Benchmarking the Operating Performance of Asian Airlines

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This study benchmarks 14 major Asian airlines against one another using linear programming technique of data envelopment analysis (DEA). We evaluate the operating efficiencies of 14 Asian airlines for the period 2015 to 2019. The study finds that only three airlines have been consistently efficient relative to their peers in terms of their operating efficiency throughout the sample period. The DEA model uses well-performing airlines (efficiency of 1 or 100%) that are closest to the under-performing airline on the efficiency frontier as a "role model" (peer units) for the under-performing airline.

Keywords: Asian Airlines, benchmarking, data envelopment analysis, efficiency

INTRODUCTION

With ongoing shifts in the airline industry's operating climate, the airline's operating performance continues to draw academic and business interest. The Asian market, where airlines have more new orders than anywhere else when it comes to buying and leasing plans, is seeing the most substantial rise in air traffic. Despite the surge in air travel in Asia, only 6 of the 20 publicly traded airlines based in the region made a profit in the last reported quarter of 2018 (https://www.scmp.com/week-asia/economics/article/2184740/asias-aviation-industry-booming-so-why-isnt-it-making-money). The main reason for the lack of profitability is intense competition within the industry. Airlines are not able to increase fares despite higher demand for air travel. As a result, airlines are looking for ways to become leaner and more cost-efficient to improve profitability through restructuring and reorganizations by entering alliances, mergers, and acquisitions. The Asian airlines industry continued to see an eventful year in 2018, with several impactful development from the joint ventures and alliances scene. For instance, Korean Air and Delta Airlines launched a joint venture on routes between Asia and the U.S. Air China and Air Canada signed the first joint venture agreement between a Chinese and North American airline, which will enable both parties to expand their existing codeshare relationship on flights between Canada and China on key connecting domestic flights in both countries. Air China Southern Airlines, Xiamen Airlines, KLM Royal Dutch Airlines and Air France signed an agreement to combine their existing joint ventures, which will offer customers a wider range of destinations and attractive transfer times. In August 2018, Japan Airlines and China Eastern Airlines signed a memorandum of understanding to pursue a joint-business partnership in 2019, which will encompass Japan Airlines' domestic network of more than 50 cities and China Eastern Airline's domestic network of more than 80 destinations. Japan Airlines is a member of One World while China Eastern Airline is a member of The SkyTeam Alliance.

While alliances have benefited airlines by facilitating international flights, which typically generate higher revenue per flight, they can also reduce costs. Airlines can share facilities, including airport lounges, and split the expense of marketing campaigns, including discount offers and frequent-flyer programs. Other benefits can result from joint purchases of jet fuel or negotiation of combined maintenance contracts. The Star Alliance, for example, created its own fuel company, which buys jet fuel for multiple carriers at several international hubs. Advocates of the system say that alliances can create most of the same benefits achieved through mergers.

In this study, we benchmark 14 airlines from Asia against one another to evaluate the operating efficiency and profitability over a period of five years from 2015 to 2019

The study is important for several reasons. Firstly, we are not aware of any study that compares the operating efficiency and profitability of the major airlines in Asia.

Secondly, in the wake of the alliances, mergers and restructurings, operating efficiency and profitability have become more important than ever. The airline industry has fewer competitors and less capacity chasing customers, which should help the industry to be more disciplined on capacity, so airlines can price their product in a way that generates a sustainable return on invested capital. This study will highlight if all the airlines are equally doing well.

Thirdly, given that there are 14 major airlines, this study will also help in terms of establishing industry leaders. Finally, the study will help regulators understand the impact of alliances and mergers on the profitability of companies. Companies usually argue that they need to merge, because it helps them improve their operating efficiency and profitability.

