only the number of aircraft types operated by an airline is misleading because an airline's fleet can exist of 90 per cent one aircraft type and 10 per cent another four different aircraft types. For example, an airline operating 50 737-700s and 50 A320s has a substantially lower fleet commonality than an airline operating 99 737-700s and 1 A320. This operationalisation leads to a fleet commonality value between 0 and 1, whereas an airline that operates only one aircraft type has a fleet commonality value of 1.

Average oil prices (US\$ per barrel) for the respective financial years have been derived from data published by the US Energy Information Administration.³ Staff costs per employee, as a proxy for staff productivity, follow from the annual reports (staff costs divided by number of employees at year-end). Additionally, dummy variables have been added for alliance membership, private ownership, the respective years and the region to which the airline belongs. Moreover, dummy variables have been used to indicate whether an airline operates no hub, one hub or multiple hubs.⁴ Finally, measures of route dominance and hub dominance⁵ have been added to the database. Route dominance has been operationalised as follows:

$$\text{Route dominance airline } x = \frac{N \text{ of aircraft movements by airline } x \text{ on all routes}}{N \text{ of aircraft movements of all airlines on all routes airline } x \text{ operates}} \quad (5)$$

Hub dominance has been measured as follows:

$$\text{Hub dominance airline } x = \frac{N \text{ of aircraft movements by airline } x \text{ from all its hubs or bases}}{N \text{ of aircraft movements of all airlines from all airline } x \text{'s hubs or bases}} \quad (6)$$

operations, number of points served and average stage length are derived from the OAG database. The latter three are often not mentioned in annual reports.

Airline fleet variables such as average aircraft size, average aircraft age and fleet size and the dummies for the use of turboprop and full freighter aircraft are taken from the airline's annual report. The aircraft utilisation variable has been operationalised as follows:

$$\text{Aircraft utilisation} = \frac{N \text{ of operations} \times \text{average stage length}}{N \text{ of aircraft in fleet at year - end}} \quad (3)$$

Finally, fleet commonality has been operationalised as follows:

$$\text{Fleet commonality} = \left(\frac{N \text{ of most common aircraft type in fleet}}{N \text{ of aircraft in fleet}} + \frac{1}{N \text{ of aircraft types in fleet}} \right) / 2 \quad (4)$$

In this way, next to the number of aircraft types,² the level of dominance of one aircraft type has been taken into account as

Data for both the route and hub dominance have been derived from the OAG database.

To conclude, no separate dummy variable for low-cost carriers has been added to the database because today there is no precise distinction between low-cost carriers and full-service carriers. Some full-service carriers have adopted low-cost carrier elements and vice versa. In addition, this paper aims to identify the effect of specific airline characteristics, which possibly disappear or reduce if a dedicated LCC dummy is added to the econometric models. Later, this paper discusses the implications of the econometric results for low-cost carriers and full-service carriers based on characteristics of those two airline types. In future research, it would be interesting to examine the results if airline-type dummy variables are added.

4. Econometric results

Table 3 shows the results of the econometric analyses of the factors influencing aircraft operating costs. The summary of the random

³ http://www.eia.gov/dnav/pet/pet_pri_spt_s1_d.htm.

⁴ In a few cases, it is slightly arbitrary whether an airline operates a hub at a certain airport. However, the assumptions made do not affect the econometric results.

⁵ In the case of a low-cost carrier, it concerns its dominance at its base(s).

² Aircraft types of the same family (for instance, Boeing 737–700 and Boeing 737-800) have been considered as similar aircraft types.

