Fleet Standardization and Airline Performance

Li Zou[a*], Chunyan Yu[a] and Martin Dresner[b]

[a]College of Business, Embry-Riddle Aeronautical University,
Daytona Beach, FL 32114

[b]The Robert H. Smith School of Business, University of Maryland,
College Park, MD 20742

[*] Corresponding author: College of Business, Embry-Riddle Aeronautical University
600 S. Clyde Morris Blvd., Daytona Beach, FL 32114

[*]Phone: 386-226-6700
*Email: zoul@erau.edu

Abstract

We develop three new measures for fleet standardization in order to estimate its impact on airline costs and profitability. Using panel data for 28 U.S. airlines over the period 1999 to 2009, we find that fleet standardization, as expected, leads to lower unit costs. However, after controlling for the downward effect of standardization on unit cost, fleet standardization is negatively related to profit margin. Our findings provide quantitative evidence of the trade-off between the costs and benefits from fleet commonality. Although it has been widely accepted that airlines can benefit from cost savings in flight operations and maintenance with a more standardized fleet, the potential negative revenue impacts from fleet standardization have generally been overlooked.

Keywords: Fleet Standardization, Airline Performance, Operating Cost, Profitability

Data of Final Version: November 17, 2012

1.0 Introduction

Flying operations account for 37.5 per cent of passenger airlines' operating expenses in the United States, and maintenance accounts for an additional 9.8 per cent. It has been generally accepted that a standardized fleet reduces both flying operations expenses and maintenance costs. Moreover, a high degree of fleet standardization enables an airline to benefit from additional cost savings related to aircraft purchasing (Brüggen and Klose 2010). Because of its distinct cost advantages, fleet commonality has been considered to be a key attribute for the low cost carrier (LCC) model (Zhang et al. 2008; Brüggen and Klose 2010; Conrady et al. 2010).

Despite the well-acknowledged benefits from fleet standardization, there may be disadvantages as well. For example, a standardized fleet may lack flexibility in terms of payload and range to tailor to the demands of a complex route structure, and thus may become a hindrance for an airline to maximize its revenue potential. Even low-cost airlines may benefit from introducing new aircraft types to an existing standardized fleet, since the increased diversification could generate additional revenue and help to increase profitability.

In addition to the route selection constraint, airlines with a highly uniform fleet may lack the agility to react to changing market demand, especially on routes where flight frequency cannot be easily modified due to slot control limitations. In contrast, airlines with a diversified fleet are more capable to adjust aircraft size, not only to accommodate demand changes, but also to better respond to competitors' actions. Airlines often trade aircraft size for flight frequency in order to gain market share in a competitive setting (Wei and Hansen 2005) or in a market with growing traffic (Pitfield et al. 2010).

According to Kilpi (2007), fleet composition refers to the similarities and differences in the technical and operational characteristics among the aircraft in a particular fleet. Aircraft differ in terms of their payload capabilities at different ranges, fuel consumptions, maintenance requirements, reliability, etc. Major aircraft manufacturers generally offer multiple product lines termed as aircraft families, with each family consisting a number of models. For example, the Boeing 777 family consists of five passenger models and one freighter model, including 777-200, 777-200ER, 777-200LR, 777-300, 777-300ER, and 777-Freighter. The passenger models range from 301 seats to 368 seats in a three-class configuration with a range capability of 5,240 nautical miles (9,700 km) to 9,395 nautical miles (17,395 km). Aircraft from the same family tend to share similar characteristics, whereas aircraft by different manufacturers often have significantly different technical and operational characteristics. Therefore, we develop measures to distinguish fleet standardization at three different levels: manufacturer, family, and model. Such a hierarchical classification approach is helpful in determining which level of standardization is most associated with potential cost savings and profitability increases.

The objectives of this paper are to empirically investigate how fleet standardization affects airline unit costs and profitability. The paper extends previous research and addresses the following questions: First, to what extent can fleet standardization reduce an airline's unit cost? Second, what is the impact of fleet standardization on profitability? Third, are the impacts of fleet standardization at the aircraft family level different from the impacts at the aircraft model or manufacturer levels? Our results shed light on two important fleet composition decisions faced by an airline: whether to have a more diversified or standardized fleet; and at which level does fleet standardization maximize profitability.

The rest of the paper is organized as follows. Section 2 provides a brief review of the literature on fleet standardization and presents how we measure the degree of fleet standardization. Section 3 shows the overall trend in fleet standardization for U.S. airlines from 1999 to 2009 (the most recent data available at the time of writing) and presents differences in standardization among airline groups (network carriers vs. low-cost carriers vs. regional carriers). In Section 4, we describe our empirical model and provide a data summary. The estimation results are reported in Section 5, followed by simulation analyses. The final section draws conclusions and discusses the managerial implications from this research.

2.0 Fleet Standardization – Measurement and Impact

Generally speaking, a more diverse fleet may result in higher costs associated with pilot training, maintenance, scheduling, ground handling, and the lack of simplicity in operations. Therefore, an argument can be made that there is a significant cost advantage for carriers from operating a highly standardized fleet (West and Bradley, 2008; Brüggen and Klose, 2010). However, an airline with a standardized fleet may be constrained in its route selection; it may not be able to fly to smaller cities in order to feed traffic into hubs; and it may not be able to operate different sized aircraft on a route to meet fluctuating demand during the day, during the week, or from season to season. The lack of flexibility associated with a standardized fleet may have a negative effect on an airline's revenue. Because of these offsetting effects on cost and revenue, the overall impact of fleet standardization on profitability is uncertain.

Figure 1 illustrates the potential offsetting impacts of fleet standardization on profitability. On one hand, standardization is likely to reduce costs and thus increase profits. On the other hand, fleet standardization reduces airline flexibility, thereby potentially inhibiting revenue generation and consequently reducing profitability.

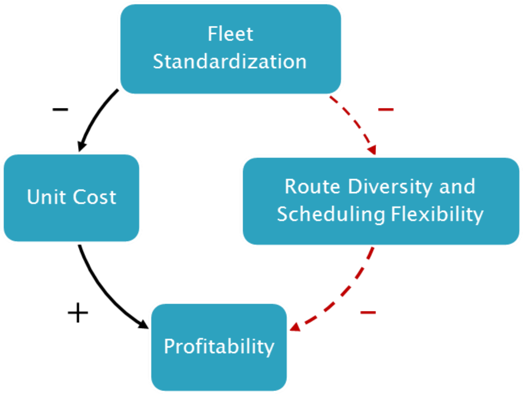


Figure 1. The Graphical Illustration of the Double-edged Effects from Fleet Standardization on Profitability

In order to assess the impact of fleet standardization on profitability, one must first establish measures of standardization. De Borges Pan and Espirito Santo (2004) introduce the IPF[1], IPC[2], and IPM[3] indices as measurements for fleet standardization. They consider three categories of aircraft characteristics including aircraft cell (or model), engine powerplant and avionics parts, and develop two fleet standardization measures: IPC for aircraft cell (or model) standardization and IPM for power-plant standardization. Building on IPC and IPM, a composite index, namely IPF, is created to measure the overall degree of an airline's fleet standardization. Using the IPC standardization measurement, Kilpi (2007) finds a positive correlation between fleet uniformity and airline operating profit margin for ten major airlines using worldwide data from 1997 to 2005. Using a similar standardization measurement approach, Brüggen and Klose (2010) conclude that fleet standardization has a positive impact on return on sales, and that this positive

---

[1] IPF refers to *Fleet Standardization Index, and* is from the initials in Portuguese of *Indice de Padronização de Frotas.*

[2] IPC refers to *Cell Standardization Index, and* cell was used by the authors to refer to the *hull of aircraft. See Appendix A for a detailed formulation for IPC.*

[3] IPM refers to *Powerplant Standardization Index.*

impact increases as fleet size grows. Finally, basing their standardization measure on a count of the different aircraft types in a fleet, West and Bradley (2008) find that for 10 major U.S. airlines during the period 2004-2006, the operating profit margin from domestic services increases as fleet complexity decreases.