LITERATURE REVIEW

Several studies have looked at the operational performance of airlines around the globe. Hu, Li and Tung (2017) measured the operating performance of 15 ASEAN airlines for the period 2010 to 2014. They reported that operating performance was on a downward trend. Wu, Seong-Jong & Fowler (2014) used data envelopment analysis to calculate the relative productivity of 90 airlines in Asia, Europe and North America. They also noticed that the productivity of airlines in Europe is the lowest of airlines in these three regions. Min & Min (2015) has established a series of target performance criteria to help airlines track their service delivery process, recognize relative shortcomings, and take corrective steps for continuous service improvements. Wu & Ying-Kai (2014) used an integrated DEA-BSC model to evaluate the operating efficiency of 38 major airlines around the world to evaluate their relative performance. The analysis found that airlines with outstanding efficiency at productive borders continued to do well in terms of resources, capital and other operational costs. Carastro (2010) stressed the use of non-financial metrics to assess the airline industry. Assaf & Josiassen (2011) assessed U.K. technical efficiency. Airlines using the Data Envelopment Analysis (DEA) bootstrap technique. They announced that the productivity of UK airlines has been gradually decreasing since 2004 to hit 73.39 per cent in 2007. Factors considered to be strongly and positively linked to differences in technical performance include airline size and load factor. Schefczyk (1993) tests 14 airlines using data envelopment analysis as a tool for assessing and evaluating the operating efficiency of airlines. The report ended with an overview of the high profitability and efficiency competitive variables in the airline industry. In this article, we expand previous studies by benchmarking the operational performance of 14 Asian airlines.

MODEL AND METHODOLOGY

We use the Data Envelopment Analysis (DEA) model to analyze the operational performance of airlines in the Asian region. Data envelopment analysis is a non-parametric technique used to estimate efficiencies. DEA technique is rooted in production theory and production function, with the goal of achieving optimal output through a range of input combinations. DEA is the analytical implementation of this simple microeconomic production function in which we optimize output and decrease input so that we can reach optimum productive efficiency. DEA broadens this logic of productive efficiency to calculate the efficiency of several decision-making units if the model requires a collection of inputs and outputs. DEA uses linear programming techniques to achieve maximum performance by minimizing inputs and optimizing outputs (Charnes et al., 1978). The DMUs in this study are 14 Asia airlines. The entities/organizational units under study are considered Decision-Making Units (DMUs). DEA calculates the efficiency with which the DMU uses available resources (inputs) to produce a given output set and describes efficiency as the ratio of total outputs to total inputs to determine the relative performance of the DMU. DEA calculates the efficiency with which the DMU uses available resources (inputs) to produce a given output set and describes efficiency as the ratio of total outputs to total inputs to determine the relative performance of the DMU. In addition, this generalized optimization strategy tests the relative efficiency of various decision-making units with multiple targets (outputs) and structures with multiple inputs.

The DEA approach calculates the performance of each DMU as the percentage of weighted outputs to the weighted inputs. Charnes et. Charnes et. Al. (1978) calculates the measure of efficiency as one that allocates to each unit the most desirable weights. In general, the weights of all units are not identical.

To effectively implement the DEA technique, we must choose homogeneous groups conducting similar tasks and achieving similar objectives. In this study, the companies are homogenous as they are identified by Standard and Poor's Netvadvantage in their industry Surveys report to be competitors. In addition, a major factor is also the number of DMUs. In addition, the number of DMUs should be optimal in order to capture high performance units and clearly identify the relationship between inputs and outputs. The choice of input and output variables is the most important aspect of DEA performance analysis. The inputs should, in general, represent the amount of resources used or a factor which should be reduced. Outputs represent the extent of the economic variable factor and the degree to which the economic variable contributes to its viability. Without increasing or reducing efficiency, we can linearly scale the inputs and outputs. Non-Decreasing Returns to Scale indicates that the output adjusts to a greater degree than the relative effect by changing all inputs by the same proportion. Similarly, Non-Increasing Returns to Scale Scaling is forbidden, whereas scaling down is allowed. Variable Returns to Scale blends these three choices – NDRS, CRS and NIRS for various performance ranges.

The choice of inputs and outputs and the number of participating DMUs are driven by certain basic rules of thumb.[1]

To evaluate the effectiveness of DEA to benchmark companies, we collected data on fourteen airlines from Asia. We use six variables to evaluate the operating efficiency of Asian airlines during the period that spans 2015 to 2019. We use one two input variables and four output variables. The input variables are inventory growth over the previous year and capital efficiency or capital productivity that we define as total assets per dollar of sales revenue.