Table 3
Econometric results.⁶

	Random effects model		Step 1: Fixed effects model		Step 2: OLS model	
	Estimate	Std error	Estimate	Std error	Estimate	Std error
Dependent variable:	Operating costs/ac movement (ln)		Operating costs/ac movement (ln)		Average fixed effect score	
Airline-output characteristics:						
Average stage length (ln)	0.995***	0.138	1.156***	0.171		
Operations (ln)	-0.141***	0.053	-0.447***	0.061		
Points served (ln)	0.096*	0.054	0.178**	0.069		
Load factor (ln)	-0.175	0.249	-0.046	0.268		
Airline-fleet characteristics:						
Aircraft size	0.004***	0.001	0.001	0.001		
Aircraft utilization (ln)	-0.379***	0.106	-0.309***	0.107		
Fleet commonality (ln)	-0.038	0.059	-0.092	0.072		
Dummy turboprop	0.016	0.034	–	–	-0.074	0.117
Dummy full freighter	0.271***	0.087	–	–	0.442***	0.131
Aircraft age ² (ln)	0.008	0.025	-0.036*	0.020		
Airline-market characteristics:						
Oil price	0.004***	0.001	0.004***	0.001		
Staff costs/employee	0.004***	0.001	0.003**	0.001		
Dummy no hubs	-0.299**	0.125	–	–	-0.294*	0.154
Dummy one hub	-0.272***	0.105	–	–	-0.682***	0.155
Route dominance ⁴ (ln)	-0.025	0.022	-0.004	0.026		
Hub dominance ⁴ (ln)	0.013	0.019	0.050*	0.029		
Alliance membership	0.033	0.030	0.053**	0.025		
Private ownership	-0.136	0.087	–	–	-0.039	0.157
Dummy 2007	0.058***	0.162	0.031*	0.018		
Dummy 2008	0.080***	0.183	0.066***	0.019		
Dummy 2009	0.028	0.017	0.011	0.018		
Dummy 2010	Ref.		Ref.			
Dummy Europe	0.187*	0.102	–	–	0.373**	0.149
Dummy North America	-0.029	0.112	–	–	0.177	0.179
Dummy Asia	-0.029	0.108	–	–	0.166	0.167
Dummy other continent	Ref.		–	–	Ref.	
Constant	8.270***	1.315	10.122***	1.347	0.052	0.215
N	211		211 (59 airlines)		55	
R-squared	64.72		69.66 (within)		50.92	

***Significant at 1% level.

**Significant at 5% level.

*Significant at 10% level.

effects regression is shown in the first two columns, while the results of the fixed effects estimation are summarised in the last four columns, including the OLS estimation of the average fixed effects. For reasons of clarity, only the results of the fixed effects regression will be discussed in detail because the time-invariant airline-specific characteristics are to some extent expected to correlate with the explanatory variables in the model. In this case, the fixed effects model is more appropriate than the random effects model.

4.1. Step 1: fixed effects regression results

The results of the fixed effects analysis based on airline data for 2007–2010 yield the following estimation, with ln(OCA) being the natural logarithm of the operating costs per aircraft movement:

$$\begin{aligned}
 \ln(\text{OCA}) = & 10.1222 + 1.1556 \ln(\text{ASL}) + -0.4473 \ln(\text{OPR}) \\
 & + 0.1778 \ln(\text{PTS}) + -0.3086 \ln(\text{UTI}) \\
 & + -0.0362 \ln(\text{ACA}) + 0.0040 \text{OIL} + 0.0035 \text{STC} \\
 & + 0.0500 \ln(\text{HDO}) + 0.0529 \text{ALM} + 0.0312 \text{D07} \\
 & + 0.0661 \text{D08}
 \end{aligned}
 \tag{7}$$

Obvious airline-output effects exist. Keeping all other variables constant, the number of airline operations (ln(OPR)) correlates negatively with aircraft operating costs, which is evidence of the existence of substantial economies of density. This is consistent with previous literature on cost economies in the aviation industry (see e.g. Bailey and Friedlaender, 1982; Braeutigam, 1999; Brueckner and Spiller, 1994; Caves et al., 1984; Gillen and Morrison, 2005). In addition, airlines can profit from substantial cost savings by concentrating operations on fewer destinations because an increase in the number of points served (ln(PTS)) leads to higher operating costs per aircraft movement. Moreover, the results do not provide evidence of the existence of economies of stage length because an increase in average stage length (ln(ASL)) leads to a slightly higher than proportional increase in operating costs per aircraft movement. There is no significant effect of load factor on the operating costs per aircraft movement, proving the existence of economies of load factor. This implies that the marginal costs of additional passengers are negligible, resulting in decreasing operating costs per passenger as a result of increasing load factors.

The results concerning the airline-fleet characteristics show no signs of significant aircraft size effects. This suggests that economies of aircraft size exist because an increase in aircraft size does not lead to an increase in operating costs per aircraft movement. In addition, the results show a significant negative effect of aircraft utilisation (ln(UTI)) on the operating costs per aircraft movement. This implies that higher fleet utilisation leads to lower average operating costs, as Gillen and Morrison (2005)

⁶ The cluster(id) function in Stata has been used to estimate robust parameters.

suggested. Most remarkably, however, is the significant negative effect of aircraft age ($\ln(\text{ACA})$) on average operating costs per aircraft movement, which contradicts [Ryerson and Hansen \(2013\)](#). The negative effect suggests that ownership costs (depreciation and leasing costs) of new aircraft outweigh the increasing maintenance costs of old aircraft. This is partly in line with [Hazel et al. \(2012\)](#), who concluded that aircraft older than 15 years have lower maintenance costs than aircraft between 10 and 15 years old. Finally, the results show the expected sign concerning fleet commonality; however, this effect is not statistically significant.