A potential shortcoming of the IPC measurement is that all differences between aircraft are counted the same, whether they are distinctions between aircraft manufactured by different companies (Boeing 737 vs. Airbus A320), or differences between models within the same aircraft family (Boeing 737-300 vs. Boeing 737-800). Clearly, the training costs, maintenance costs, and staffing costs will be greater when the aircraft used by an airline are "more diverse". Therefore, as stated earlier, we propose three levels of fleet standardization indices as follows: (1) aircraft manufacturer as the basic level (Boeing vs. Airbus); (2) aircraft family as the 2nd level (Boeing 737 vs. Boeing 757); and (3) aircraft model as the 3rd level (Boeing 737-300 vs. Boeing 737-800). Note that these measures form a hierarchy. Aircraft differences at the manufacturer level also reflect differences at the family level, while aircraft differences at the family level also reflect differences at the model level.[4]

Our calculation for fleet standardization at all three levels is similar to Herfindahl-Hirshman Index (HHI), which is widely used to measure the degree of market concentration in industrial organization economics. To assess fleet standardization at the manufacturer level, HHI_mfr, we first calculate the share of aircraft made by the same manufacturer in the fleet of an airline. Second, we calculate the squared values of aircraft share derived for each aircraft manufacturer. Finally, the squared shares are added up across all aircraft manufacturers in the fleet. In a similar way, fleet standardization indices are derived at the aircraft family level, HHI_family, and at the aircraft model level, HHI_model. The formulae for HHI_mfr, HHI_family, and HHI_model are as follows.

$$\text{HHI\_mfr} = \sum_{\text{i}=1}^{\text{N}} \left(\frac{\text{The number of aircraft made by Manufacturer } i}{\text{The total number of aircraft in the fleet}}\right)^2 \qquad (1)$$

---

[4] The standardization indices are based on a hierarchy of differences, with differences between manufacturers the most basic distinction, followed by family differences and then distinctions among models. As an example, if an airline owns one aircraft from Family A and another from Family B, then, by definition, the two aircraft must not only represent two different families but must also be distinct models. Likewise, if an airline owns one aircraft from Manufacturer X and another from Manufacturer Y, then, by definition, the aircraft must also be from different families and must be distinct models.

$$\text{HHI\_family} = \sum_{j=1}^{F} \left(\frac{\text{The number of aircraft belonging to Aircraft Family } j}{\text{The total number of aircraft in the fleet}}\right)^2 \quad (2)$$

$$\text{HHI\_model} = \sum_{k=1}^{M} \left(\frac{\text{The number of aircraft belonging to Aircraft Model } k}{\text{The total number of aircraft in the fleet}}\right)^2 \quad (3)$$

Using our fleet standardization measures, we can assess the extent of fleet commonality at the three levels, respectively, and therefore, differentiate in terms of standardization levels between an airline that uses aircraft from multiple manufacturers and an airline that uses multiple models from the same aircraft family (or multiple families from the same manufacturer). A comparison between our standardization measurements and IPC is provided in Table 1. The table illustrates fleet data for three airlines. The table shows that whereas the IPC values indicate that all three airlines have the same degree of fleet standardization, our measures show discrepancies at the model, family and manufacturer level, potential causes of cost and profitability differences among the carriers. Thus, our HHI-based measures can provide a closer look at standardization differences among airlines than the IPC proposed by De Borges Pan and Espirito Santo (2004).

Table 1. The Comparison of Fleet Standardization Measurements

	Year	Fleet			HHI_ model	HHI_ Family	HHI_ mfr	IPC
Southwest	2006	193 Boeing 737-300	25 Boeing 737-500	265 Boeing 737-700	0.46	1	1	0.33
Air Wisconsin	2003	17 BAE146	49 Canadair CL6002B19 100/200	7 Dornier 382	0.51	0.51	0.51	0.33
Spirit Airlines	2006	18 A319	6 A321	12 MD DC9-80	0.38	0.55	0.55	0.33

3.0 Fleet Standardization Over Time and Among Airline Groups

Before we analyze the impact of fleet standardization on airline costs and profitability, it is useful to examine trends in standardization over time and differences in standardization among airline groups. Our analysis focuses on 28 U.S. airlines, including 7 network airlines, 8 low-cost carriers, and 13 regional airlines, during the 1999-2009 period.[5] These airlines represent 93 per cent of revenue-passenger miles among U.S. carriers during the period.

Figure 2 shows that U.S. airlines generally increased their fleet standardization over the 1999-2009 period. This result holds true for all three of our fleet standardization measurements, as well as for the previously used, IPC measurement. Such an increase in standardization occurred as low-cost airlines expanded market share in the U.S. and network carriers sought to emulate some of the key low-cost strategies, for example, by simplifying fleet composition.

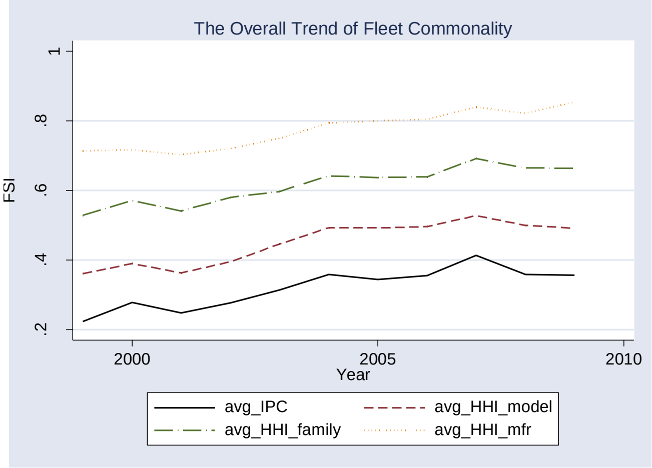
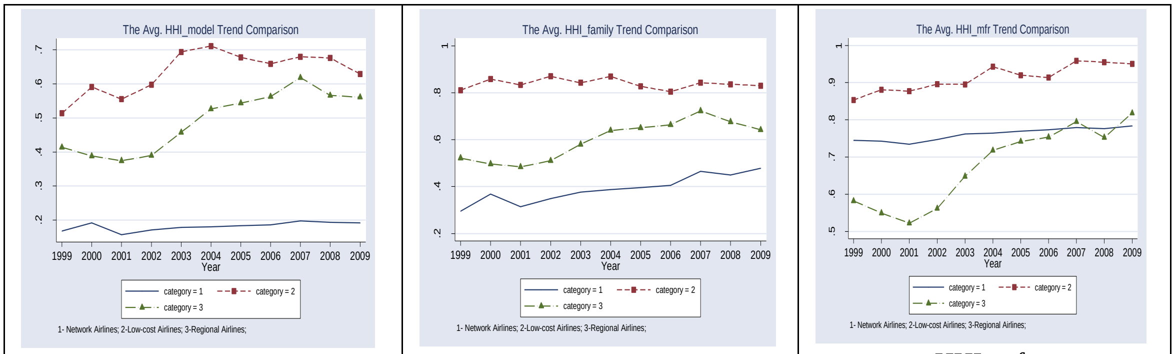


Figure 2. Fleet Standardization over Time

Figure 3 compares the degree of fleet standardization at the different levels (manufacturer, family and model) among network, low-cost, and regional airlines. For all three types of airlines, average standardization values generally increased during the 1999-2009 period. However, Figure 3 also illustrates that low-cost airlines, on average, have a higher degree of fleet standardization than do regional airlines, while the fleet for network airlines, in general, is the least standardized among these three types of airlines.

---

[5] The seven network airlines include American, Alaska, Continental, Delta, Northwest, United, and US Airways; the eight low-cost carriers are Airtran Airways, Allegiant Air, Frontier, Hawaiian, JetBlue Airways, Southwest, Spirit Airlines, and Sun Country; and the thirteen regional airlines include Air Wisconsin, American Eagle, ATA Airlines, Atlantic Southeast, COMAIR, ExpressJet, Horizon Air, Mesa Airlines, MESABA, Midwest Express, Pinnacle, Skywest, Trans States Airlines.



HHI_model HHI_family HHI_mfr

Figure 3. The Comparison of Fleet Standardization (measured by HHI_model, HHI_family & HHI_mfr) among Network, Low-cost and Regional Airlines

In the next section of the paper, we describe the model that we use to assess the impact of fleet standardization on airline costs and profitability.

4.0 Empirical Analysis

In this section, we conduct empirical analyses to investigate the relationship between an airline’s fleet standardization and the airline’s unit operating cost (as measured by operating expenses per available seat-mile (ASM)) and operating profit margin. We measure fleet standardization using our three measures, HHI_model, HHI_family, and HHI_mfr, plus IPC, the measure previously used in the literature, which serves as our base case.

4.1 Data Description

To address our research questions, we focus on U.S. airlines, since costs and profits are more comparable across carriers in the same country than among carriers from different countries. The data are mainly collected from three OAG Aviation Solutions databases, including FORM41, T100 and Fleet iNet. In addition, we compile fleet composition and aircraft utilization information for U.S. airlines from the ICAO database. After combining the OAG and ICAO datasets and eliminating cases with missing values and probable data errors, the final sample consists of 276 annual observations for 28 U.S. airlines through 11 years from 1999 to 2009. A total of 91 aircraft models are operated by the airlines, and these models are categorized into 35 aircraft families from 16 aircraft manufacturers. To fit the different aircraft models into their appropriate families, we follow the 2000 version of aircraft type classification adopted by FAA for pilot certification purposes. Moreover, we follow the latest Bureau of Transportation

Statistics (BTS) classification to group the airlines into three categories, resulting in 7 network airlines, 8 low-cost airlines and 13 regional airlines in our dataset.