The output variables are earnings before interest, taxes, amortization and depreciation (EBITDA), return on assets, revenue growth over the previous year, and interest rate coverage ratio.

- Earnings before interest, taxes, amortization and depreciation is a good way to measure the profitability of the airline industry, because it evaluates earnings on the basis of operations of the airline by focusing on operating costs only. This is helpful when comparing peers within an industry. A high EBITDA will be an indicator of operating efficiency.
- Return on assets: Return on assets is equal to the net income divided by the total assets of a business. As a metric of profitability, ROA tests the value gained from each dollar spent in assets.

- Total revenue growth: The year-over-year growth rate calculates the percentage change during the past twelve months. Year-over-year (YOY) is an effective way of looking at growth for two reasons: removing the effects of seasons and demarcating long-term trends.
- Inventory growth over the previous year: Airline seats are perishable inventory. Once a plane is aloft, its empty seats or unused load can no longer be sold. To minimize such losses, the industry has developed sophisticated computer programs to help determine how much demand there will be for each route at different times of the day, days of the week, and seasons of the year. A high ratio is an indicator of poorly managed inefficient airline.
- Interest coverage ratio: interest coverage ratio is a measure of a company's ability to honor its debt payments. When the interest coverage ratio is smaller than one, the company is not generating enough cash from its operations EBIT to meet its interest obligations and the company may be headed into liquidity troubles.
- Capital Productivity or capital efficiency ratio is calculated as total assets divided by total sales revenue. It measures the capital intensity of operations of an airline. Higher ratio means that the airline is consuming more capital per dollar of revenue and it may be adding to its cost. It is an input variable in our model.

Thus, to determine the comparative operational efficiencies of these entities, we should apply the DEA technique. The DEA model maximizes the output variables to assess the relative success of different firms and minimizes the input variable. We regard each of the firms as a homogenous entity in order to benchmark companies, and we will use the DEA technique to analyze these companies' comparative results.

DATA

Data for the airlines is obtained from Standard & Poor's NetAdvantage (S&P NetAdvantage). Data set covers the time period from December 31, 2015 to December 31, 2019. The study sample includes 14 airlines from Asia region. Table 1 shows descriptive statistics of the variables used in this study.

TABLE 1
A SUMMARY OF THE DATA USED IN THIS STUDY

	Earnings before interest, taxes, depreciation, and amortization (EBITDA)	Return On Assets (%)	Interest Coverage Ratio	Total Revenue Growth over the previous year (%)	Inventory Growth over the previous year (%)	Capital Efficiency
2015						
Mean	15.62	2.7	11.22	2.42	5.24	1.76
Std. Dev.	12.21	2.51	27.93	5.94	23.53	0.75
2016						
Mean	16.22	3.27	17.45	13.9	2.99	1.78
Std. Dev.	11.03	2.34	46.53	48.53	23.16	0.74
2017						
Mean	13.56	2.65	19.18	25.89	84.54	1.64
Std. Dev.	8.31	2.10	52.82	49.01	297.11	0.62
2018						
Mean	11.18	2.06	20.02	12.21	5.41	1.58
Std. Dev.	7.54	2.28	57.55	61.11	27.27	0.63
2019						
Mean	9.97	1.2	18.94	-15.44	2.44	1.62
Std. Dev.	8.04	2.58	58.06	28.64	15.59	0.44

Table 1 shows that, on an average,

- Earnings before interest, taxes, depreciation, and amortization have declined significantly from a higher of 15.62% in 2015 to 9.97% in 2019.
- Return on assets has declined from 2.7% in 2015 to 1.2% in 2019.
- Interest coverage ratio has improved from 11.22 in 2015 to 18.94 in 2019.
- Highest total revenue growth of 25.89% over the previous year was registered in 2017. In 2019, revenue growth over the previous is significantly negative at -15.44%.
- Inventory growth was 5.44% in 2015 and has declined to 2.44% in 2019
- Capital intensity ratio was 1.76 in 2015 and stands at 1.62 in 2019.