The staff costs per employee (STC), as well as the average oil price (OIL), play a significant role in aircraft operating costs: higher staff costs per employee and higher average oil price lead to substantially higher aircraft operating costs. Surprisingly, airlines that are members of an alliance (ALM) bear higher aircraft operating costs than airlines that are not. The main reason for this is probably that low-cost carriers are not members of any worldwide alliance, while in general they have the lowest operating costs per aircraft movement. Another possible explanation is that financially weak network carriers are more likely to seek cooperation within a worldwide alliance, while financially more viable carriers (like some Gulf carriers) prefer their independence. A third possible explanation is that airlines must meet certain conditions to join an alliance. Complying with those conditions can go hand in hand with increasing operating costs. However, only significant at the 10 per cent level, hub or base dominance ($\ln(\text{HDO})$) correlates positively with the operating costs per aircraft movement. This contradicts [Banker and Johnston \(1993\)](#) and the hypothesis that hub dominance results in lower operating costs per aircraft movement because of the probable increased airline buyer power and the possibility of more optimal aircraft and/or crew utilisation. The result may imply that the absence of serious competitive pressure on their hub or base enables airlines to charge higher ticket prices and, with that, leads to a limited focus on cost savings. Finally, in 2007 and 2008, operating costs per aircraft movement were significantly higher than in 2010, which seems intuitive because of the extensive cost-cutting measures many airlines have taken in response to the financial crisis. The effects of those measures first came to light in 2009 and 2010, leading to significantly lower aircraft operating costs.

4.2. Step 2: decomposing the fixed effects

In a second step, the effects of the time-invariant variables forming the fixed effects are identified by regressing the average predicted fixed effect score for every airline on the time-invariant variables. The abovementioned regression results in the following estimation, with AFE being the average fixed effects score:

$$\text{AFE} = 0.4422 \text{ FFR} + -0.2943 \text{ NHU} + -0.6816 \text{ 1HU} + 0.3730 \text{ EUR} \quad (8)$$

The results do not show evidence supporting the notion that airlines that operate turboprop aircraft have lower average operating costs per aircraft movement, which partly contradicts [Bitzan and Chi \(2006\)](#), who found that turboprop aircraft are cheaper to operate. On the other hand, airlines that operate full freighters (FFR) have higher average operating costs per aircraft movement than airlines that do not operate a freight network. This suggests that having a freight operation next to a passenger operation results in substantially higher overhead costs.

Furthermore, the results show significant evidence of the existence of complexity costs, as put forward by [Bootsma \(1997\)](#) and [Düdden \(2006\)](#), because airlines that operate no (NHU) or only one hub (1HU) have significantly lower operating costs per aircraft movement than airlines that operate multiple hubs. The results do not show any significant effect of private ownership. Finally, not surprisingly, airlines based in Europe (EUR) have significantly higher operating costs per aircraft movement than airlines based in less developed continents.

4.3. Implications of the results

The results of the fixed effects analysis show substantial effects of airline-output characteristics. A 10 per cent increase in the average stage length leads, *ceteris paribus*, to an increase in operating costs per aircraft movement of approximately 11.6 per cent. With this, the results provide no evidence for any economies of stage length, suggesting that long(er) haul operations bring (at least) proportionally higher operating costs.⁷ Furthermore, an increase in the total number of operations of 10 per cent results in operating cost savings per aircraft movement of approximately 4.2 per cent. On the other hand, a 10 per cent increase in the number of destinations (points served) leads to an increase in operating costs per aircraft movement of approximately 1.7 per cent. A load factor increase does not lead to a significant change in aircraft operating costs.

Some effects of airline-fleet characteristics are statistically significant as well: a 10 per cent increase in aircraft utilisation leads to operating cost savings of approximately 2.9 per cent. More surprisingly, a 10 per cent increase in fleet age results in an operating cost reduction of around 0.3 per cent. Finally, airlines that operate full freighter aircraft have on average 55.6 per cent higher operating costs per aircraft movement. There is no significant effect of aircraft size on operating costs per aircraft movement.