4.2 Variable Development

Our unit of analysis is for airline *i* in year *t*. Four indices are calculated to measure the degree of fleet standardization, including IPC_{it}, HHI_model_{it}, HHI_family_{it}, and HHI_mfr_{it}. To estimate the cost savings from having a more standardized fleet, we develop the following general model:

$$\text{Unit operating cost}_{it} = g\,(\text{Fleet Standardization}_{it}, \text{Input Factor Prices}_{it}, \text{Output Quantities}_{it}, \text{Operating Characteristics}_{it}, \text{Productivity Measures}_{it}, \text{Other Fleet Characteristics}_{it}) \qquad \text{Eq. (1)}$$

The two main input factors considered are labor and fuel. *Total RTMs* is included to control for output quantities and *Number of Points* is used as a measure for market scope. Operating characteristics include *stage length*, *stage length squared*, and *revenue share of passenger services*. Other fleet characteristics considered include *fleet size*, *average age of aircraft*, and *average size of aircraft*. We also control for productivity in labor, fuel, and aircraft usage. In particular, we use *RTMs per employee* to represent labor productivity, *RTMs per gallon* to represent fuel efficiency, and *revenue block-hours per aircraft* to represent aircraft utilization. Due to the use of panel data, we also include year dummy variables to control for unobserved common factors that may impact unit cost for an airline over the time period of analysis.

We use operating profit margin to measure profitability. Three sources of operating revenues are considered: passenger services, cargo services, and other services. Operating expenses are the total expenses of an airline, including labor and related expenses such as pension benefits and payroll taxes, facility expenses such as aircraft rent and depreciation, fuel costs, and all other costs. Seristo and Vepsalainen (1997) develop a theoretical framework to analyze the primary drivers for airline profits. Based on their model, we specify the general profit margin equation as follows:

$$\text{Operating profit margin}_{it} = h\,(\text{Fleet Standardization}_{it}, \text{Load Factor}_{it}, \text{Yield}_{it}, \text{Input Factor Prices}_{it}, \text{Output Quantities}_{it}, \text{Operating Characteristics}_{it}, \text{Productivity Measures}_{it}, \text{Other Fleet Characteristics}_{it}) \qquad \text{Eq. (2)}$$

The control variables in Eq. (2), such as Input Factor Prices$_{it}$, Output Quantities$_{it}$, Operating Characteristics$_{it}$, Productivity Measures$_{it}$, and Other Fleet Characteristics$_{it}$, are the same determinants as used for unit operating cost shown in Eq. (1). The definition and descriptive statistics for all the variables used in our analysis are presented in Table 2. Table 3 provides the correlations between the key variables across all the observations in our dataset.

Table 2. Variable Description and Descriptive Statistics

Variable	Description	Mean (Std. Dev.)
Unit cost (cents)	The total operating expenses per available seat mile (CASM) for airline *i* in year *t*	12.24 (3.85)
Profit margin	The operating profit margin (i.e., EBIT/Operating revenue) for airline *i* in year *t*	0.016 (0.099)
IPC	The overall fleet standardization index for airline *i* in year *t*	0.33 (0.23)
HHI_model	The degree of fleet standardization measured by the diversity of aircraft models in the fleet for airline *i* in year *t*	0.45 (0.25)
HHI_family	The degree of fleet standardization measured by the diversity of aircraft families in the fleet for airline *i* in year *t*	0.62 (0.28)
HHI_mfr	The degree of fleet standardization measured by the diversity of aircraft manufacturers in the fleet for airline *i* in year *t*	0.78 (0.22)
Labor cost ($ per employee)	The total salaries and related fringe benefits per employee for airline *i* in year *t*	62930.5 (17577.7)
Fuel price ($ per gallon)	The fuel cost per gallon for airline *i* in year *t*	1.41 (0.80)
Total RTMs (million)	The total revenue ton miles for all services including scheduled and non-scheduled passenger and cargo revenue traffic for airline *i* in year *t*	3,090 (4,500)
Number of points	The number of airport destinations including domestic and international points served by airline *i* in year *t*	88.62 (53.41)
Stage length (miles)	The average airport-to-airport great circle distances flown by airline *i* in year *t* during revenue service	748.74 (353.96)
% of passenger service revenue	The percentage of passenger revenue in the total operating revenue for airline *i* in year *t*	0.91 (0.09)
Fuel efficiency (ASMs per gallon)	The amount of available seat miles flown by airline *i* from consuming one US gallon of jet fuel in year *t*	56.42 (15.15)
RTMs per employee	The total revenue ton miles for all services divided by the number of employees for airline *i* in year *t*	159551.2 (71652.53)
Block hours per aircraft	The average daily revenue block hours per aircraft for airline *i* in year *t*	9.66 (1.88)
Fleet size	The average number of aircraft for airline *i* at the	197.41

	beginning and end of year *t*	(196.08)
Avg. age of aircraft	The sum of the average age of various aircraft models weighted by their percentage in the fleet for airline *i* in year *t*	9.35 (5.20)
Avg. size of aircraft	The sum of the average number of seats for various aircraft models weighted by their percentage in the fleet for airline *i* in year *t*	115.69 (54.53)
Yield (cents)	The total passenger yield (Cents/RPMs) including scheduled and non-scheduled passenger services	15.98 (6.82)
Load factor (%)	The total RPMs divided by the total ASMs including both scheduled and non-scheduled revenue services operated by airline *i* in year *t*	72.97 (7.22)

4.3 Empirical Models

Two reduced-form equations are first estimated based on Eq. (1), the unit cost estimation, and Eq. (2), the profit margin estimation, as indicated below:

$$\begin{aligned} \ln(\text{Unit cost}_{it}) = {} & \alpha_0 + \alpha_1 \ln(\text{FSI}_{it}) + \alpha_2 \ln(\text{labor cost}_{it}) + \alpha_3 \ln(\text{fuel price}_{it}) + \alpha_4 \ln(\text{total RTMs}_{it}) + {} \\ & \alpha_5 \ln(\text{number of points}_{it}) + \alpha_6 \ln(\text{stage length}_{it}) + \alpha_7 [\ln(\text{stage length}_{it})]^2 + \alpha_8 \ln(\text{revenue share of passenger services}_{it}) + {} \\ & \alpha_9 \ln(\text{fuel efficiency}_{it}) + \alpha_{10} \ln(\text{RTMs per employee}_{it}) + \alpha_{11} \ln(\text{revenue block hours per aircraft}_{it}) + \alpha_{12} \ln(\text{fleet size}_{it}) + {} \\ & \alpha_{13} \ln(\text{average age of aircraft}_{it}) + \alpha_{14} \ln(\text{average size of aircraft}_{it}) + \sum_{t=1}^{10} \beta_t (\text{year dummy variables}) + \varepsilon_{it} \qquad \text{Eq. (3)} \end{aligned}$$

$$\begin{aligned} \text{Operating profit margin}_{it} = {} & \gamma_0 + \gamma_1 \ln(\text{FSI}_{it}) + \gamma_2 \ln(\text{passenger yield}_{it}) + \gamma_3 \ln(\text{passenger load factor}_{it}) + \gamma_4 \ln(\text{labor cost}_{it}) + {} \\ & \gamma_5 \ln(\text{fuel price}_{it}) + \gamma_6 \ln(\text{total RTMs}_{it}) + \gamma_7 \ln(\text{number of points}_{it}) + \gamma_8 \ln(\text{stage length}_{it}) + \gamma_9 [\ln(\text{stage length}_{it})]^2 + {} \\ & \gamma_{10} \ln(\text{revenue share of passenger services}_{it}) + \gamma_{11} \ln(\text{fuel efficiency}_{it}) + \gamma_{12} \ln(\text{RTMs per employee}_{it}) + {} \\ & \gamma_{13} \ln(\text{revenue block hours per aircraft}_{it}) + \gamma_{14} \ln(\text{fleet size}_{it}) + \gamma_{15} \ln(\text{average age of aircraft}_{it}) + \gamma_{16} \ln(\text{average size of aircraft}_{it}) + {} \\ & \sum_{t=1}^{10} \lambda_t (\text{year dummy variables}) + \theta_{it} \qquad \text{Eq. (4)} \end{aligned}$$

In Eqs. (3) and (4), we use four measures to represent fleet standardization indices (FSI), including IPC, HHI_model, HHI_family, and HHI_mfr. Tables 4 and 5 summarize the estimation results for Eqs. (3) and (4), respectively. Because of the nature of the panel data, we cannot assume that the error terms, ε_{it}, in Eq. (3) and θ_{it} in Eq. (4) are independent and identically distributed. Instead, the error terms are likely to be serially correlated within the panel and/or heteroskedastic and contemporaneously correlated across panels (Judge et al. 1988). To address these concerns, we first conduct White's general test for heteroskedasticity (White 1980). Specifically, we run OLS estimations for Eqs. (3) and (4), using the four alternative FSI measurements, respectively. The implementation of White's test involves regressing the squared error term from the OLS estimations on the explanatory variables, squared values of the explanatory variables, and their cross-product terms. Then the *R*-squared values from the second set of regressions are multiplied by the number of observations. If the test statistics following chi-square distributions are insignificant, then the results suggest that the null hypotheses for homoscedasticity cannot be rejected. The White's tests for both Eq. (3) and (4) using the different fleet standardization measures all indicate the absence of heteroskedasticity. For example, the χ^2-statistic for the estimation of Eq. (3) using IPC to measure fleet standardization is 251.00 with a p-value of 0.4703. The insignificant results suggest the null hypothesis of homoscedasticity cannot be rejected.