EMPIRICAL ANALYSIS

Using the DEA methodology, we can calculate an efficiency score for the 14 airlines on a scale of 1 to 100. Table 2 illustrates the efficiency scores of the 14 airlines for the years 2015 to 2019.

TABLE 2
EFFICIENCY SCORES FOR 14 ASIAN AIRLINES FOR THE PERIOD 2015 TO 2019.

	2015	2016	2017	2018	2019	Average for each airline
Air China	100%	45%	90%	49%	62%	69%
AirAsia	100%	100%	65%	100%	100%	93%
ANA Holdings, Inc.	41%	18%	81%	18%	27%	37%
Asiana Airlines, Inc.	100%	100%	100%	78%	100%	96%
China Airlines	100%	100%	100%	100%	100%	100%
China Eastern Airlines	58%	100%	98%	100%	100%	91%
EVA Airways	43%	64%	100%	43%	76%	65%
Hainan Airlines Holding	100%	100%	100%	100%	100%	100%
Japan Airlines	14%	3%	73%	25%	23%	28%
Korean Air Lines	100%	83%	100%	93%	89%	93%
Qantas Airways	51%	36%	85%	32%	36%	48%
Shandong Airlines	44%	40%	99%	68%	76%	65%
Singapore Airlines	34%	14%	100%	18%	100%	53%
Thai Airways International	100%	100%	100%	100%	100%	100%
Average for each year	70%	65%	92%	66%	78%	

As shown in Table 1, there three airlines that have been consistently efficient relative to their peers throughout the sample period of 2015 to 2019. China Airlines, Hainan Airlines, and Thai Airways have been consistently 100% efficient relative to their peers each year during the sample period of 2015 to 2019. Air Asia group has been 100% efficient every year during the sample period of 2015 to 2019 except for the year 2017 when it is only 65% efficient relative to its peers. Table 1 shows that there are 7 airlines out of 14 that are 100% efficient relative to their peers in 2019. Asiana airline shows 100% efficient relative to its peers every year except for 2018 when it is 78% efficient relative to its peers. Air China is 100% efficient only in 2015, China Eastern is 100% efficient relative to its peers in 2018 and 2019 only. EVA airways is 100% efficient in 2017 only. Korean Airline is 100% efficient in 2015 and 2017 only. Singapore Airlines in 100% efficient in 2017 only. ANA, Japan Airlines, Qantas, and Shandong airlines are not 100% efficient relative to their peers in any year during the sample period of 2015 to 2019. In 2019, Japan Airlines is the least efficient airline with an efficiency score of 23% followed closely by ANA with an efficiency score of 27% and Qantas at an efficiency score of 36% relative to their peers. During the sample period of 2015 to 2019, Japan Airlines, on an average, has the least efficiency score at 28% relative to its peers followed by ANA Holdings with an average efficiency score of 37%.

Table 1 also shows the average efficiency score of Asian airlines improved from 70% in 2015 to 92% in 2017 but declined to 66% in 2018 before improving to 78% in 2019.

Figure 1a and 1b show the efficiency frontier plot for 14 airlines for the year 2015 and 2019, respectively. Figure 1c shows the efficiency frontier plot based on the average efficiency score for the sample period of 2015 to 2019.

