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Exploring operational efficiency and scale of production in Indian aviation sector: A data envelopment analysis (DEA) approach

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Abstract
The current study evaluates the technical and scale efficiency of airlines companies operating in Indian. An attempt has been made to evaluate how efficiently the operating cost and its components are utilized by each airline companies relative to its peers. The study was conducted from the financial year 2004-05 to 2018-19 on six major airline companies operating in India covering both the full service and low-cost carriers using secondary data drawn from various sources. An input-oriented Data Envelopment Analysis (DEA) is used to estimate the efficiency of select airline companies. The analysis begins with constant returns to scale (CRS) and later extends to variable returns to scale (VRS) following the CCR (Charnes, Cooper, and Rhodes) Model and BCC (Banker, Charnes, and Cooper) Model respectively. The empirical estimates show that airlines are operating with Overall Technical Efficiency (OTE) between 62.2 per cent and 92.7 per cent. It is observed that Jet Airways is the most efficient unit during the period of study. It is also observed that major source of the overall technical inefficiency for the select aviation companies is scale inefficiency and not pure technical efficiency. Additionally, Scale Deficiency Index (SDI) indicates that aviation companies experiencing DRS is more than the percentage of aviation companies experiencing IRS. Hence, the findings suggest that the majority of Indian airline companies are too small to achieve economies of scale. Therefore, to reap the benefits of economies of scale, most of Indian aviation companies need to scale up their production to achieve efficiency.

Keywords: Aviation sector, efficiency, DEA, technical efficiency, scale efficiency, SDI, CCR Model, BCC Model, returns to scale

Introduction

One of the essential parts of the nation's transportation network is its aviation sector. Empirically, Indian aviation began its first commercial flight in 1911, and with the nationalization of the sector in 1953, it saw significant advancements. The 1990 reforms in the Indian aviation sector were a turning point for private carriers and it also opened the door for Low-Cost Carriers (LCCs) into the market. Truly speaking, the industry dynamics were altered by the entry of private and low-cost carriers. Due to a burgeoning middle class and their rising disposable incomes, currently, the Indian aviation market is one of the fastest-growing in the world. However, despite its growth, the business still confronts several obstacles, such as legislative barriers, infrastructural limitations, and financial volatility. In light of this, increasing operational efficiency has emerged as the top priority for all airlines in order to endure the hindrances and continue their operations (Cui & Yu, 2021) [13]. According to Chen (2007) [10], efficiency is described as the ability of a business to employ their resources to maximise its output. Therefore, efficiency is an important parameter for evaluating the operational performance of an airline company. An aviation company's capacity in optimising its performance while consuming a minimum possible resource has been examined in past researches (Forsyth *et al*., 1986) [19].

1. Objectives of the Study

The objectives of the study are as follows:

1. To identify the reasons behind inefficiency in Indian aviation sector (Refer to Section 5.1); and
2. To analyze the scale of production of the Indian aviation sector (Refer to Section 5.2).

Material and Methods

1. Selection of Decision-Making Units (DMUs) & Data Period

The study considers secondary data and the period of study is 2004-05 to 2018-19. During this long period, several airlines operated in India. Out of these airlines, a few exist today while the rest ceases to have their existence. During 2004-05 there were three national passenger carriers in India (Air India, Indian Airlines, and Alliance Air) and three private passenger airlines (Jet Airways, Sahara Airways, Air Decan) operating in India. While in the year 2018-19, there were three national carriers (Air India, Air India Express, and Alliance Air) and nine private airlines (Jet Airways, Jet Lite, Air Asia, Air Deccan, Air Odisha, Air Heritage, Go Air, Indigo, Spice Jet, Star Air, True Jet, Zoom Air, and Vistara) operating in India (DGCA, 2019a) [15, 16, 17, 18]. However, out of these airlines, only six airlines (Air India, Jet Airways, Spice Jet, Kingfisher Airline, Indigo, and Go Air) have been selected for the current study based on convenience Sampling Technique. Out of the selected airlines, Air India is a national carrier and public airline; on the other hand, the remaining five airlines are private passenger airlines. SPSS 20.0 and MS Excel 2019 are used to analyze the secondary data sets.

Table 1: Public and Private Airlines Selected During the Period of Study

No.	Public Airline Company	No.	Private Airline Company
1.	Air India	1.	Jet Airways
		2.	Spice Jet
		3.	Kingfisher Airline
		4.	Indigo
		5.	Go Air

Source: Airline Companies Operating in India (DGCA)

2. Selection of Input and Output Variables

The objective of the study is to check the efficiencies of the selected public and private airline companies. Efficiency is typically a function of input and output as follows: Efficiency = Output ÷ Input. With a view to estimating the efficiency of the competing units, appropriate financial or nonfinancial variables about airline companies were identified. Prior research has shown that operating and administrative expense (Jain & Natarajan, 2015) [22] and the number of employees (Cui & Yu, 2021, Lin & Hong, 2020) [13, 26] are the two most important inputs for estimating efficiency. Whereas, Operating Income (Assaf & Josiassen, 2011) [2] and Ton Kilometer (KM) available (Assaf & Josiassen, 2011, Jain & Natarajan, 2015) [2, 22] are selected as the output of the aviation industry. According to Cooper, *et al*. (2007) [12], number of units should be greater than or equal to the product of number of inputs and number of outputs. i.e. $n \geq (p \times q)$ where, n = number of units [i.e. decision-making units (DMUs)], p = number of inputs, q = number of outputs]

Table 2: Selection of Inputs & Outputs during the Period of Study

No.	Inputs	No.	Outputs
1.	Operating and Administrative Expenses	1.	Operating Income
2.	Number of employees	2.	Ton KM Available

As (p×q) for the current study is four, though total DMUs for the current study is 6 fulfilling the condition and two input-two output combinations may be considered here. The data on the input and output variables for all 6 airline companies (DMUs) during the period 2004-05 to 2018-19 are collected from Handbook of India Air Transport Statistics 2018-19 published by the Directorate General of Civil Aviation (DGCA) (DGCA, 2019) [15, 16, 17, 18]. With a view to assess the efficiency of competing Indian airline companies each year, Data Envelopment Analysis (DEA) is applied (Berger & Humphrey 1997) [7].

3. Data Collection

The yearly data of aforesaid input and output variables of the selected airline companies operating during the study period (2004-05 to 2018-19) are collected from Capitaline database (Capitaline, 2019) [8] and Handbook on Indian Aviation Statistics published by the DGCA (DGCA, 2019) [15, 16, 17, 18].