Second, we perform the Wooldridge test (Wooldridge 2002) for serial autocorrelation in panel data and find that the assumption of no first order autocorrelation, AR(1), in both Eqs. (3) and (4) is strongly rejected. All the *F*-statistics under the Wooldridge test for the two equations are found to be significant at the 1% level under all four measures for fleet standardization. When the autocorrelation coefficient is unknown, the feasible generalized least squares (FGLS) approach is recommended for estimation (Judge et al. 2003). According to Beck and Katz (1995), the use of FGLS for variance-covariance estimates is especially suitable when there are 10-20 panels and 10-40 time periods per panel (Stata 2003). Given that our dataset has 28 sample airlines over 11 years, we use the FGLS procedure for both Eqs. (3) and (4) allowing for AR(1). The estimation results are presented in the following section.

Table 3. The Correlation Matrix for Key Variables

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)
(1) Unit cost	1.00																			
(2) Profit Margin	-0.07	1.00																		
(3) IPC	**-0.16**	**0.13**	1.00																	
(4) HHI_model	**-0.23**	**0.16**	**0.89**	1.00																
(5) HHI_family	**-0.31**	**0.17**	**0.65**	**0.75**	1.00															
(6) HHI_mfr	**-0.45**	0.05	**0.37**	**0.46**	**0.69**	1.00														
(7) Labor cost	**-0.14**	**-0.24**	**-0.35**	**-0.42**	**-0.26**	**-0.13**	1.00													
(8) Fuel price	**0.23**	0.01	0.04	0.03	0.04	0.12	**0.16**	1.00												
(9) Total RTMs	-0.06	**-0.17**	**-0.54**	**-0.57**	**-0.50**	-0.02	**0.65**	0.04	1.00											
(10) Num. of points	**0.33**	0.08	**-0.44**	**-0.45**	**-0.56**	**-0.25**	**0.25**	0.06	**0.60**	1.00										
(11) Stage length	**-0.46**	**-0.33**	**-0.16**	**-0.17**	-0.05	**0.34**	**0.51**	**0.20**	**0.58**	0.04	1.00									
(12) % of passenger rev.	-0.08	**0.20**	**0.41**	**0.47**	**0.26**	-0.03	**-0.58**	**-0.27**	**-0.63**	**-0.31**	**-0.57**	1.00								
(13) Fuel efficiency	**-0.42**	**-0.23**	0.08	0.04	0.09	**0.24**	**0.32**	**0.27**	**0.14**	**-0.26**	**0.55**	**-0.24**	1.00							
(14) RTMs per employee	**-0.56**	**-0.13**	0.03	0.02	0.04	**0.31**	**0.56**	**0.35**	**0.35**	-0.08	**0.74**	**-0.45**	**0.59**	1.00						
(15) Block hours per aircraft	**-0.35**	0.004	0.09	0.12	**0.16**	**0.31**	**0.17**	**0.22**	**0.14**	-0.10	**0.39**	-0.07	**0.59**	**0.34**	1.00					
(16) Fleet size	0.04	-0.09	**-0.56**	**-0.57**	**-0.50**	-0.07	**0.59**	-0.02	**0.92**	**0.74**	**0.36**	**-0.48**	-0.01	**0.16**	0.06	1.00				
(17) Avg. age of aircraft	-0.12	**-0.14**	**-0.38**	**-0.37**	**-0.14**	0.007	**0.24**	-0.05	**0.35**	0.05	**0.27**	**-0.40**	-0.08	**0.21**	**-0.27**	**0.25**	1.00			
(18) Avg. size of aircraft	**-0.55**	**-0.35**	**-0.20**	**-0.24**	-0.09	**0.31**	**0.59**	0.11	**0.52**	**-0.17**	**0.80**	**-0.56**	**0.59**	**0.79**	**0.30**	**0.29**	**0.40**	1.00		
(19) Yield	**0.82**	**0.21**	0.01	-0.01	**-0.15**	**-0.43**	**-0.45**	-0.04	**-0.34**	**0.15**	**-0.72**	**0.38**	**-0.55**	**-0.78**	**-0.35**	**-0.18**	**-0.27**	**-0.78**	1.00	
(20) Load factor	**-0.27**	0.05	-0.02	-0.01	-0.02	**0.24**	**0.45**	**0.50**	**0.31**	**0.16**	**0.49**	**-0.47**	**0.32**	**0.71**	**0.12**	**0.21**	**0.14**	**0.50**	**-0.62**	1.00

Note: Coefficients in bold indicate the significance at 5% level.

5.0 Estimation Results and Case Studies

Models (1) – (4) in Table 4 report the estimation results for Eq. (3) using IPC, HHI_model, HHI_family, and HHI_mfr to measure the degree of fleet standardization, respectively. As expected, the coefficients for all four FSI measures are negative and highly significant, suggesting that fleet standardization reduces unit cost, *ceteris paribus*; that is, unit cost will be lower for an airline with a fleet consisting of fewer aircraft models, families, or manufacturers. However, after controlling for fleet standardization at the aircraft model and family levels, fleet standardization at the manufacturer level (that is, HHI_mfr) does not have any significant effect on unit cost, as shown by Model (5). Further, Model (5) shows that the coefficient for HHI_model is not statistically different from the coefficient for HHI_family ($\chi^2_{(1)}$ = 0.33, with its *p*-value as 0.5652), implying that an increase in fleet standardization at either the aircraft model or aircraft family level reduces unit cost to a similar extent.

The results from Model (1) using IPC as the standardization measure show that a 10 per cent increase in the IPC value leads to a 0.3 per cent decrease in unit operating cost, *ceteris paribus*. The following summarizes the estimation results for other variables of interests based on Model (1):

- The unit cost, as expected, increases as fuel price or labor cost rises, *ceteris paribus*.
- The coefficient on the number of points is positive and significant, suggesting that when an airline serves more destinations, its unit cost tends to increase, holding revenue ton-miles (RTMs) constant.
- The unit cost, as expected, decreases as stage length increases, *ceteris paribus*. However, the magnitude of the cost reduction effect gets smaller as stage length increases.
- The revenue share from passenger services to total revenue is negatively related to unit cost.
- The unit cost, as expected, tends to decrease as fuel efficiency improves, *ceteris paribus*. Similarly, an increase in the productivity of labor and/or aircraft utilization is shown to reduce the unit cost.

- The average age of aircraft does not significantly influence unit cost. This result suggests that after controlling for fuel efficiency, aircraft utilization, labor cost, and fuel price, the higher aircraft depreciation and leasing costs associated with a younger fleet may be offset by savings in maintaining and servicing newer aircraft. Overall, the net effect is insignificant.
- Neither fleet size nor average size per aircraft (i.e., seating capacity) is found to have any significant effect on unit cost.

Table 4. The FGLS Estimation Results for Unit Cost Equation

Independent Variables	Model (1)	Model (2)	Model (3)	Model (4)	Model (5)
Constant	7.53^{***} (1.20)	7.81^{***} (1.22)	6.73^{***} (1.19)	7.34^{***} (1.26)	7.44^{***} (1.22)
Ln (IPC)	-0.03^{*} (0.01)				
Ln(HHI_model)		-0.08^{***} (0.02)			-0.06^{***} (0.02)
Ln(HHI_family)			-0.10^{***} (0.02)		-0.08^{***} (0.03)
Ln(HHI_mfr)				-0.07^{**} (0.03)	0.03 (0.03)
Ln (labor cost)	0.51^{***} (0.03)	0.49^{***} (0.03)	0.49^{***} (0.03)	0.51^{***} (0.03)	0.48^{***} (0.03)
Ln (fuel price)	0.11^{***} (0.01)	0.10^{***} (0.01)	0.10^{***} (0.01)	0.10^{***} (0.01)	0.11^{***} (0.01)
Ln (total RTMs)	-0.04 (0.03)	-0.05 (0.03)	-0.04 (0.03)	-0.04 (0.03)	-0.05 (0.03)
Ln (number of points)	0.11^{***} (0.03)	0.09^{***} (0.02)	0.08^{***} (0.03)	0.10^{***} (0.03)	0.08^{***} (0.03)
Ln (stage length)	-1.18^{***} (0.38)	-1.18^{***} (0.39)	-0.83^{**} (0.39)	-1.15^{***} (0.40)	-1.00^{***} (0.39)
[Ln (stage length)]^2	0.09^{***} (0.03)	0.09^{***} (0.03)	0.06^{**} (0.03)	0.09^{***} (0.03)	0.08^{***} (0.03)
Ln (% of passenger services rev)	-0.92^{***} (0.08)	-0.82^{***} (0.08)	-0.93^{***} (0.07)	-0.86^{***} (0.08)	-0.87^{***} (0.09)
Ln (fuel efficiency)	-0.12^{***} (0.04)	-0.15^{***} (0.04)	-0.14^{***} (0.04)	-0.13^{***} (0.04)	-0.15^{***} (0.04)
Ln (RTMs per employee)	-0.47^{***} (0.03)	-0.46^{***} (0.03)	-0.48^{***} (0.03)	-0.49^{***} (0.03)	-0.46^{***} (0.03)
Ln (block hours per aircraft)	-0.09^{**} (0.04)	-0.08^{**} (0.04)	-0.05 (0.04)	-0.05 (0.04)	-0.06 (0.04)
Ln (fleet size)	-0.04	-0.04	-0.05	-0.03	-0.05

	(0.04)	(0.03)	(0.03)	(0.04)	(0.03)
Ln (avg. age of aircraft)	-0.005 (0.01)	-0.02 (0.01)	-0.004 (0.01)	-0.003 (0.01)	-0.01 (0.01)
Ln (avg. size of aircraft)	-0.03 (0.05)	-0.02 (0.05)	-0.04 (0.05)	-0.001 (0.06)	-0.05 (0.06)
Number of Obs.	251	251	251	251	251
Wald χ^2	2298.01	2464.29	2477.08	2052.44	2548.42
$Prob > \chi^2$	0.0000	0.0000	0.0000	0.0000	0.0000
The coefficients on year dummy variables are not reported. The numbers in parentheses are std. errors for coefficients. *** Significant at 0.01 level; **Significant at 0.05 level; * Significant at 0.1 level.					