FIGURE 1A
EFFICIENCY FRONTIER FOR THE YEAR 2015

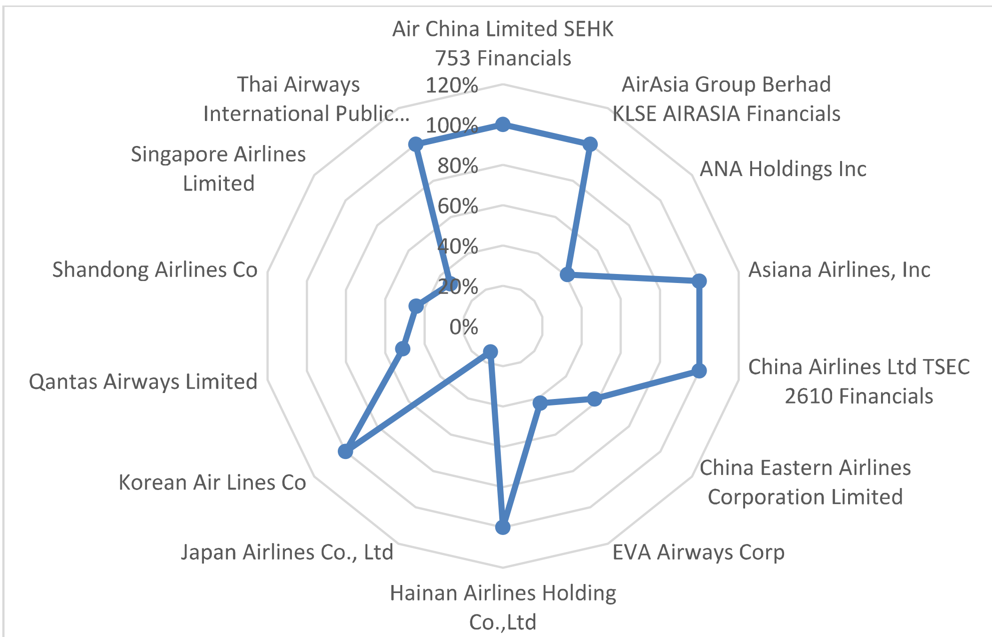

FIGURE 1B
EFFICIENCY FRONTIER FOR THE YEAR 2019

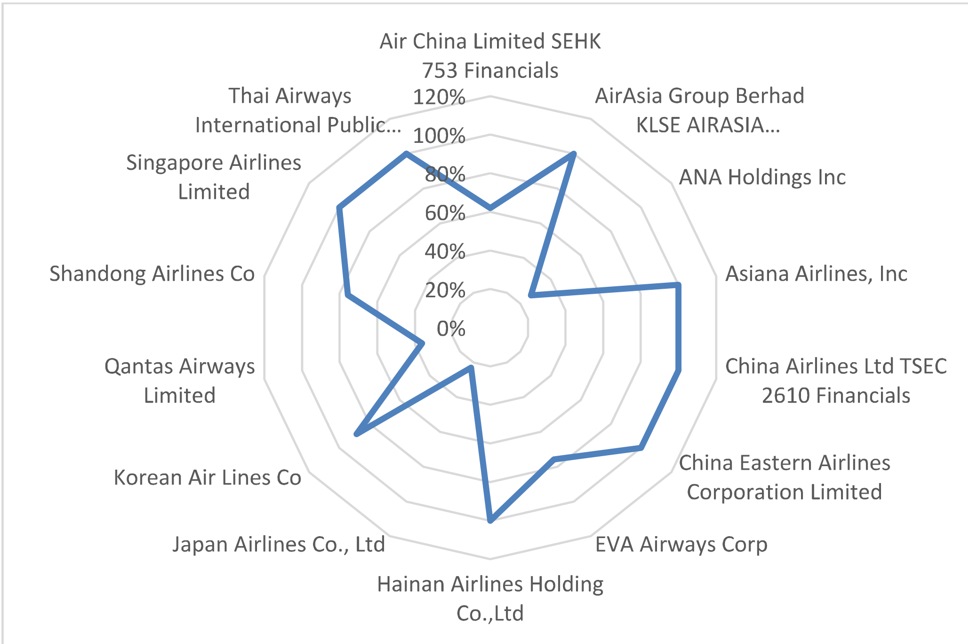

FIGURE 1C
EFFICIENCY FRONTIER BASED ON AVERAGE EFFICIENCY SCORE FOR THE SAMPLE PERIOD 2015 TO 2019

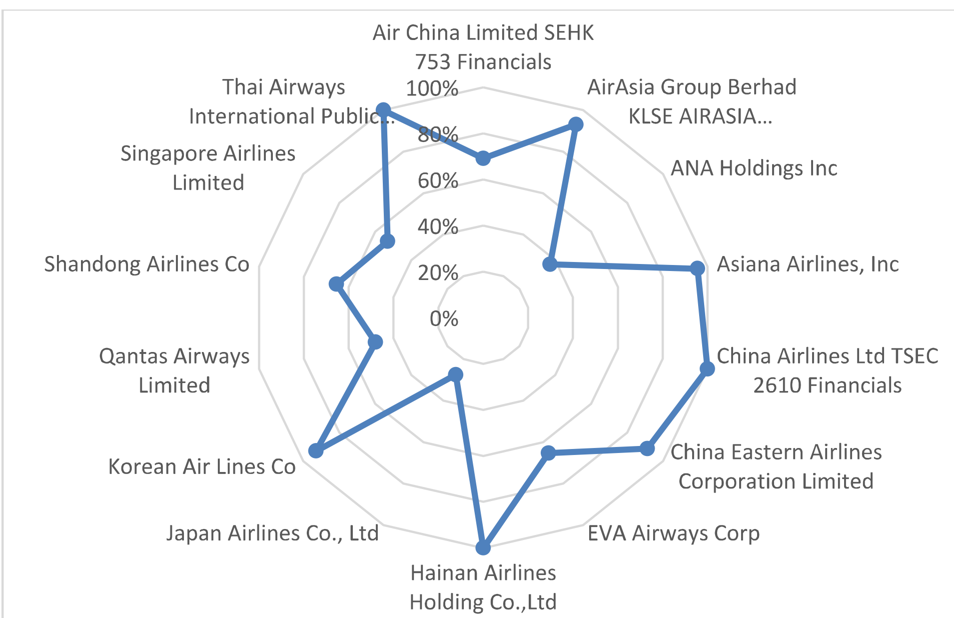

Figure 1a shows that Air China Limited. AirAsia Group Berhad, Asiana Airlines, Inc., China Airlines Ltd, Hainan Airlines Holding Co. Limited, Korean Airlines Company, and Thai Airways International are on the efficiency frontier with an efficiency score of 100% and envelope less than 100% efficient airlines that include ANA Holdings Inc., China Eastern Airlines Corporation Limited, EVA Airways Corp, Japan

Airlines Co., Ltd, Qantas Airways Limited, Shandong Airlines Co., and Singapore Airlines Limited. Figure 1b that AirAsia Group Berhad, China Airlines Ltd, China Eastern Airlines Corporation Limited, Hainan Airlines Holding Co. Limited, Korean Air Lines Co, Singapore Airlines Limited, and Thai Airways International Public Company Limited are on the efficiency frontier with an efficiency score of 100%.

Figure 1c shows that, based on average efficiency scores for the sample period 2015 to 2019, China Airlines Limited, Hainan Airlines Holding Co. Limited, and Thai Airways International Public Company Limited are on the efficiency frontier with 100% efficiency score and envelope other 11 airlines that below the efficiency frontier.

Using data envelopment analysis models, we calculated the efficiency of a company and identified the efficient peers. We then identify the peers for the inefficient airlines so that they can follow the best practices of their efficient peers to become more efficient. Table 3 illustrates the peer group for the inefficient companies.