Hub-related effects appear as well. The results show that airlines that operate no hub (often low-cost carriers) or concentrate their activities in one hub have, respectively, 25.5 per cent and 49.4 per cent lower operating costs per aircraft movement than airlines operating multiple hubs, suggesting the presence of significant complexity costs as a result of split operations. Furthermore, airlines that have 10 per cent higher hub dominance face approximately 0.5 per cent higher operating costs per aircraft movement.

Additionally, lower staff costs per employee lead to lower operating costs per aircraft movement as well: a decrease in staff costs per employee of \$1000 US on a yearly basis results in 0.4 per cent operating cost savings. In addition, a \$1 US lower oil price per barrel leads to aircraft operating cost savings of about 0.4 per cent. Airlines that are members of a worldwide alliance on average face 5.4 per cent higher operating costs per aircraft movement. Moreover, airlines based in Europe have on average 45.2 per cent higher operating costs than airlines based in Latin America, Africa or the Middle East. The results show conclusively that airlines had higher operating costs per aircraft movement before (2007: 3.2 per cent) and at the beginning (2008: 6.8 per cent) of the financial crisis.

In general, the results show that airlines can achieve cost savings by increasing the density of their networks: a higher number of operations, without increasing the network size (points served), leads to lower operating costs per aircraft

⁷ Note that the presence of economies of stage length has not been examined separately within the short-haul and the long-haul markets.

movement. On the other hand, a larger network in terms of number of points served leads to higher operating costs per aircraft movement. This implies that the results do not provide evidence of the existence of economies of scale. In addition, the results demonstrate that airlines can achieve additional cost savings per aircraft movement by maximising aircraft utilisation. Interestingly, acquiring new aircraft does not seem profitable. In fact, airlines can save costs by operating older aircraft. This suggests that depreciation or leasing costs of new aircraft outweigh the increasing maintenance costs of older aircraft with limited economic value. Furthermore, airlines can reduce their operating unit costs per passenger by maximising their load factor because an increasing load factor does not lead to higher operating costs per aircraft movement. Hence, airlines can increase their profit by increasing their load factor, without facing higher operating costs. The same holds for average aircraft size: an increase does not lead to higher operating costs per aircraft movement. Also, airlines that do not operate a costly full freighter network and do not face the complexity costs of a multi-hub system enjoy lower aircraft operating costs. Joining a worldwide airline alliance also leads to higher operating costs per aircraft movement. Finally, airlines can achieve significant operating cost savings by limiting staff costs per employee and by efficient fuel hedging.

Most of the abovementioned causes for lower aircraft operating costs constitute evidence supporting the difference in cost structure between low-cost carriers and full-service carriers. After all, low-cost carriers normally have high aircraft utilisation, high load factors, do not operate full freighters, do not operate a costly multi-hub system, are not members of a worldwide airline alliance and have substantially higher labour productivity. Additionally, it appears from our database that most low-cost carriers on average have rather low dominance at their bases, which also points to lower operating costs per aircraft movement. On the other hand, high fleet commonality, a typical low-cost carrier feature, does not lead to lower operating costs per aircraft movement.

Finally, some cost-saving elements especially point to cost economies for full-service carriers. Here, most profound are the obvious economies of density, which mainly stem from hub-and-spoke networks. In addition, full-service carriers often have a higher average fleet age (low-cost carrier Allegiant being the most remarkable exception here); in particular, full-service carriers in the Middle East and Asia often operate with a large average aircraft size. Many full-service carriers outside Europe and the United States also concentrate their operations on one hub airport, avoiding additional complexity costs resulting from split operations.

5. Concluding remarks

This paper has identified the airline characteristics that influence operating costs per aircraft movement. The econometric analysis is based on financial and operational data from annual reports, as well as from network data from the Official Airline Guide. The paper shows the results of a fixed effects estimation based on data for 2007–2010. The results especially add to the existing literature on airline cost economies because of the comprehensive set of explanatory and control variables available for the econometric analyses. Unlike most of the existing literature, this paper combines a wide variety of airline-output variables, airline-fleet variables and airline-market variables. This limits the risk of spurious relationships.

The results show significant economies of density, which is consistent with the majority of the existing literature (see e.g. Bailey and Friedlaender, 1982; Braeutigam, 1999; Brueckner and

Spiller, 1994; Caves et al., 1984; Gillen and Morrison, 2005). In addition, economies of load factor appear. The results do not show evidence of the existence of significant economies of scale or economies of stage length.