4. Fulfillment of Conditions (Test of Isotonicity)

An isotonicity test is conducted to find out whether the relationship between inputs and outputs is erratic (Avkiran, 1999) [3]. The test was conducted to ensure the validity of the DEA model specification which encompasses the calculation of all inter-correlations between inputs and outputs. This helps to identify whether increasing amounts of inputs should result in greater outputs, implying that there should be positive correlations between inputs and outputs.

Table 3: Test of Isotonicity

		Operating and Administrative Expenses	No. of Employees	Operating Income	Ton Km Available (mn)
Operating and Administrative Expenses	Pearson Correlation	1	0.665**	0.617**	0.631**
	Sig. (2-tailed)		0.000	0.000	0.000
	N	82	82	82	82
No. of Employees	Pearson Correlation	0.665**	1	0.800**	0.853**
	Sig. (2-tailed)	0.000		0.000	0.000
	N	82	82	82	82
Operating Income	Pearson Correlation	0.617**	0.800**	1	0.952**
	Sig. (2-tailed)	0.000	0.000		0.000
	N	82	82	82	82
Ton Km Available (mn)	Pearson Correlation	0.631**	0.853**	0.952**	1
	Sig. (2-tailed)	0.000	0.000	0.000	
	N	82	82	82	82

Source: Compilation of secondary data using MS Excel, 2019

In Table 3 Pearson's correlation is calculated to test the isotonicity relationship between the selected inputs and outputs. From the table it is apparent that the inter-correlation of all the indicators is positive and significant, recommending that the specification of the DEA model is valid.

5. CCR & BCC Model

In Data Envelopment Analysis (DEA), the CCR (Charnes, Cooper, and Rhodes) and BCC (Banker, Charnes, and Cooper) models are widely used to measure the efficiency of decision-making units (DMUs). These models are used in operations research to evaluate the relative efficiency of decision-making units (DMUs). They are particularly useful when there are multiple inputs and outputs, and the efficiency of each DMU needs to be measured against others.

5.1 CCR Model (Constant Returns to Scale)

An input-oriented DEA with the assumption of Constant Returns to Scale (CRS) (Charnes, Cooper & Rhodes, 1978)

[9] would aim for an equal-proportionate reduction of inputs to produce a standard output of the efficient units by solving the following Linear Programming (LP) problem:

$$\begin{aligned} \min_{\theta,\lambda} \quad & = \quad \theta \\ \text{subject to} \quad & \theta x_0 - X\lambda \geq 0 \\ & Y\lambda - y_0 \geq 0 \\ & \lambda \geq 0 \end{aligned}$$

Where,

- Xλ = optimum minimum input
- X0 = actual input
- Yλ = optimum standard output
- Yo = actual output.

5.2 BCC Model (Variable Returns to Scale)

The BCC model is an extension of the CCR model that allows for variable returns to scale (VRS) (Banker *et al*., 1984) [6], meaning that the efficiency scores are not constrained to be equal for all DMUs. In the BCC model, the efficiency scores can differ among DMUs based on their scale of operation. The linear programming formulation of the input-oriented BCC (Banker-Charnes-Cooper) model is as follows:

$$\begin{aligned} \min_{\theta_B,\lambda} \quad & = \quad \theta_B \\ \text{subject to} \quad & \theta_B x_0 - X\lambda \geq 0 \\ & Y\lambda - y_0 \geq 0 \\ & e\lambda = 1 \\ & \lambda \geq 0 \end{aligned}$$

It can be clearly observed that from the two envelopment models of CCR and BCC that the only difference is the introduction of a convexity constraint $e\lambda = 1$

5.3 Returns to Scale (RTS) Model

The calculation of overall technical efficiency, pure technical efficiency, and scale efficiency measures in the previous objective can now be represented in terms of linear programming models that can be utilized to determine the efficiency of individual DMUs using actual data on input and output variables. From the study of literature, it is evident that many mathematical programming models have been used to study the efficiency of individual DMUs (Charnes *et al*., 1994; Cooper *et al*., 2007, Banker *et al*., 1984) [6, 12]. In the present study, the BCC model, named after Banker, Charnes, and Cooper (1984) [6] is utilized to obtain efficiency measures under VRS (variable returns to scale assumptions). The notations of used input-oriented DEA models for measuring TE scores for DMU, under different scale assumptions are as follows:

$$\begin{aligned} \text{Min } TE_O \quad & = \theta_0 - \varepsilon \left(\sum_{i=1}^{m} s_i^- + \sum_{r=1}^{s} s_r^+\right) \\ \theta_0, \lambda_1, \lambda_2 \ldots, \lambda_n, s_i^-, s_r^+ & \\ \text{Subject to} & \\ s_i^-, s_r^+ \geq 0 \quad & \text{(i = 1, …., m; r=1,….s)} \\ \sum_{j=1}^{n} \lambda_j = 1 \quad & \text{if it is VRS} \end{aligned}$$

The current model is based on the BCC model (Banker *et al*., 1984) [6] and provides Farrell's input-oriented TE measure (Farrell, 1957) under the assumption of variable returns-to-scale. The measure of efficiency provided by the BCC model is known as pure technical efficiency (PTE) and is denoted as θ_0^{BCC}. The ratio $(\frac{\theta_0^{CCR}}{\theta_0^{BCC}})$ provides a measure of scale efficiency (SE). All the measures of efficiency mentioned here are bounded between one and zero. The measure of scale efficiency (SE) does not indicate whether the DMU in question is operating in the area of increasing or decreasing returns-to-scale (Kumar & Gulati, 2008) [24]. The nature of returns-to-scale can be determined from the magnitude of optimal. Banker, (1984) [6] & Seiford and Zhu (1999) listed the following three cases:

Case 1: If $\sum_{j=1}^{n} \lambda_j^* = 1$ in any alternate optima, CRS prevails on DMU o which implies operating at the most productive scale size.

Case 2: If $\sum_{j=1}^{n} \lambda_j^* < 1$, then scale inefficiency appears due to increasing returns-to-scale (IRS) which implies that the airline company has sub-optimal scale size.

Case 3: If $\sum_{j=1}^{n} \lambda_j^* > 1$, then scale inefficiency occurs due to decreasing returns-to-scale (DRS) which implies that the airline company has a supra-optimal scale size.

6. Analytical Tools

DEA Solver, an MS Excel based analytical package is used estimate the efficiencies of airline companies in the individual years during the study period. In the current study, data on input and output variables of all select airline companies are taken together and OTE scores are calculated based on above model in each year under the study. This addresses the first objective of the study. To calculate the distribution of Increasing Returns to Scale (IRS), Constant Returns to Scale (CRS), and Decreasing Returns to Scale (DRS) over the study period Lopez-Cortes, Snowden (LCS) (1998) Scale Deficiency Index (SDI) was used, which addresses the second objective.