TABLE 3
INEFFICIENT AIRLINES AND THEIR PEERS FOR THE YEAR 2019

Companies	efficiency	AirAsia Group	Asiana Airlines	China Airlines Ltd	China Eastern	Hainan Airlines	Singapore Airlines	Thai Airways	Sum
Air China Limited	62%	0.07	0.00	0.20	0.39	0.29	0.00	0.06	1.00
AirAsia Group	100%	1.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00
ANA Holdings Inc	27%	0.02	0.00	0.71	0.00	0.00	0.00	0.27	1.00
Asiana Airlines	100%	0.00	1.00	0.00	0.00	0.00	0.00	0.00	1.00
China Airlines	100%	0.00	0.00	1.00	0.00	0.00	0.00	0.00	1.00
China Eastern	100%	0.00	0.00	0.00	1.00	0.00	0.00	0.00	1.00
EVA Airways Corp	76%	0.00	0.00	0.68	0.00	0.22	0.00	0.09	1.00
Hainan Airlines	100%	0.00	0.00	0.00	0.00	1.00	0.00	0.00	1.00
Japan Airlines	23%	0.02	0.00	0.75	0.00	0.00	0.00	0.23	1.00
Korean Air Lines	89%	0.05	0.00	0.00	0.26	0.36	0.00	0.32	1.00
Qantas Airways	36%	0.03	0.25	0.72	0.00	0.00	0.00	0.00	1.00
Shandong Airlines	76%	0.33	0.30	0.23	0.00	0.00	0.00	0.15	1.00
Singapore Airlines	100%	0.00	0.00	0.00	0.00	0.00	1.00	0.00	1.00

China Airlines Ltd serves as a major peer for ANA, EVA Airlines, Japan Airlines, and Qantas Airlines. Chain Airlines also serves as a minor peer for Air China Limited and Shandong Airlines. Air Asia is the peer for Air China Limited, ANA Holdings, Inc., Japan Airlines Co., Ltd, Korean Air Lines Co, Qantas Airways Limited, Shandong Airlines Co. Thai Airways is the peer for Air China Limited, ANA Holdings, EVA Airways Corporation, Japan Airlines, Korean Airlines, and Shandong Airlines. Asiana Airlines serves as a peer for Qantas Airlines and Shandong Airlines. China Eastern Airline serves as a peer for Air China Limited and Korean Airlines. Hainan Airlines is the peer for Air China Limited, EVA Airways Corporation, and Korean Airlines. It means the inefficient airlines should emulate efficient airlines in terms of earnings before interest, taxes, amortization and depreciation (EBITDA), return on assets (ROA), interest coverage ratio, year over year total revenue growth, year over year inventory growth, and capital efficiency ratio.

The DEA Efficiency Measure informs us whether a company (out of 14 sampled companies) can boost its performance compared to its competitive peers in order to achieve pareto-efficient levels. We therefore determine the optimum set of slack values with the assurance that performance efficiency will not increase at the cost of the slack values of input and output variables. When productivity has been maximized, the model would pursue the optimum number of input and output slacks. If each of these values is positive for an optimum solution to the DEA model, this ensures that the resulting output of the business (DMU) will boost even after the performance factor has been improved, without the need for additional input. If the performance is 100 per cent and the variables are zero, the output level of an organization cannot be extended jointly or individually without increasing its input level. In addition, given its output values, its input level should not be reduced. Thus, the organizations or companies are pareto-efficient with technical output efficiency of 1 If the company is 100% effective but one slack value is positive for the optimum solution, then the DEA model has established an efficiency boundary point that provides the same amount of output as the company A in question, but offers the output in excess of the company A corresponding to the positive slack. Company A is therefore not Pareto-efficient, but with a radial efficiency of 1, since its output cannot be jointly extended. Finally, if the company A is not effective (<100%) or the efficiency factor is greater than 1, then the company in question is not Pareto-efficient and the efficiency factor is the highest factor by which all its production levels observed can be improved without modifying its input. If we have not only output efficiency > 1, but also some positive slack in the optimum solution, then the output of company A corresponding to the positive slack can be increased by more than the output efficiency factor, without the need for additional input. As the additional output does not apply across all output dimensions, the potential additional output at firm A is not reflected in its efficiency measure. Table 4 illustrates the slack values identified in the next stage of the DEA analysis. The slack variables for 100% efficient organizations are zero. Table 4 shows the slack variables for the year 2019.