The analysis of airline-fleet characteristics shows clear signs of economies of aircraft utilisation and economies of aircraft size. More remarkably, the regression results suggest that airlines that use newer aircraft and passenger airlines that also operate full freighters have higher average operating costs per aircraft movement. The former suggests that ownership costs (depreciation and leasing costs) of new aircraft outweigh the increasing maintenance costs of old aircraft. Additionally, the results show no significant evidence of the presence of economies of fleet commonality.

Obvious significant positive effects from oil and labour prices are also found. Moreover, airlines that are members of a worldwide airline alliance face higher average operating costs per aircraft movement. In addition, the results show that operating multiple hubs is more costly than operating no or just one hub. This suggests that substantial complexity costs appear as a result of operating more than one hub, which is in line with Bootsma (1997) and Düdden (2006). Finally, the results show that airlines that have a dominant position at their hub(s) or base(s) have higher operating costs per aircraft movement, implying that the absence of serious competitive pressure on their hub or base enables airlines to charge higher ticket prices and, with that, leads to a limited focus on cost savings.

In general, the results provide evidence of the difference in cost structure between low-cost carriers and full-service carriers. After all, low-cost carriers normally have high aircraft utilisation, high load factors, do not operate full freighters, do not operate a costly multi-hub system, are not members of a worldwide airline alliance, have a substantially higher labour productivity and are on average less dominant at their bases than full-service carriers at their hubs. On the contrary, full-service carriers especially enjoy cost economies of density because of their hub-and-spoke systems. In addition, they operate on average older aircraft and partly operate with a larger average aircraft size.

This paper has some limitations. First, it only looks at the cost component of airlines. While in the airline industry having relatively low operating costs is essential for a healthy business model, enjoying low costs does not automatically guarantee high profits. Second, because of the limited sample size, single observations have a higher impact on the final results than in the case of a larger sample.

Future research can focus on factors affecting an airline's profitability by adding a revenue component to the analysis. Furthermore, it would be valuable to examine the precise effect of aircraft leasing on airline finances. It would also be interesting to have a better understanding of the relationship between hub and route dominance and operating performance, which is a rather under-exposed subject in aviation literature. Finally, explicitly distinguishing between low-cost carriers and full-service carriers (see e.g. Tsiriktsis, 2007), as well as between different regions, would shed additional light on the differences in cost economies between airline types and between regions.

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Appendix A. Airline-year combinations in database.

Airline	2007	2008	2009	2010	Airline	2007	2008	2009	2010
Adria Airways	x	x	x		Gol	x	x	x	x
Aer Lingus	x	x	x	x	Hawaiian Airlines	x	x	x	x
Aeroflot			x	x	Iberia	x	x	x	x
Air Asia	x	x	x	x	Japan Airlines	x	x		
Air Astana	x	x	x	x	Jet Airways	x	x	x	x
Air Berlin	x	x	x	x	Jetblue Airways	x	x	x	x
Air Canada	x	x	x	x	Kenya Airways	x	x	x	x
Air France-KLM	x	x	x	x	Kingfisher Airlines		x	x	x
Air Mauritius		x	x	x	LAN	x	x	x	x
Air New Zealand	x	x	x	x	Lufthansa	x	x	x	x
Air Seychelles	x	x			Malaysia Airlines	x	x	x	x
AirTran	x	x	x	x	Norwegian Air Shuttle	x	x	x	x
Alaska Airlines	x	x	x	x	Oman Air	x	x	x	x
All Nippon Airways	x	x	x	x	Qantas	x	x	x	x
Allegiant Air	x	x	x	x	Ryanair	x	x	x	x
American Airlines	x	x	x	x	SAS	x	x	x	x
Blue1	x	x	x	x	Singapore Airlines	x	x	x	x
British Airways	x	x	x		South African Airways	x	x	x	x
Cathay Pacific	x	x	x	x	Southwest Airlines	x	x	x	x
China Eastern Airlines		x	x		TAM	x	x	x	
Continental Airlines	x	x	x		Thai International Airways	x	x	x	x
Croatia Airlines		x	x	x	Tiger Airways			x	x
Czech Airlines	x	x	x	x	Turkish Airlines	x	x	x	x
Delta Airlines			x	x	United Airlines	x	x	x	
EasyJet	x	x	x	x	US Airways	x	x	x	
Emirates		x	x	x	Virgin Australia	x	x	x	
Ethiopian Airlines	x	x	x	x	Vueling	x	x	x	x
Finnair	x	x	x	x	Westjet	x	x	x	x
Flybe			x	x	Wideroe	x	x	x	x
Garuda	x	x	x	x					

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