Results

1. Addressing to Objective 1: Identifying the Reasons behind Inefficiency in Indian Aviation Sector

a. Measuring OTE and PTE scores and estimate SE scores from OTE and PTE for each company in each year

In DEA, Overall Technical Efficiency (OTE) is decomposed into two mutually exclusive, non-additive components: pure technical efficiency (PTE) and scale efficiency (SE). This process of decomposition helps us to identify the source of the inefficiencies of DMUs. Hence, PTE is used as an index of managerial performance. Once OTE and PTE are obtained, the ratio of OTE to PTE is used to calculate scale efficiency (SE). This is a measure of the ability of the management to choose the optimum size of resources or to choose the optimum scale of production that will help them attain the expected production level. (Kumar & Gulati, 2008) [24]. According to Banker, Charnes, and Cooper (BCC) model, the variable returns to scale help to separate scale efficiency from pure technical efficiency. When the production technology allows variable returns to scale (VRS) at different points on the frontier of the production possibility set, the technical efficiency (either input- or output-oriented) of a DMU will differ from its scale

efficiency. Pure technical efficiency is measured by comparing the average productivity of a DMU with the corresponding average productivity at its input- or output-oriented projection onto the VRS frontier. Contrastingly, Scale efficiency compares the average productivity at the efficient input- or output-oriented projection with the maximum average productivity attained at the Most Productive Scale Size (MPSS) on the VRS frontier (Jain & Natarajan, 2015) [22].

Table 4(a): Average Efficiency of Companies

Year	Air India			Jet Airways			SpiceJet		
	OTE	PTE	SE	OTE	PTE	SE	OTE	PTE	SE
2005	1.000	1.000	1.000	1.000	1.000	1.000	0.744	0.756	0.984
2006	1.000	1.000	1.000	1.000	1.000	1.000	0.508	0.607	0.836
2007	1.000	1.000	1.000	1.000	1.000	1.000	0.914	1.000	0.914
2008	1.000	1.000	1.000	0.906	1.000	0.906	0.992	1.000	0.992
2009	1.000	1.000	1.000	0.978	1.000	0.978	1.000	1.000	1.000
2010	1.000	1.000	1.000	0.963	1.000	0.963	1.000	1.000	1.000
2011	1.000	1.000	1.000	0.652	0.777	0.839	0.923	1.000	0.923
2012	0.600	1.000	0.600	1.000	1.000	1.000	1.000	1.000	1.000
2013	0.654	1.000	0.654	1.000	1.000	1.000	1.000	1.000	1.000
2014	0.725	1.000	0.725	0.992	1.000	0.992	1.000	1.000	1.000
2015	0.793	1.000	0.793	1.000	1.000	1.000	0.920	1.000	0.920
2016	1.000	1.000	1.000	0.947	1.000	0.947	1.000	1.000	1.000
2017	1.000	1.000	1.000	0.769	0.770	0.999	0.490	1.000	0.490
2018	1.000	1.000	1.000	0.699	1.000	0.699	0.479	0.874	0.548
2019	1.000	1.000	1.000	1.000	1.000	1.000	0.437	0.930	0.469
Mean	0.918	1.000	0.918	0.927	0.970	0.955	0.827	0.945	0.872

Source: Compilation of secondary data using MS Excel, 2019

Table 4 (b): Average Efficiency of Companies

Year	Kingfisher Airline			Indigo			GoAir			
	SE	OTE	PTE	SE	OTE	PTE	SE	OTE	PTE	SE
2005	0.984	0.454	0.502	0.905	-	-	-	1.000	1.000	1.000
2006	0.836	0.661	0.807	0.819	-	-	-	1.000	1.000	1.000
2007	0.914	0.808	0.913	0.885	0.636	0.887	0.717	1.000	1.000	1.000
2008	0.992	0.503	0.540	0.932	1.000	1.000	1.000	0.696	1.000	0.696
2009	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.368	1.000	0.368
2010	1.000	0.700	0.700	1.000	1.000	1.000	1.000	1.000	1.000	1.000
2011	0.923	0.791	0.804	0.984	1.000	1.000	1.000	1.000	1.000	1.000
2012	1.000	0.600	0.635	0.945	1.000	1.000	1.000	0.783	1.000	0.783
2013	1.000	0.078	0.399	0.195	1.000	1.000	1.000	0.852	1.000	0.852
2014	1.000	-	-	-	1.000	1.000	1.000	0.975	1.000	0.975
2015	0.920	-	-	-	0.960	1.000	0.960	1.000	1.000	1.000
2016	1.000	-	-	-	0.832	0.845	0.985	0.726	1.000	0.726
2017	0.490	-	-	-	0.694	0.706	0.984	0.652	1.000	0.652
2018	0.548	-	-	-	0.605	1.000	0.605	0.651	1.000	0.651
2019	0.469	-	-	-	0.474	1.000	0.474	0.674	1.000	0.674
Mean	0.872	0.622	0.700	0.852	0.862	0.957	0.902	0.825	1.000	0.825

Source: Compilation of secondary data using MS Excel, 2019

In the case of Air India, the OTE score is 1 for the maximum number of years during the period of study except for 4 years, 2012, 2013, 2014, and 2015. The PTE score of the said airline is 1 throughout the period of study. The SE score of Air India is also 1 for the maximum number of years except the earlier mentioned years 2012, 2013, 2014, and 2015. The OTE, PTE, and SE score of Air India is 1 and the company performed efficiently in 11 years i.e., 2005, 2006, 2007, 2008, 2009, 2010, 2011, 2016, 2017, 2018, and 2019. The mean OTE, PTE, and SE percentages of Air India are 91.8%, 100%, and 91.8% respectively [Table (4(a)]. Air India which was our national carrier made efficient utilization of its resources (i.e. aircraft, manpower and material) and enhanced its operational efficiency in key areas reflected in their OTE, PTE and SE scores and contributed significantly towards profit generation. Air India Express, which was a low-cost international subsidiary of Air India, reported net profit continuously for five years since 2005 (IANS, 2020) [21].