The estimation results for Eq. (4) are presented in Table 5. Models (1) – (4) estimate the effects on profit margin from the IPC, HHI_model, HHI_family, and HHI_mfr estimations, respectively. The positive and highly significant coefficients on all four FSI measures provide support for the contention that fleet standardization has a positive impact on airline profit margins, thus supporting prior findings (Kilpi 2007, Brüggen and Klose 2010, West and Bradley 2008**)**. Based on the results in Model (1), the profit margin for an airline will increase by 0.2 per cent as a result of a 10 per cent increase in its overall fleet standardization, as measured by IPC.

To better understand how profit margin impacts vary depending on the level of standardization, we estimate Model (5) including all three of the HHI-based fleet standardization indices on the right-side of Eq. (4). The findings show that standardization at the family level contributes to greater profit margins, while the other two standardization measures are not significant. The result showing that the coefficient for HHI_mfr is insignificant is reasonable, as HHI_mfr has minimal variation after controlling for the degree of standardization at both aircraft model and family levels. The insignificant results for HHI_model may be due to offsetting revenue and cost effects from fleet standardization. When an airline operates a single type of aircraft model, HHI_model takes the value of 1. In this case, the airline obtains the greatest cost savings from having a uniform aircraft model in its fleet. On the other hand, the airline's revenue potential may be constrained from this standardization, since the standardized aircraft model may be suitable for only a limited number of markets[6]. Finally, an airline with a highly standardized fleet in terms of aircraft family may still have a quite diversified composition of aircraft models.[7]

Table 5. The FGLS Estimation for Profit Margin Equation

Independent Variables	Model (1)	Model (2)	Model (3)	Model (4)	Model (5)
Constant	-4.10*** (0.95)	-4.90*** (1.04)	-4.95*** (1.01)	-4.43*** (1.00)	-5.07*** (1.03)
Ln (IPC)	0.02** (0.01)				
Ln (HHI_model)		0.03* (0.02)			0.006 (0.02)
Ln (HHI_family)			0.07*** (0.02)		0.06** (0.02)
Ln (HHI_mfr)				0.06*** (0.02)	0.01 (0.03)
Ln (passenger yield)	0.33*** (0.04)	0.37*** (0.04)	0.35*** (0.04)	0.34*** (0.04)	0.35*** (0.04)
Ln (passenger load factor)	0.30*** (0.11)	0.34*** (0.11)	0.31*** (0.09)	0.24** (0.11)	0.33*** (0.11)
Ln (labor cost)	-0.25*** (0.03)	-0.27*** (0.04)	-0.25*** (0.03)	-0.25*** (0.03)	-0.25*** (0.03)
Ln (fuel price)	-0.03*** (.007)	-0.03*** (0.01)	-0.03*** (0.01)	-0.03*** (0.01)	-0.03*** (0.01)
Ln (total RTMs)	0.09*** (0.03)	0.07** (0.03)	0.08*** (0.03)	0.08*** (0.03)	0.08*** (0.03)
Ln (number of points)	-0.07*** (0.02)	-0.08*** (0.02)	-0.07*** (0.02)	-0.09*** (0.02)	-0.07*** (0.02)
Ln (stage length)	0.40 (0.28)	0.61* (0.31)	0.59* (0.30)	0.60** (0.28)	0.62** (0.30)
[Ln (stage length)]^2	-0.03 (0.02)	-0.05** (0.02)	-0.05** (0.02)	-0.05** (0.02)	-0.05** (0.02)
Ln (% of passenger services rev)	-0.22*** (0.08)	-0.28*** (0.08)	-0.22*** (0.07)	-0.29*** (0.07)	-0.23*** (0.08)
Ln (fuel efficiency)	0.02	0.02	0.03	0.03	0.03

---

[6] Appendix B presents the results from our preliminary analysis suggesting that there is a negative association between fleet standardization and stage length variation, traffic density variation, and the number of points served by airlines.

[7] Consider Alaska Airlines for an example, although its fleet in 2007 consisted of a single aircraft family - Boing 737, it operated five different models in that year including 737-200/400/700/800/900 with seat capacity ranges from 111 to 172. Thus, Alaska Airlines is able to achieve cost savings associated with having a uniform fleet of 737 aircraft without sacrificing its route network diversity.

	(0.03)	(0.03)	(0.03)	(0.03)	(0.03)
Ln (RTMs per employee)	0.24^{***} (0.03)	0.27^{***} (0.03)	0.26^{***} (0.03)	0.27^{***} (0.03)	0.26^{***} (0.03)
Ln (block hours per aircraft)	0.08^{**} (0.04)	0.08^{**} (0.03)	0.06^{*} (0.03)	0.06^{*} (0.03)	0.06^{*} (0.04)
Ln (fleet size)	-0.03 (0.03)	-0.003 (0.03)	-0.02 (0.03)	-0.02 (0.03)	-0.01 (0.03)
Ln (avg. age of aircraft)	-0.0001 (.01)	-0.007 (0.01)	-0.002 (0.01)	-0.004 (0.01)	-0.003 (0.01)
Ln (avg. size of aircraft)	-0.20^{***} (0.05)	-0.20^{***} (0.05)	-0.19^{***} (0.05)	-0.25^{***} (0.04)	-0.19^{***} (0.05)
Number of Observations	251	251	251	251	251
Wald χ^2	523.99	359.09	358.11	352.90	365.94
$Prob > \chi^2$	0.0000	0.0000	0.0000	0.0000	0.0000

The coefficients on year dummy variables are not reported.
The numbers in parentheses are standard errors.
*** Significant at 0.01 level; **Significant at 0.05 level; * Significant at 0.1 level.

To further investigate the impact of fleet standardization on profit margin above and beyond its effect through unit cost, we estimate a two-stage generalized least squares (GLS) model. The model is specified as follows:

Unit operating cost = *g* (Fleet Standardization, Input Factor Prices, Output Quantities, Operating Characteristics, Productivities, Year Dummy Variables) Eq. (5.1)

Operating Profit Margin = *h* (Fleet Standardization, Estimated Unit Operating Cost, Load Factor, Yield, Year Dummy Variables) Eq. (5.2)

In Equation (5.1), unit cost is regressed on a set of explanatory variables, including fleet standardization, labor cost, fuel price, total RTMs, number of points served, stage length, revenue share of passenger services, fuel efficiency, RTMs per employee, revenue block hours per aircraft, fleet size, average age of aircraft, average size of aircraft, and year dummy variables. Next, the fitted value of unit cost is included as an explanatory variable in Equation (5.2) for profit margin estimation, along with fleet standardization, passenger yield, load factor, and year dummy variables.

The estimation results for Equation (5.2) are presented in Table 6.[8] In Model (1), the coefficient for Ln (IPC) is negative and highly significant (γ=-0.02, p=0.02), suggesting that after controlling for the unit cost effect, fleet standardization, as measured by IPC, has a negative impact on profit margin. This finding provides evidence that increased standardization is likely to constrain operating flexibility and, thus, profit margins as well. The results from Model (2) using HHI_model to measure fleet standardization suggest that profit margin is negatively associated with fleet standardization at the aircraft model level after controlling for the impact of standardization on unit cost. Thus, having fewer models may restrict an airline's ability to serve different types of markets, thereby limiting revenue and profit potential.

The insignificant coefficient for HHI_family (γ=0.0046, p=0.769), as shown in Model (3), suggests that if an airline increases its fleet standardization at the aircraft family level, its revenue decline may not exceed its cost savings. An airline with standardization at the family level may still have sufficient diversity to serve various types of markets. Similarly, HHI_mfr is found to have an insignificant effect (γ=-0.0233, p=0.301) on profits, after controlling for the cost impact. Standardization at the manufacturer level does not preclude diversity at either the family or model levels.

As indicated by the results from Model (5), when all three HHI measures are included, the coefficient for HHI_model is negative and significant (γ=-0.0396, p=0.023) at the 5 per cent level, whereas the coefficient for HHI_family is positive and significant (γ=0.0477, p=0.053) at the 10 per cent level. The contrasting results suggest that fleet standardization at the family level has a direct, positive effect on profit margin, beyond its impact through cost savings. On the contrary, fleet standardization at the aircraft model level has a negative effect on profit margin, offsetting some of the benefits from cost reduction. These results imply that in order to increase profit margin, an airline may concentrate its fleet among fewer aircraft families as long as its fleet consists of a wide variety of aircraft models. Finally, the coefficient for HHI_mfr is not significant in Model (5).