TABLE 4
SLACK VARIABLES FOR INEFFICIENT COMPANIES FOR THE YEAR 2019

Airlines	efficiency	Return on Assets (%)	EBITDA Margin (%)	EBIT / Interest Exp.	12-month Total Revenue Growth	12-month Inventory Growth	Capital Productivity
Air China	62%	0.033	0.243	0.000	0.757	0.132	0.000
ANA	27%	0.048	0.224	0.000	0.885	0.222	0.428
EVA Airways	76%	0.023	0.128	0.000	0.323	0.303	0.000
Japan Airlines	23%	0.066	0.276	0.000	0.883	0.233	0.441
Korean Air Lines	89%	0.010	0.138	0.000	0.305	0.001	0.000
Qantas Airways	36%	0.049	0.225	0.000	0.620	0.180	0.446
Shandong Airlines	76%	0.017	0.097	0.000	0.651	0.000	0.572

Table 4 shows the areas in which airlines need to improve to attain 100% efficiency. As shown in Table 4, all inefficient airlines need to improve their 12-month revenue growth, EBITDA margin and return on assets to reach 100% efficient levels. Table 4 also shows that all inefficient airlines except Korean Air Lines and Shandong Airline need to bring down their 12-month inventory growth rate relative to their 100% efficient peers. Furthermore, ANA, Japan Airlines, Qantas Airways, and Shandong Airlines need to improve their capital productivity relative to their efficient peers. Table 4 shows that none of the inefficient airlines is lagging in their interest coverage ratio, because the slack value for earnings before interest and taxes divided by interest expense is zero.

SUMMARY AND CONCLUSIONS

Despite the rise in air traffic in Asia, only 6 of the 20 publicly traded airlines operating in the region made a profit in the last published quarter of 2018. (https://www.scmp.com/week-asia/economics/article/2184740/asias-aviation-industry-booming-so-why-isnt-it-making-money). Intense rivalry within the industry is the primary reason for the lack of profitability. This study benchmarked 14 major Asian airlines against one another using linear programming technique of data envelopment analysis (DEA). We evaluated the operating efficiencies of 14 Asian airlines for the period 2015 to 2019. The DEA model uses well-performing airlines (efficiency of 1 or 100%) that are closest to the under-performing airline on the efficiency frontier as a "role model" (peer units) for the under-performing airline. We found that only three of the 14 airlines were 100% efficient compared to their peers over the study duration from 2015 to 2019. The study also showed that the average efficiency score of Asian airlines rose from 70% in 2015 to 78% in 2019. The study also established appropriate peer "role model" for inefficient firms for the year 2019. For seven inefficient Asian airlines, Air Asia and China Airlines act as a "role model". Thai Airways is a "role model" for six inefficient airlines, while Hainan airline is a "role model" for four inefficient airlines. The study also found that Asiana airlines and China Eastern airline function as a "role model" for three inefficient airlines.

The model of data envelopment analysis also allows one to recognise the places in which inefficient airlines lag behind productive peers. By specifying the slack variables, DEA can help airlines focus their resources on those fields that require the most emphasis to boost the airline's efficiency. The aviation sector is one of the most seriously affected by COVID-19. This analysis was conducted prior to the devastation unleashed by COVID-19. It would be important to examine the effect of this event on the sector in the years to come and how the industry is reforming in order to tackle the worst economic downturn ever faced by the airline industry.

ENDNOTES

[1] The following are the guidelines for DMU model selection:

a. The number of DMUs is required to be greater than the number of inputs and outputs generated (Darrat et. Al., 2002; Avkiran, 2001) to efficiently distinguish between productive and inefficient DMUs. The number of inputs and outputs should be at least 2 or 3 times greater than the sum of the sample size (Ramanathan, 2003).
b. The parameters for input and output selection are often very arbitrary. The DEA research should begin with an exhaustive, peer-reviewed list of inputs and outputs deemed to be important to the study. Screening inputs and outcomes may be very objective (e.g. statistical) or qualitative, strictly judgmental, using expert guidance, or using approaches such as analytical hierarchical processes (Saaty, 1980). Inputs are usually the resources used by DMUs or factors that influence the output of DMUs. Outputs, on the other hand, are the benefits produced by the operation of the DMUs and, in terms of efficiency, report higher performance. We should usually limit the total number of inputs and outputs to an acceptable degree. If the number of inputs and outputs increases, there is an efficiency level of 1 for more DMUs as they become too advanced to be measured in comparison to other units. (Ramanathan, 2003).

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