In the case of Jet Airways, the OTE score is 1 for 7 years during the period of study and it is less than 1 for 8 years, i.e., 2008, 2009, 2010, 2011, 2014, 2016, 2017, and 2018. The PTE score of the said airline is 1 for almost all years except 2 years, i.e., 2011 and 2017. The SE score of Jet Airways is also 1 for 7 years except the earlier mentioned years i.e., 2008, 2009, 2010, 2011, 2014, 2016, 2017, and 2018. The OTE, PTE, and SE score of Jet Airways is 1 and the company performed efficiently in 7 years i.e., 2005, 2006, 2007, 2012, 2013, 2015, and 2019. The mean OTE, PTE, and SE percentages of Jet Airways is 92.7%, 97%, and 95.5% respectively [Table (4(a)]. Jet Airways made a mark in the industry through its warm hospitality, exceptional inflight services and operational excellence. In order to diversify their offerings and tap the market of LCCs, Jet

acquired Air Sahara and rebranded it as Jet Lite. Like other airlines, Jet Airways was also hit by the global economic recession in 2008 but it promptly introduced cost cutting measures and implemented strategic initiative to overcome the challenge and enhance its operational efficiency (Mandal & Singhal, 2024) [28]. As a result, their OTE, PTE and SE scores were quite high during that period.

In the case of Spice Jet (shown in Table 4), the OTE score is 1 for 6 years during the period of study and it is less than 1 for 9 years, i.e., 2005, 2006, 2007, 2008, 2011, 2015, 2017, 2018, and 2019. The PTE score of the said airline is 1 for almost all years except 4 years, i.e., 2005, 2006, 2018, and 2019. The SE score of Spice Jet is also 1 for 6 years except the earlier mentioned years i.e., 2005, 2006, 2007, 2008, 2011, 2015, 2017, 2018, and 2019. The OTE, PTE, and SE score of Spice Jet Airways is 1 and the company performed efficiently in 6 years i.e., 2009, 2010, 2012, 2013, 2014, and 2016. The mean OTE, PTE and SE percentages of Spice Jet are 82.7%, 94.5% and 87.5% respectively [Table (4(a)]. Rapid growth and market penetration, established Spice Jet as one of the India's prominent low-cost carriers. Spice Jet's strategic partnership with key investors helped them in expanding its network of routes; introducing strategic pricing; and capitalizing on the growing demand for air travel (Baliga, 2024) [5]. However, Spice Jet tried a few pricing strategies, such as discount scheme, promotional fares and super sale technique in which it sold all-inclusive tickets at marginal prices that eventually resulted in negative cash flow (Sahay & Banerjee, 2020). It ultimately marked their poor operational or managerial efficiency reflected through low OTE and PTE scores.

In the case of Kingfisher Airlines, the OTE score is 1 for only one year during the period of study i.e., 2009. Similarly, the PTE and SE score of the said airline is 1 for only one year i.e., 2009. For the remaining 8 years, i.e., 2005, 2006, 2007, 2008, 2010, 2011, 2012, and 2013, the OTE score of the company is less than 1. The OTE, PTE, and SE score of Kingfisher Airlines was 1 in the year 2009 only and the company performed efficiently in that particular year. The mean OTE, PTE, and SE percentages of Kingfisher Airline are 62.2%, 70%, and 85.2% respectively [Table 4 (b)]. Unlike other airline companies which had their share of ups and downs, Kingfisher Airline had never recorded any profit since 2005. Kingfisher Airline's losses mounted up with the increase in fuel price in 2010-11. Kingfisher Airline's poor financial performance stood in contrast to its award-winning performance for the service that they have extended in fulfilment of their business model that catered only high-end fliers. However, Indian consumers were price sensitive which resulted in the downfall of the airline. Kingfisher was forced to close its low-cost arm Kingfisher Red (India Today, 2011) [25]. Despite its initial success, Kingfisher Airline began facing financial problems from 2008. Airline's high operating costs combined with high fuel price and increased competition started taking a toll on the company's financial viability. It struggled to maintain its profitability but began accumulating debt (Hub, 2024) [20]. As a result, throughout the period of study, the company recorded low OTE, PTE and SE scores.

In the case of Indigo, the OTE score is 1 for 7 years during the period of study and it is less than 1 for 6 years, i.e., 2007, 2015, 2016, 2017, 2018, and 2019. The PTE score of the said airline is 1 for almost all years except 3 years, i.e., 2007, 2016, and 2017. The SE score of Indigo is also 1 for 7 years except the earlier mentioned years i.e., 2007, 2015, 2016, 2017, 2018, and 2019. The OTE, PTE, and SE score of Indigo is 1 and the company performed efficiently in 7 years i.e., 2008, 2009, 2010, 2011, 2012, 2013, and 2014. The mean OTE, PTE, and SE percentages of Indigo are 86.2%, 95.7%, and 90.2% respectively [Table 4 (b)]. Over the years Indigo made a strong monopoly position in Indian aviation industry after giving a tough competition to aviation giants like Jet Airways and Kingfisher Airline. The downfall of Kingfisher Airline helped Indigo to come up the ladder. Indigo used some game changing strategies, like sale and lease back model to reduce cost of operation. Indigo used more air cars with relatively little capital as compared to its peers with the help of these strategies (Ayare, 2022) [4]. Indigo was also able to rotate their cash more efficiently as compared to its competitors by reducing its operational costs which was marked by their higher PTE and SE scores.

In the case of Go Air, the OTE score is 1 for 6 years during the period of study and it is less than 1 for 9 years, i.e., 2008, 2009, 2012, 2013, 2014, 2016, 2017, 2018, and 2019. The PTE score of the said airline is 1 for all years during the period of study. The SE score of Go Air is also 1 for 6 years except the earlier mentioned years i.e., 2008, 2009, 2012, 2013, 2014, 2016, 2017, 2018, and 2019. The OTE, PTE, and SE score of Spice Go Air is 1 and the company performed efficiently in 6 years i.e., 2005, 2006, 2007, 2010, 2011, and 2015. The mean OTE, PTE, and SE percentages of Go Air are 82.5%, 100%, and 82.5% respectively [Table 4 (b)]. Go Air was a LCC which operated point to point flights with minimal aircraft park time. It had a reputation of being slow in expanding its business. It was a budget airline and it always maintained a minimalistic approach. It charged for all meals served on-board and it had no in-flight entertainment system available to its passengers. These strategies reduced their maintenance costs significantly (Modgil *et al*., 2020) [29]. It was considered as a reflection of higher managerial efficiency marked by their high PTE scores. However, the airline faced capacity bottlenecks due to low inventory of aircrafts.

b. Measuring Overall Technical Inefficiency (OTIE), Pure Technical Inefficiency (PTIE) and Scale Inefficiency (SIE) for each company in each year and analyzing the reasons behind inefficiency

In this section, an attempt has been made to identify the years (within the study period), in which an airline was operationally inefficient and analyze the reasons behind such inefficiency – managerial underperformance or inappropriate scale of production.