---

[8] Estimation results for the first stage of the model, Eq. (5.1) are available upon request.

Table 6. The 2nd-stage GLS Estimation for Profit Margin

	Model (1)	Model (2)	Model (3)	Model (4)	Model (5)
Constant	-1.59^{***} (0.43)	-1.65^{***} (0.44)	-1.84^{***} (0.43)	-1.51^{***} (0.44)	-1.78^{***} (0.43)
Ln (IPC)	-0.02^{**} (.008)				
Ln (HHI_model)		-0.02^{**} (0.01)			-0.04^{**} (0.02)
Ln (HHI_family)			0.01 (0.01)		0.05^{*} (0.02)
Ln (HHI_mfr)				-0.02 (0.02)	-0.02 (0.03)
Ln(passenger yield)	0.32^{***} (0.03)	0.32^{***} (0.03)	0.29^{***} (0.03)	0.30^{***} (0.03)	0.31^{***} (0.03)
Ln(load factor)	0.38^{***} (0.09)	0.39^{***} (0.09)	0.43^{***} (0.09)	0.36^{***} (0.09)	0.42^{***} (0.09)
Unit Cost (fitted)	-0.37^{***} (0.04)	-0.36^{***} (0.04)	-0.30^{***} (0.04)	-0.33^{***} (0.04)	0.34^{***} (0.04)
Number of Obs.	251	251	251	251	251
Wald χ^2	216.09	215.75	212.89	200.56	217.69
$Prob > \chi^2$	0.0000		0.0000	0.0000	0.0000
The coefficients on year dummy variables are not reported. The numbers in parentheses are standard errors. *** Significant at 0.01 level; **Significant at 0.05 level; * Significant at 0.1 level.					

To further illustrate the impacts of fleet standardization on airlines' unit cost, we conduct a scenario analysis based on the data for Southwest and American Airlines in the year 2007. Table 7 presents the comparison between these two airlines in their fleet characteristics and other key aspects of their operations for 2007.

Table 7: The Comparison between Southwest and American Airlines in 2007

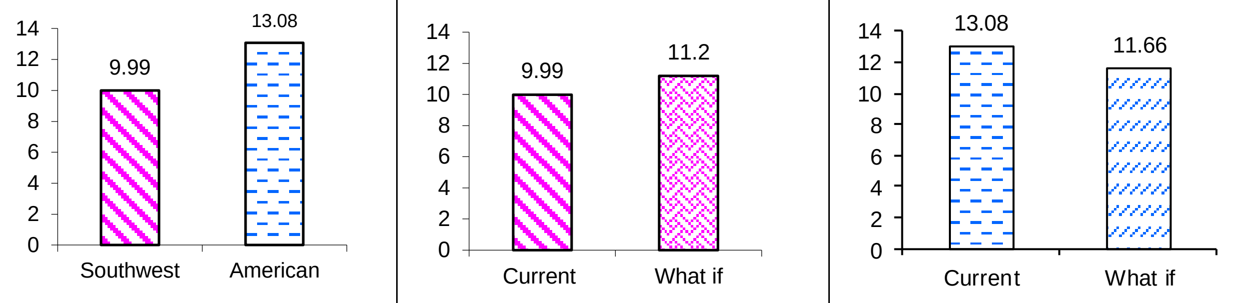
	Southwest	American Airlines
Fleet composition	Boeing 737-300/500/700	Airbus 300-B4600; Boeing 737-800; Boeing 757-200; Boeing 767-200/300ER; DC9-80
IPC	0.33	0.12
HHI_model	0.46	0.29
HHI_family	1	0.33
HHI_mfrn	1	0.91
Unit cost (CASM)	9.09 cents per ASM	13.03 cents per ASM
Profit margin	0.08	0.03
Passenger yield	12.69 cents per RPM	13.07 cents per RPM

Load factor	72.58%	81.49%
Labor cost	$100,455.2	$89,318.46
Fuel price	$1.69 per gallon	$2.05 per gallon
Number of points	64	167
Total RTMs	7,380 million	16,000 million
Stage length	630 miles	1251 miles
Fuel efficiency	66.89 ASMs per gallon	59.98 ASMs per gallon
RTMs per employee	219,038.9	222,417.4
Block hours per aircraft	11.17	9.97
Fleet size	484	689
Avg. age of aircraft	9.85 years	15.14 years
Avg. size of aircraft	136 seats	177 seats

It is evident that Southwest Airlines has a more standardized fleet than American Airlines and also lower unit costs. Based on the HHI fleet standardization indices and the unit cost estimation results from Model (5) in Table 4, the predicted unit cost is 9.99 cents per available seat-mile (ASM) for Southwest and 13.08 cents for American Airlines (Figure 4a). We conduct a simulation analysis to address the following two questions:

- What would be the unit cost for Southwest Airlines if it had the same degree of fleet diversification as American Airlines?
- What would be the unit cost for American Airlines if it had the same degree of fleet standardization as Southwest Airlines?

Note that we are not suggesting that American Airlines can easily be converted to a Southwest clone (nor Southwest to an American clone). We provide this example only as a way of illustrating the costs of operating a diversified fleet or, conversely, the benefits that can be derived from standardization. Results from the simulation (Figures 4b and Figure 4c) show that the unit cost for Southwest would increase by 1.21 cents if the airline had exactly the same degree of fleet diversification as American Airlines (that is, HHI_model, HHI_family, and HHI_mfr). Conversely, American Airlines would reduce its unit cost by 1.42 cents if it had the same extent of fleet standardization as Southwest.



4a. The estimated unit costs based on the actual degree of airlines' fleet standardization;
Cost gap: 3.09 cents

4b. Cost increase for Southwest: 1.21 cents (12.1 per cent ↑) under the hypothetical scenario;
Cost gap: 1.88 cents (39 per cent ↓)

4c. Cost decrease for American: 1.42 cents (10.9 per cent ↓) under the hypothetical scenario;
Cost gap: 1.67 cents (46 per cent↓)

Figure 4. The Estimated Unit Costs for Southwest Airlines and American Airlines

To illustrate the findings from our profit margin estimations, we use Southwest Airlines as an example and compare the following three scenarios for its fleet composition. In Scenario I, we consider the existing fleet composition for the airline in 2007 consisting of 193 Boeing 737-300, 25 Boeing 737-500 and 266 Boeing 737-700 aircraft. Scenario II simulates the recent fleet expansion plan of the airline. On March 8, 2012, Southwest took the delivery of its first Boeing 737-800 aircraft and expects to receive a total of 73 such aircraft by the end of 2018 (Compart, 2012).[9] The selection of the 737-800 model fits well with the airline's LCC strategy of operating a highly standardized fleet. With the addition of the 73 737-800 model aircraft, the airline's fleet will become more diversified at the aircraft model level, but its HHI_family and HHI_mfr diversity measures are unchanged.

Our analysis in Scenario III is based on a hypothetical example. In this scenario, Southwest Airlines is assumed to fully integrate the 88 Boeing 717s from its acquisition of AirTran Airways. The addition of the 717s would diversify the airline's fleet not only

---

[9] Mike Van de Ven, Chief Operating Officer, made the following comments (Transportation Business Journal, 2012): *"Not only is this a beautiful aircraft, and one our customers are sure to love, but it will also play an important strategic role in our future. The -800 aircraft carries 175 passengers, close to a 30 percent increase over our current fleet configuration, which will improve our unit cost per flight. Additionally, it complements our existing fleet with opportunities for longer-haul flying and schedule flexibility by allowing additional capacity in high demand, slot-controlled, or gate-restricted airport."*

at the aircraft model level, but also at the family level. Table 8 presents the simulation results for Scenarios I-III.

Table 8. The Comparison among Scenario I, II, and III

	Scenario I	Scenario II	Scenario III
HHI_model	0.46	0.37	0.36
HHI_family	1	1	0.74
HHI_mfr	1	1	1
Unit Cost (cents)	9.89	10.02	10.25
Profit Margin	9.72%	10.08%	7.79%

As shown in Table 8, the projected profit margin for Southwest is the highest with Scenario II where the airline diversifies its fleet at the model level, but maintains its standardization at the family and manufacturer level. In Scenario III, when the airline adds 717s into its fleet, the profit margin is found to be the lowest among the three scenarios because of the higher operating costs associated with a combined 737/717 fleet. This simulation result may explain why Southwest decided to lease all of AirTran's 717s to Delta Airlines.

6.0 Conclusions and Implications

As evident by the number of airline bankruptcies in recent years, airlines operate in a volatile and very competitive market, and few carriers have been consistently profitable. Therefore, airlines constantly seek new ways to reduce costs and to increase revenues. Costs associated with operating and maintaining aircraft account for a significant portion of airline operating expenses. As a result, it is important for airlines to understand how fleet composition may impact their financial performance in order to remain competitive in a very challenging industry. Despite the important practical implications of fleet composition, there are very few studies investigating the impacts of fleet standardization on airline costs and profitability.