Table 5: Years in which Air India Performed Inefficiently

Year	Air India			
	Overall Technical Efficiency (OTE)	Pure Technical Efficiency (PTE)	Scale Efficiency (SE)	Reason of Inefficiency
2012	0.600	1.000	0.600	Inappropriate Scale
2013	0.654	1.000	0.654	Inappropriate Scale
2014	0.725	1.000	0.725	Inappropriate Scale
2015	0.793	1.000	0.793	Inappropriate Scale

Source: Compilation of secondary data using MS Excel, 2019

The OTE scores of Air India is less than 1 during 2012, 2013, 2014, and 2015. However, PTE scores of these years are equal to 1. This signifies that the OTE score is less than 1 due to SE scores. In these years SE score is less than 1 which is the reason behind the inefficiency of Air India. Thus, the inefficiency of Air India in these 4 years is caused due to inappropriate scale of operation. However, the OTE, PTE, and SE score of Air India is 1 and the company performed efficiently in 11 years i.e., 2005, 2006, 2007, 2008, 2009, 2010, 2011, 2016, 2017, 2018, and 2019.

Air India, despite being a national carrier had turned out to be a loss-making concern and was under huge debt. In 2011, the airline reached a point when it could not pay salaries to its staffs on time. The erstwhile Government bailed out the company by providing them with a loan of Rs 30,000 crores through equity funding spread over a decade. The situation continued till 2017 when the company had a huge financial burden originating from its 111 aircrafts and working capital loans. The airline lost its market share in domestic and international market. The debt of Air India ballooned from Rs 5,000 crores to Rs 50,000 crores within a decade (Khan, 2021) [23]. This actually marked the reduction of their scale efficiency during the period.

Table 6: Years in which Jet Airways Performed Inefficiently

Year	Jet Airways			
	OTE	PTE	SE	Reasons for inefficiency
2008	0.906	1.000	0.906	Inappropriate Scale
2009	0.978	1.000	0.978	Inappropriate Scale
2010	0.963	1.000	0.963	Inappropriate Scale
2011	0.652	0.777	0.839	Inappropriate Scale & managerial underperformance
2014	0.992	1.000	0.992	Inappropriate Scale
2016	0.947	1.000	0.947	Inappropriate Scale
2017	0.769	0.770	0.999	Inappropriate Scale & managerial underperformance
2018	0.699	1.000	0.699	Inappropriate Scale

Source: Compilation of secondary data using MS Excel, 2019

The OTE scores of Jet Airways are less than 1 due to SE scores for 6 years i.e., 2008, 2009, 2010, 2014, 2016, and 2018. In these years SE score is less than 1 which is the reason behind the inefficiency of Jet Airways. Thus, the inefficiency of Jet Airways in these 6 years is caused due to inappropriate scale of operation. However, in the years 2011 and 2017, the OTE score is less than 1 since both the PTE and SE scores are less than 1. Hence, in these two years, the airline performed inefficiently due to inappropriate scale of operation as well as due to managerial underperformance. However, the OTE, PTE, and SE score of Jet Airways is 1 and the company performed efficiently in 7 years i.e., 2005, 2006, 2007, 2012, 2013, 2015, and 2019.

For an airline to sustain, its revenue must be greater than it expenses, especially in price-sensitive markets like India. Unfortunately, the operating costs per seat kilometer of Jet Airways exceeded its revenue per seat kilometer amid an intense competition after 2004. Consequently, the airline lost money on every seat, regardless of the distance travelled by the passenger. The business model followed by Jet Airways was different from the models usually followed by other LCCs. As a result, despite offering similar fares, Jet Airways had significantly higher operating costs compared to its peers. This cost disadvantage made it difficult for Jet Airways to turn a profit, even if it did manage to generate revenue. Furthermore, since Jet Airways was a full-service operator, it missed out on the opportunity of generating an additional revenue stream (e.g. fees for services like on-board meals, excess baggage, seat selection, and cancellations) that LCCs could easily avail (Pandey, 2019) [30]. This extra revenue could be a game changer and could significantly boost the airline's profitability.

Table 7: Years in which Spice Jet Performed Inefficiently

Year	SpiceJet			
	OTE	PTE	SE	Reasons for inefficiency
2005	0.744	0.756	0.984	Inappropriate Scale & managerial underperformance
2006	0.508	0.607	0.836	Inappropriate Scale & managerial underperformance
2007	0.914	1.000	0.914	Inappropriate Scale
2008	0.992	1.000	0.992	Inappropriate Scale
2011	0.923	1.000	0.923	Inappropriate Scale
2015	0.920	1.000	0.920	Inappropriate Scale
2017	0.490	1.000	0.490	Inappropriate Scale
2018	0.479	0.874	0.548	Inappropriate Scale & managerial underperformance
2019	0.437	0.930	0.469	Inappropriate Scale & managerial underperformance

Source: Compilation of secondary data using MS Excel, 2019

The OTE score of Spice Jet is less than 1 due to SE scores for 5 years i.e., 2007, 2008, 2011, 2015, and 2017. In these years SE score is less than 1 which is the reason behind the inefficiency of Spice Jet. Thus, the inefficiency of Spice Jet in these 5 years is caused due to inappropriate scale of operation. However, in the years 2005, 2006, 2018, and 2019, the OTE score is less than 1 since both the PTE and SE scores are less than 1. Hence, in these four years, the airline performed inefficiently due to inappropriate scale of operation as well as due to managerial underperformance. However, the OTE, PTE, and SE score of Spice Jet Airways is 1 and the company performed efficiently in 6 years i.e., 2009, 2010, 2012, 2013, 2014, and 2016.

Spice Jet officially commenced its operations with a modest fleet of leased aircrafts in 2005. Though initially it went through a turbulent phase, it marked its footstep in the

aviation industry as a significant LCC. In 2010, growth in passengers in the domestic air routes was largely driven by the LCCs, where Spice Jet only projected a growth of 44% in passengers carried (Sahay & Banerjee, 2020). Amid financial turbulence and operational challenges, SpiceJet changed its ownership structure in 2015 and applied new strategic moves to stabilize the airline's operations and charting a course for recovery and growth (Baliga, 2024) [5]. These efforts resulted in profitability for the company in 2016. Airline industry is a volatile industry where cost leadership and differentiation in services play a major role. Fluctuating Aviation Turbine Fuel (ATF) prices and duties imposed by the Central and State Governments affect the revenues of the airline companies. Hence, the airline companies always try to capture a larger chunk of the market to stay profitable. While Spice Jet tried its best in achieving this end, it stayed behind Indigo and Jet Airways during the study period.

Table 8: Years in which Kingfisher Airline Performed Inefficiently

Year	Kingfisher Airline			
	OTE	PTE	SE	Reasons for inefficiency
2005	0.454	0.502	0.905	Inappropriate Scale & managerial underperformance
2006	0.661	0.807	0.819	Inappropriate Scale & managerial underperformance
2007	0.808	0.913	0.885	Inappropriate Scale & managerial underperformance
2008	0.503	0.540	0.932	Inappropriate Scale & managerial underperformance
2010	0.700	0.700	1.000	Managerial underperformance
2011	0.791	0.804	0.984	Inappropriate Scale & managerial underperformance
2012	0.600	0.635	0.945	Inappropriate Scale & managerial underperformance
2013	0.078	0.399	0.195	Inappropriate Scale & managerial underperformance

Source: Compilation of secondary data using MS Excel, 2019

The OTE scores of Kingfisher Airlines are less than 1 for 8 years, i.e., 2005, 2006, 2007, 2008, 2010, 2011, 2012, and 2013. Out of these 8 years only in one year, i.e. 2010 OTE score is less than 1 since the PTE score is less than 1. Hence, this year, the airline performed inefficiently due to managerial underperformance. In the remaining 7 years the OTE scores of the company are less than 1 since both the PTE and SE scores of the company are less than 1. Therefore, in these seven years, the airline performed inefficiently due to inappropriate scale of operation as well as due to managerial underperformance. The OTE, PTE, and SE score of Kingfisher Airlines was 1 only in the year 2009 and the airline company performed efficiently in that particular year. However, the company ceased its operation in 2013, so no data is available after this period.

Kingfisher Airline has never earned a profit since 2005. Although, in 2006, the airline achieved a five-star status and became popular among the business class travelers due to the personalized in-flight entertainment provided by it (Sharma & Rao, 2019). During the economic slowdown in 2008, the already cash starved airline was caught in a precarious web of debts in connection with airport fees, fuel, staff salaries, service tax and bank loans. In 2011, the airline decided to shut down Kingfisher Red, a low-cost segment of the airline to reduce the surmounting cash crunch to some extent. The Annual Report of the company in 2011 also raised reasonable doubts over its financial sustainability. It was observed that the company never deposited the money collected in the form of Tax Deducted at Source (TDS) and employees' contribution towards Provident Fund (PF) with the Government exchequer. Over time, the situation worsened and in 2012, the company accumulated a loss of over Rs. 7,000 (Panigrahi *et al*., 2019) [31]. In the same year, the DGCA suspended its flying license and the airline had to shut its operation down (DGCA, 2014) [14]. The financial results of the company in all the years during the study period is closely linked with their inappropriate scale of operation and managerial inefficiency.

Table 9: Years in which Indigo Performed Inefficiently

Year	Indigo			
	OTE	PTE	SE	Reasons for inefficiency
2007	0.636	0.887	0.717	Inappropriate Scale & managerial underperformance
2015	0.960	1.000	0.960	Inappropriate Scale
2016	0.832	0.845	0.985	Inappropriate Scale & managerial underperformance
2017	0.694	0.706	0.984	Inappropriate Scale & managerial underperformance
2018	0.605	1.000	0.605	Inappropriate Scale
2019	0.474	1.000	0.474	Inappropriate Scale

Source: Compilation of secondary data using MS Excel, 2019

The OTE scores of Indigo are less than 1 for 3 years i.e., 2015, 2018, and 2019. In these years SE score is also less than 1. Thus, the inefficiency of Indigo in these 3 years is caused due to inappropriate scale of operation. However, in the years 2007, 2016, and 2017, the OTE score is less than 1 since both the PTE and SE scores are less than 1. Hence, in these three years, the airline performed inefficiently due to inappropriate scale of operation as well as due to managerial underperformance. The OTE, PTE, and SE score of Indigo is 1 and the company performed efficiently in 7 years i.e., 2008, 2009, 2010, 2011, 2012, 2013, and 2014. However, the airline started its operation in 2007 hence no data is available for the years 2005 and 2006.

Indigo started its operation in 2006 and by 2011, it became the second-largest airline carrier in India, overtaking Kingfisher Airlines. In the following year, Indigo surpassed Jet Airways and became the largest Indian carrier. In these six years of operations, it maintained its profitable streak for more than four years (AJVC, 2022) [1]. The profit of Indigo increased over the years but the company suffered from scale and managerial inefficiencies during the period of study.

Table 10: Years in which Go Air Performed Inefficiently

Year	GoAir			
	OTE	PTE	SE	Reasons for inefficiency
2008	0.696	1.000	0.696	Inappropriate Scale
2009	0.368	1.000	0.368	Inappropriate Scale
2012	0.783	1.000	0.783	Inappropriate Scale
2013	0.852	1.000	0.852	Inappropriate Scale
2014	0.975	1.000	0.975	Inappropriate Scale
2016	0.726	1.000	0.726	Inappropriate Scale
2017	0.652	1.000	0.652	Inappropriate Scale
2018	0.651	1.000	0.651	Inappropriate Scale
2019	0.674	1.000	0.674	Inappropriate Scale

Source: Compilation of secondary data using MS Excel, 2019

The OTE scores of Go Air less than 1 for all 9 years, 2008, 2009, 2012, 2013, 2014, 2016, 2017, 2018, and 2019. In all these year's SE score is less than 1 which is the reason behind the inefficiency of Go Air. Thus, the inefficiency of Go Air in these 9 years is caused by an inappropriate scale of operation. However, the OTE, PTE, and SE score of Go Air is 1 and the company performed efficiently in 6 years i.e., 2005, 2006, 2007, 2010, 2011, and 2015.

The growth of Go Air in terms of market share, fleet size and destinations served had been on a slow-run compared to its peers (i.e. IndiGo and SpiceJet) that started their operation at the same time as that of Go Air. The main focus of the airline had always been a steady profitability rather than a higher market share, fleet size or network coverage (Modgil *et al*., 2020) [29]. Though, it was regarded as the fifth largest airline in the country with market share of 8%, it could not avail economies of scale to optimize its efficiency.

c. Company-wise Average Overall Technical Inefficiency (OTIE), Pure Technical Inefficiency (PTIE) and Scale Inefficiency (SIE)

The mean OTE of Jet Airways is 92.7% which is highest during the period of study. The inefficiency of 7.30% of Jet Airways is caused due to inappropriate scale of operation as well as due to managerial underperformance. The lowest mean OTE is recorded by Kingfisher Airlines at 62.2% during the period of study. The inefficiency of 38.8% is caused due to inappropriate scale of operation as well as due to managerial underperformance. The mean PTE of 100% is achieved by Air India and Go Air during the period of study which signifies that these companies have the highest level of managerial performance. The mean PTE score of Kingfisher Airline is 62.2% which is the lowest during the period of study among the selected companies which indicates that the company has managerial inefficiencies. The mean SE score of Jet Airways is 95.5% which is highest during the period of study among the selected companies which signifies that the management has chosen the optimum size of resources or optimum scale of production that helped them to attain the said production level. The mean SE score of GoAir is 82.5% which is the lowest during the period of study among the selected companies which indicates that the company is least benefited by scale economies [Table 11(a) and 11 (b)].