We develop three HHI-based fleet standardization measures to assess the impact of standardization on airline costs and profit margins based on panel data for 28 U.S. airlines for the period 1999 to 2009. The results show that fleet standardization, as expected, leads to lower unit costs. Further, we find evidence in support of the argument that having fewer aircraft models may restrict an airline's ability to serve different types of markets, thereby limiting its revenue potential. Nevertheless, the overall impact on profit margin from fleet standardization at the aircraft family and manufacturer levels is positive, which is consistent with previous studies (for example, Kilpi 2007; Brüggen and Klose 2010; and West and Bradley 2008**).**

It has been well recognized that fleet standardization provides airlines with cost savings in flight operations and maintenance. However, the potential negative revenue impacts from fleet standardization have generally been overlooked. In this paper, we test the hypothesis that fleet standardization has double-edged effects on airline profitability, and the overall performance impacts from fleet standardization may vary depending on the standardization level. Our empirical results provide quantitative evidence of the trade-off between the cost and benefits from fleet commonality. Moreover, our results indicate that airlines can improve profitability by standardizing their fleet at the manufacturer level and family level, but standardization at the aircraft model level may lead to lower profits. In other words, these results suggest that while maintaining fleet standardization at the family level, an airline with its fleet consisting of more diversified aircraft models may achieve higher profit margin.

References

"Aerospace and defense companies; southwest airlines celebrates the arrival of the carriers first Boeing 737-800 aircraft", Transportation Business Journal (April 8, 2012), pp. 84.

"Alaska air group reports record fourth quarter and full-year results; announces order for 15 Boeing 737 aircraft", PR Newswire (Jan. 25, 2011), Available from: http://search.proquest.com.ezproxy.libproxy.db.erau.edu/docview/847112353?accountid=27203 [Accessed in June, 2012].

Beck, N. and Katz, J.N., 1995. What to do (and not to do) with time-series cross-section data. American Political Science Review 89, 634-647.

Bruggen, Alexander and Klose, Levin, 2010. How fleet commonality influences low-cost airline operating performance: empirical evidence. Journal of Air Transport Management (16), 299-303.

Compart, A., 2012. Southwest shuffles 737 deliveries to keep fleet size flat. Aviation Daily 388(36), pp.1.

Conrady, R., Fichert, F., and Klophaus, R., 2010. European LCCs going hybrid: an empirical survey, Proceedings of 14th ATRS Conference, Porto, Portugal.

De Borges Pan, Alexis George and Espirito Santo, Respicio A., 2004. Developing a fleet standardization index for airline pricing. Journal of Air Transportation 9 (2), 97-110.

"JetBlue brings Embraer service to Dulles" (2005). *Regional Aviation News*, 23(45), 1-1.

Judge, G. G., Hill, R.C., Griffiths, W. E., Lutkepohl, H., and Lee, T.Ch., 1988. The Theory and Practice of Econometrics. 2nd edition. Singapore: John Wiley & Sons.

Kilpi, Jani, 2007. Fleet composition of commercial jet aircraft 1952-2005: developments in uniformity and scale. Journal of Air Transport Management 13, 81-89.

Kingsley-Jones, Max, 2011. Launch control. Airline Business 27 (3), pp.24.

Pitfield, D. E., Caves R.E., and Quddus M. A., 2010. Airline strategies for aircraft size and airline frequency with changing demand and competition: a simultaneous-equations approach for traffic on the north Atlantic. Journal of Air Transport Management 16, 151-158.

Ranson, Lori, 2011. Charging ahead. Airline Business 27 (6), 29-32.

Seristo, Hannu and Vepsalainen, Ari, 1997. Airline cost drivers: cost implications of fleet, routes, and personnel policies. Journal of Air Transport Management 3 (1), 11-22.

Stata Statistical Software: Release 8.0, 2003. College Station, TX: Stata Corp.

Wei, Wenbin and Hansen, Mark, 2005. Impact of aircraft size and seat availability on airlines' demand and market share in duopoly markets. Transportation Research Part E, Logistics and Transportation Review 41, 315-327.

West, David and Bradley, John, 2008. Airline flight networks, cycle times, and profitability: 2004-2006. Operational Management Research 1, 129-140.

White, H., 1980. A heteroskedasticity-consistent covariance matrix estimator and a direct test for heteroskedasticity. Econometrica 48, 817-838.

Wooldridge, J. M., 2002. Econometric Analysis of Cross Section and Panel Data. Cambridge, Massachusetts: The MIT Press.

Zhang, A., Hanaoka, S., Inamura, H., Ishikura, T., 2008. Low-cost carriers in Asia: Deregulation, regional liberalization and secondary airports. Research in Transportation Economics 24, 36-50.

Appendix A: The Formulae for Calculating IPC

The calculation for IPC requires three steps. First, the IPPCC (Cell Standardization Partial Index) is calculated for each aircraft family by dividing the total number of aircraft in the aircraft family by the number of different aircraft models in that particular family (AMF) multiplied by the total number of aircraft in the fleet (TFC). The formula for IPPCC is as follows:

$$\text{IPPCC} = \frac{\text{Number of Aircraft in the Family}}{\text{AMF} \times \text{TFC}} \qquad \text{(A.1)}$$

As shown in Equation (A.1), the greater the number of models in a particular aircraft family, the lower is its IPPCC. Second, the IPPC is calculated for each aircraft manufacture by adding the IPPCCs for different aircraft families from the same aircraft manufacture, and then dividing it by the number of aircraft families belonging to that particular manufacturer. The formula for IPPC is as follows:

$$\text{IPPC} = \frac{\sum \text{IPPCC}}{\text{Number of Aircraft Families from the Manufacturer}} \qquad \text{(A.2)}$$

Thus, the greater the number of aircraft families from a particular aircraft manufacturer, the lower is its IPPC. Finally, the IPC is calculated by adding the IPPCs for different aircraft manufactures and then dividing it by the total number of aircraft manufactures in the fleet. The formula for IPC is as follows:

$$\text{IPC} = \frac{\sum \text{IPPC}}{\text{Number of Aircraft Manufactures in the Fleet}} \qquad \text{(A.3)}$$

Formula (A.3) indicates that the overall fleet standardization index IPC will have a lower value as the number of aircraft manufacturers in the fleet increases. The maximal value for IPC is 1 representing the case where the fleet has the most uniform composition consisting of a single aircraft model.

Appendix B: The Relationship between Fleet Standardization and Stage Length Variation, Traffic Density Variation, and the Number of Points Served by Airlines

To better understand how fleet standardization may constrain the diversity of an airline's route and service offerings, we develop two variables, *stage length variation* and *seat capacity variation*, and estimate the impacts from fleet standardization on the two variables. For an airline in a given year, stage length variation is defined as the coefficient of variation in stage length on all the routes that the airline operates. For example, to calculate the coefficient of variation in stage length for airline *i* in year *t*, we use the one-way distance on all the scheduled origin and destination (O&D) airport-pair routes for airline *i* in year *t* including both its international and domestic services. The distance data is collected from the OAG T-100 dataset. As we intuitively expect, stage length variation is negatively associated with fleet standardization. Figure B.1 illustrates this negative relationship (as measured by IPC, HHI_model and HHI_family) based on data in 2004.