Table 11(a): Grand Mean of the Selected Companies

Year	Air India			Jet Airways			SpiceJet		
	OTE	PTE	SE	OTE	PTE	SE	OTE	PTE	SE
2005	1.000	1.000	1.000	1.000	1.000	1.000	0.744	0.756	0.984
2006	1.000	1.000	1.000	1.000	1.000	1.000	0.508	0.607	0.836
2007	1.000	1.000	1.000	1.000	1.000	1.000	0.914	1.000	0.914
2008	1.000	1.000	1.000	0.906	1.000	0.906	0.992	1.000	0.992
2009	1.000	1.000	1.000	0.978	1.000	0.978	1.000	1.000	1.000
2010	1.000	1.000	1.000	0.963	1.000	0.963	1.000	1.000	1.000
2011	1.000	1.000	1.000	0.652	0.777	0.839	0.923	1.000	0.923
2012	0.600	1.000	0.600	1.000	1.000	1.000	1.000	1.000	1.000
2013	0.654	1.000	0.654	1.000	1.000	1.000	1.000	1.000	1.000
2014	0.725	1.000	0.725	0.992	1.000	0.992	1.000	1.000	1.000
2015	0.793	1.000	0.793	1.000	1.000	1.000	0.920	1.000	0.920
2016	1.000	1.000	1.000	0.947	1.000	0.947	1.000	1.000	1.000
2017	1.000	1.000	1.000	0.769	0.770	0.999	0.490	1.000	0.490
2018	1.000	1.000	1.000	0.699	1.000	0.699	0.479	0.874	0.548
2019	1.000	1.000	1.000	1.000	1.000	1.000	0.437	0.930	0.469
Mean	0.918	1.000	0.918	0.927	0.970	0.955	0.827	0.945	0.872

Source: Compilation of secondary data using MS Excel, 2019

Table 11(b): Grand Mean of the Selected Companies

Year	Kingfisher Airline			Indigo			GoAir		
	OTE	PTE	SE	OTE	PTE	SE	OTE	PTE	SE
2005	0.454	0.502	0.905	-	-	-	1.000	1.000	1.000
2006	0.661	0.807	0.819	-	-	-	1.000	1.000	1.000
2007	0.808	0.913	0.885	0.636	0.887	0.717	1.000	1.000	1.000
2008	0.503	0.540	0.932	1.000	1.000	1.000	0.696	1.000	0.696
2009	1.000	1.000	1.000	1.000	1.000	1.000	0.368	1.000	0.368
2010	0.700	0.700	1.000	1.000	1.000	1.000	1.000	1.000	1.000
2011	0.791	0.804	0.984	1.000	1.000	1.000	1.000	1.000	1.000
2012	0.600	0.635	0.945	1.000	1.000	1.000	0.783	1.000	0.783
2013	0.078	0.399	0.195	1.000	1.000	1.000	0.852	1.000	0.852
2014	-	-	-	1.000	1.000	1.000	0.975	1.000	0.975
2015	-	-	-	0.960	1.000	0.960	1.000	1.000	1.000
2016	-	-	-	0.832	0.845	0.985	0.726	1.000	0.726
2017	-	-	-	0.694	0.706	0.984	0.652	1.000	0.652
2018	-	-	-	0.605	1.000	0.605	0.651	1.000	0.651
2019	-	-	-	0.474	1.000	0.474	0.674	1.000	0.674
Mean	0.622	0.700	0.852	0.862	0.957	0.902	0.825	1.000	0.825

Source: Compilation of secondary data using MS Excel, 2019

d. Year-wise average Overall Technical Inefficiency (OTIE), Pure Technical Inefficiency (PTIE) and Scale Inefficiency (SIE)

The mean OTE, PTE, and SE of Air India are 91.8%, 100%, and 91.8% respectively [Table 11(a)], which is more than the industry average OTE, PTE, and SE scores (Table 12). The mean OTE, PTE, and SE of Jet Airways is 92.7%, 97%, and 95.5% respectively [Table 11(a)], which is also more than the industry average OTE, PTE, and SE scores (Table 12). The mean OTE and SE of Spice Jet are 82.7% and 87.5% respectively [Table 11(a)], which is less than the industry averages (Table 12). But the mean PTE of Spice Jet is 94.5% [Table 11(a)] which is more than the industry average PTE, of 92.9% (Table 12). The mean OTE, PTE, and SE of Kingfisher Airline are 62.2%, 70%, and 85.2% respectively [Table 11(b)], which is less than the industry average OTE, PTE, and SE scores (Table 12). The mean OTE, PTE, and SE of Indigo are 86.2%, 95.7%, and 90.2% respectively [Table 11(b)], which is more than the industry average OTE, PTE, and SE scores (Table 12). The mean OTE and SE of Go Air is 82.5% and 82.5% respectively [Table 11(b)], which is less than the industry averages (Table 12). But the mean PTE score of Go Air is 100% [Table 11(b)] which is more than the average PTE, 92.9%, industry average (Table 12).

e. Overall Technical Inefficiency (OTIE), Pure Technical Inefficiency (PTIE) and Scale Inefficiency (SIE) for the industry

Table 12 shows the year-wise mean OTE, PTE, and SE scores of all companies taken together. The mean OTE of 94.4% is the highest and is recorded in the year 2010 when the selected companies performed most efficiently. This implies input can be reduced by another 5.6% to produce the same amount of output to be efficient. The highest PTE of 100% is recorded in the years 2009, 2014, and 2015 which signifies the highest level of managerial performance by the selected companies. The highest SE of 99.4% was recorded in 2010 which signifies that the management has chosen the optimum size of resources or optimum scale of production that helped them to attain the expected production level. Hence, in the year 2010, all the companies reached the highest level of efficiency. On the other hand, in the year 2018, the companies reached the lowest efficiency level when the mean OTE was 68.7%, the PTE was 97.5% and the SE was 70%. The inefficiency is caused due to inappropriate scale as well as due to managerial underperformance.