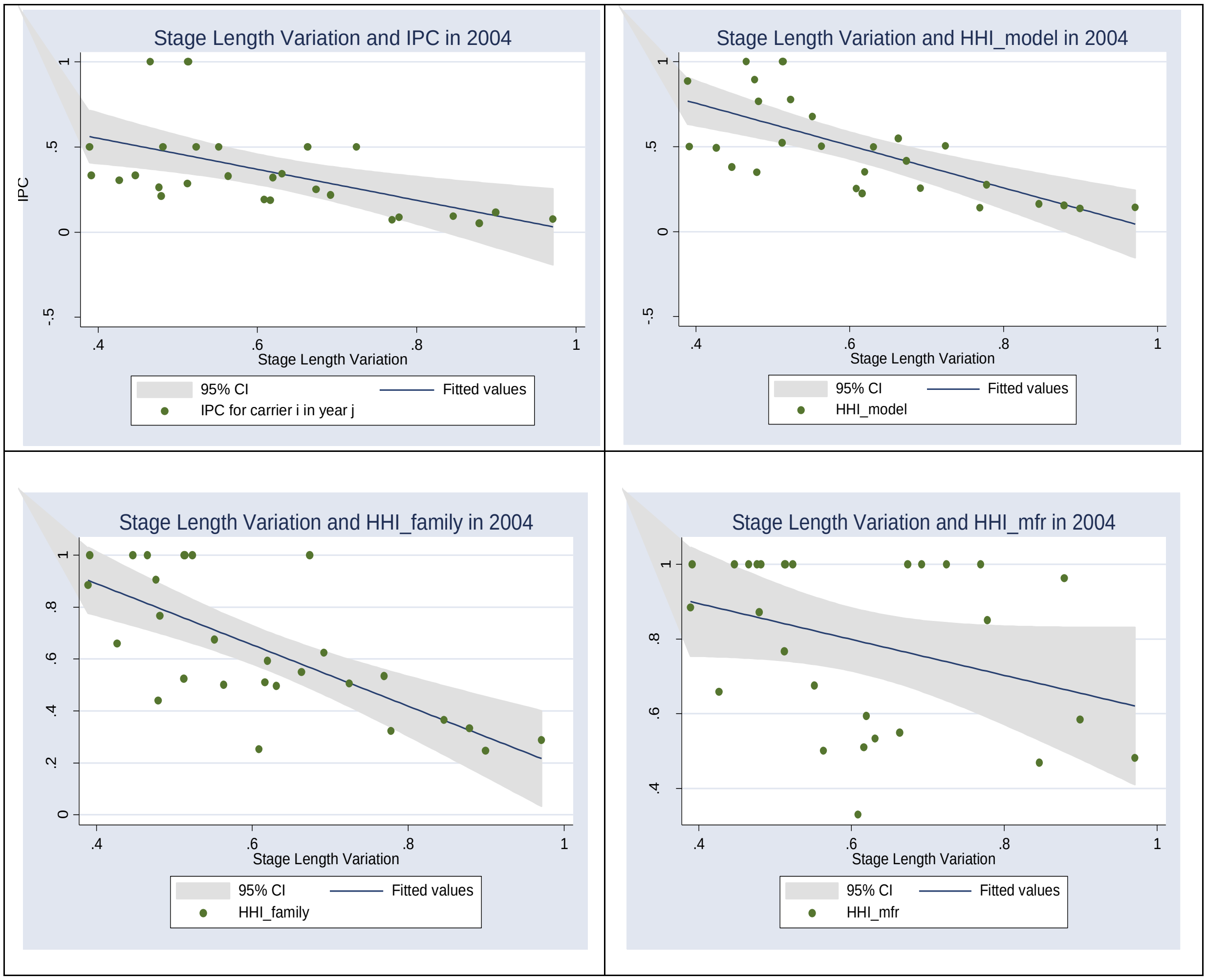


Figure B.1. The Relationship between Fleet Standardization and Stage Length Variation

Table B.1 presents the step-wise, log-linear regression results using data from 1999 to 2009. In the regressions, the stage length variation for airline *i* in year *t* is estimated on a set of fleet standardization measurements, including IPC, HHI_model, HHI_family, and HHI_mfr.

Table B.1. The Stage Length Variation Estimation

	Model (1)	Model (2)	Model (3)	Model (4)	Model (5)
Constant	-0.8341 (-14.78)	-0.8001 (-16.33)	-0.7141 (-14.06)	-0.5175 (-8.03)	-0.8043 (-16.91)
Ln (IPC)	-0.2478 (-14.77)				
Ln (HHI_model)		-0.3460 (-17.93)			-0.2298 (-7.53)
Ln (HHI_family)			-0.4240		-0.2073

			(-15.73)		(-4.38)
Ln (HHI_mfr)				-0.3161 (-5.96)	0.0405 (0.85)
R^2	0.48	0.58	0.52	0.17	0.61
The coefficients on year dummy variables are not reported. The values in parentheses are t-statistics estimates.					

If an airline operates a diversified fleet consisting of distinct aircraft models or families, it can use its own fleet to serve routes with a wide range of traffic demand. Further, it can better differentiate its services by offering a variety of ticket classes on various routes. Figure B.2 illustrates the relationship between fleet standardization and seat capacity variation, which represents the coefficient of variation in the number of seats across all the aircraft models that are operated by airline *i* in year *t*. The graph indicates that seat capacity variation has a strong, negative association with fleet standardization, as measured by IPC, HHI_model and HHI_family.

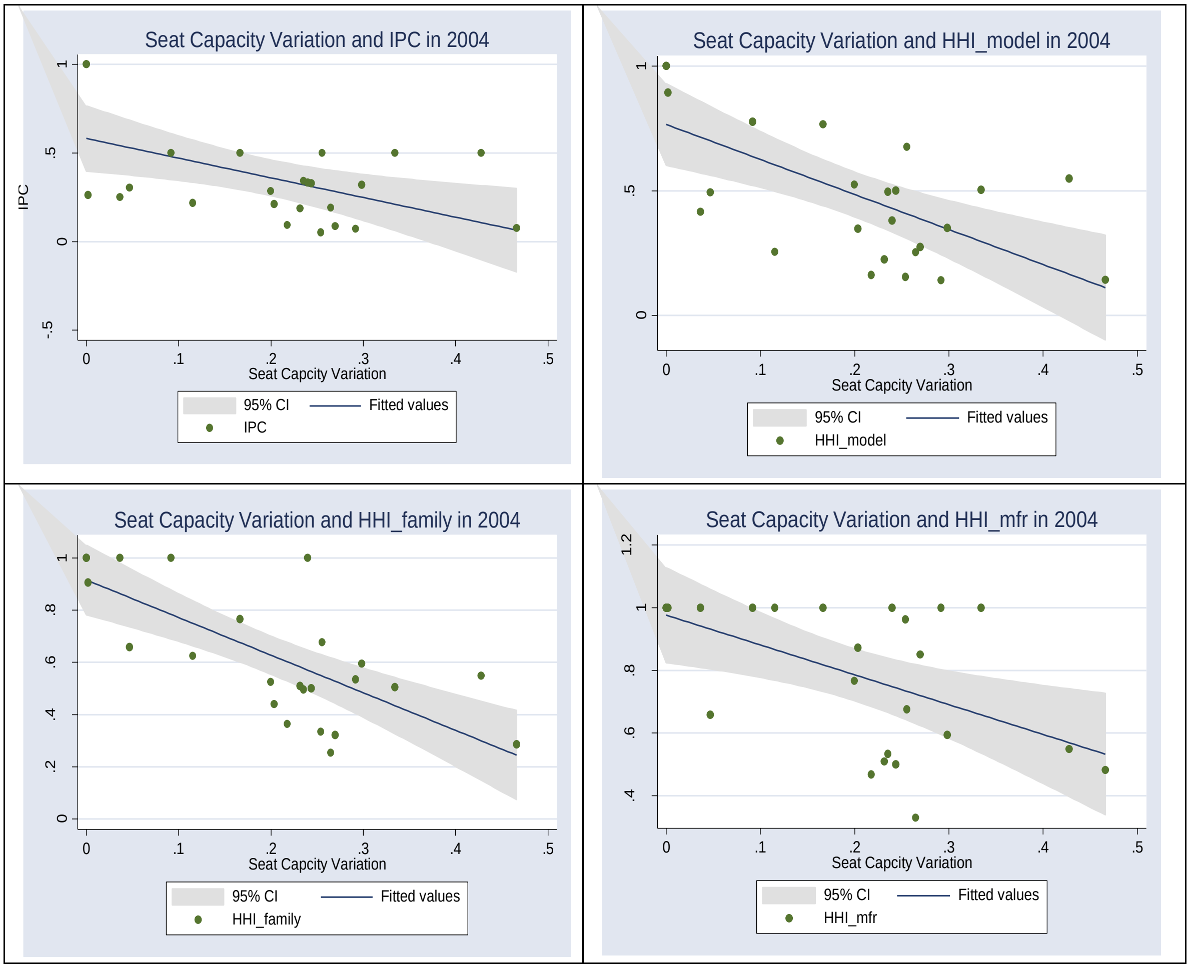


Figure B.2. The Relationship between Fleet Standardization and Seat Capacity Variation

Furthermore, we develop an alternative variable - *(traffic density variation)*$_{it}$, to measure the variation in the total passenger traffic across all the O&D airport pairs operated by airline *i* in year *t*. The value for (traffic density variation)$_{it}$ is derived by calculating the coefficient of variation in the annual passenger volume across all the O&D routes served by airline *i* in year *t*. The market scope for airline *i* in year *t* is measured by counting the number of destinations served by the airline in the year concerned. Both domestic and international routes are considered in the traffic density variation and number of points calculation.

Table B.2 presents the log-linear regression results showing that fleet standardization is inversely related to stage length variation, traffic density variation, and the number of points served. However, the negative association between traffic density variation and fleet standardization at the manufacturer level is not supported. These results suggest that an airline with a more diversified fleet at the aircraft model and family level operates a network consisting of a greater number of destinations varied in distance and traffic volume.

Table B.2. The Fleet Standardization Estimation

	Dependent Variable			
	Model (1) IPC	Model (2) HHI_model	Model (3) HHI_family	Model (4) HHI_mfr
Constant	-0.6879 (-2.41)	-0.9469 (-4.40)	-0.1959 (-1.16)	-0.2065 (-1.32)
Ln(Stage length variation)	-1.1373 (-7.06)	-1.2563 (-10.36)	-0.7268 (-7.64)	-0.3435 (-3.90)
Ln(Traffic density variation)	-0.4118 (-2.52)	-0.2253 (-1.83)	-0.3148 (-3.27)	0.1735 (1.94)
Ln(Number of points)	-0.3795 (-7.03)	-0.1781 (-4.38)	-0.2087 (-6.55)	-0.0772 (-2.62)
R^2	0.57	0.60	0.58	0.20
The coefficients on year dummy variables are not reported. The values in parentheses are t-statistics estimates.				