During the period of study of 15 years, except for 4 years (2005, 2006, 2010, and 2011), the mean PTE score of the aviation companies is found to be persistently higher than the SE score. Moreover, according to the grand mean of PTE and SE score, the average level of pure technical inefficiency is 7.1% and scale inefficiency was 11.3%. Thus, the major source of the overall technical inefficiency for the select aviation companies is scale inefficiency (output-related) and not pure technical efficiency (input-related). The findings imply that scale inefficiency is primarily due to inappropriate scale. The result suggests that there is more opportunity for improving SE by operating at optimum scale size (Table 12).

Table 12: Year-wise Grand Mean of the Selected Companies

Year	Mean of Selected Companies		
	Overall Technical Efficiency (OTE)	Pure Technical Efficiency (PTE)	Scale Efficiency (SE)
2005	0.840	0.852	0.978
2006	0.834	0.883	0.931
2007	0.893	0.967	0.919
2008	0.849	0.923	0.921
2009	0.891	1.000	0.891
2010	0.944	0.950	0.994
2011	0.895	0.930	0.958
2012	0.831	0.939	0.888
2013	0.764	0.900	0.783
2014	0.938	1.000	0.938
2015	0.934	1.000	0.934
2016	0.901	0.969	0.932
2017	0.721	0.895	0.825
2018	0.687	0.975	0.700
2019	0.717	0.986	0.724
Mean	0.830	0.929	0.887

Source: Compilation of secondary data using MS Excel, 2019

2. Addressing to Objective 2: Analyzing the Scale of Production in Indian Aviation Sector

a. **Calculation of and interpretation of Scale Deficiency Index (SDI) based on Returns to Scale (RTS) of each company during the study period**

With a view to determining the predominant form of scale economies in the aviation industry, the number and percentage of aviation companies operating under constant, increasing, and decreasing returns to scale are identified. Based on the RTS model described above (Refer to Section 4.5.3), the appropriate RTS of the companies for each year during the study period has been estimated. It allows the researcher to calculate the number of companies in the sample with CRS, IRS or DRS in each year during the study period (Table 13). Based on such information, Lo´pez-Corte´s and Snowden's (1998) Scale Deficiency Index (SDI) is computed which indicates the proportion of aviation companies that are characterized by DRS to the total number of scale-deficient aviation companies (Table 14).

Table 13: Distribution of Increasing Returns to Scale (IRS), Constant Returns to Scale (CRS), and Decreasing Returns to Scale (DRS) over the Study Period and Identification of SDI

Year	IRS	CRS	DRS	Total	Scale Deficiency Index
2005 (N=5)	0 (0%)	5 (100%)	0 (0%)	5 (100%)	0
2006 (N=5)	0 (0%)	5 (100%)	0 (0%)	5 (100%)	0
2007 (N=6)	0 (0%)	5 (83.33%)	1 (16.67%)	6 (100%)	1
2008 (N=6)	2 (33.33%)	2 (33.33%)	2 (33.33%)	6 (100%)	0.5
2009 (N=6)	1 (16.67%)	4 (66.67%)	1 (16.67%)	6 (100%)	0.5
2010 (N=6)	0 (0%)	5 (83.33%)	1 (16.67%)	6 (100%)	1
2011 (N=6)	0 (0%)	5 (83.33%)	1 (16.67%)	6 (100%)	0.5
2012 (N=6)	1 (16.67%)	4 (66.67%)	1 (16.67%)	6 (100%)	0.5

2013 (N=6)	2 (33.33%)	3 (50%)	1 (16.67%)	6 (100%)	0.33
2014 (N=5)	1 (20%)	2 (40%)	2 (40%)	5 (100%)	0.67
2015 (N=5)	0 (0%)	2 (40%)	3 (60%)	5 (100%)	1
2016 (N=5)	2 (40%)	2 (40%)	1 (20%)	5 (100%)	0.33
2017 (N=5)	4 (80%)	1 (20%)	0 (0%)	5 (100%)	0
2018 (N=5)	2 (40%)	1 (20%)	2 (40%)	5 (100%)	0.5
2019 (N=5)	2 (40%)	2 (40%)	1 (20%)	5 (100%)	0.33
TOTAL	17 (20.73%)	48 (58.54%)	17 (20.73%)	82 (100%)	0.5

Source: Compilation of secondary data using MS Excel, 2019

If the value of the SDI is greater than or equal to 0.5, then a greater number of scale-deficient aviation companies experience DRS. Conversely, if the SDI value is less than 0.5, it indicates that a greater number of aviation companies experience IRS, in any particular year. It may be noted that out of 15 years, only in six years, the aviation companies experience IRS when the SDI is less than 0.5. Whereas for the remaining nine years, the aviation companies recorded SDI of more than or equal to 0.5 which signifies a larger number of firms in that year are exhibiting DRS. Thus, the percentage of aviation companies experiencing DRS is more than the percentage of aviation companies experiencing IRS. It is observed that in four years within the study period, the value of LCS's SDI was greater than 0.5, which indicates that these scale-deficient aviation companies were not operating in the IRS. Hence, the findings suggest that the majority of Indian airline companies are too small to achieve economies of scale. Therefore, to reap the benefits of economies of scale, most of Indian aviation companies need to scale up their production to achieve efficiency.

Conclusion

The Indian aviation industry is currently navigating through a complex landscape marked by significant growth potential but also considerable challenges related to scale and technical inefficiency. The industry has seen substantial investments, including large aircraft orders by major carriers like Indigo and Air India, which signal robust future expansion. On the other hand, the aviation industry is facing significant challenges due to both technical inefficiency and scale inefficiency, impacting operational performance, cost management, and environmental sustainability. Selected airline companies are facing technical inefficiency due to increased operational cost and maintenance cost. Furthermore, technical inefficiencies also stem from the slow implementation of infrastructure upgrades and the lack of sufficient technical expertise within the workforce. Scale inefficiency of these Indian airline companies stem from higher unit cost, low negotiation power, limited-service offerings, market competitiveness, and lack of alliance and partnership. According to the analysis, the major source of the overall technical inefficiency for the select aviation companies is scale inefficiency and not pure technical inefficiency. Additionally, the scale deficiency index (SDI) indicates that percentage of aviation companies experiencing DRS is more than the percentage of aviation companies experiencing IRS. Hence, the findings suggest that the majority of Indian airline companies are too small to achieve economies of scale. Therefore, to reap the benefits of economies of scale, most of Indian aviation companies need to scale up their production to achieve efficiency. Thus, addressing both technical and scale inefficiencies is crucial for the aviation industry to improve operational efficiency, reduce costs, enhance competitiveness, and minimize environmental impact.

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