RESEARCH ARTICLE

COVID-19 and Airline Performance in the Asia Pacific region

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Abstract

Health risks associated with coronavirus disease 2019 (COVID-19) have severely affected the financial stability of airline companies globally. Recapturing financial stability following this crisis depends heavily on these companies' ability to attain efficient and productive operations. This study uses several empirical approaches to examine key factors contributing to carriers sustaining high productivity prior to, during and after a major recession. Findings suggest, regardless of economic conditions, that social distancing which requires airline companies in the Asia Pacific region to fly with a significant percentage of unfilled seats weakens the performance of those companies. Furthermore, efficient operations do not guarantee the avoidance of productivity declines, especially during a recession.

Keywords

COVID-19, Airline Performance, Asia Pacific, Data Envelopment Analysis (DEA)

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Introduction

Following liberalization policies starting in the mid-1970s, the global airline industry has generally experienced significant increases in passenger demand. Declining air fares due in part to the influx of low-cost carriers, increasing flight frequency, proliferation of routes and the maintenance of safety performance (Savage, 2004) suggest opening the skies to greater competition has benefited passengers. These policies have also contributed to enhanced airline performance as real cost per revenue ton mile has declined and the percentage of seats filled with passengers has increased (Winston, 1998). However, carrier performance has suffered when this industry has faced economic downturns, such as the 2007-2008 great recession. The airline industry is now facing just such a challenge due to the coronavirus disease 2019 (COVID-19) pandemic. While this industry has weathered previous economic recessions, the economic challenges posed by the COVID-19 pandemic are unique because it creates health risks for passengers. The potential severity of this crisis in the airline industry compared to past economic crises is demonstrated by the fact that in previous economic crises the subsequent economic growth facilitated enhanced demand for air transport services. In contrast, consumer demand post COVID-19 will likely require in-flight changes that limit carriers' ability to fly at capacity, even if an increase in passengers' post COVID-recession income supports enhanced demand for air transport services. Furthermore, survey findings from the International Air Transport Association (IATA) reveal that airline companies are expecting the recovery to take at least a year, with some airlines believing it will take even longer¹. This is consistent with the air traveler's confidence survey, which reports that 30% of the respondents would not travel by air for at least six months². Therefore, it is predicted that the airline industry is likely to experience a very sluggish recovery. Historical data on the effect of disease outbreaks on aviation reveals that the longest recovery period was during the severe acute respiratory syndrome (SARS) outbreak in 2003, following which it took approximately 9 months for revenue passenger kilometer to return to its pre-crisis level (IATA, 2020c)³. In contrast, the IATA predicts that the impact of COVID-19 could surpass that caused by SARS, in part because COVID-19 has significantly affected the Chinese airline industry and this region accounts for a nontrivial share of the global airline industry⁴.

As the IATA findings report above, the challenge posed by this pandemic is especially pronounced for airline companies based in the Asia Pacific region. Indeed, airline companies based in this region have experienced a dramatic 41.3% decline in revenue passenger kilometers year-to-year for February 2020, compared to a 14.1% decline for all regions⁵. In addition, airline companies based in the Asia Pacific region experienced a 15.1% erosion of the percentage of seats filled by passengers for the same observation period compared to a 4.8% decline for the industry as a whole, largely due to widespread movement control orders⁶. This negative impact was also recorded for the airline industry's cargo sector, with regional average cargo ton kilometers for airlines in the Asia Pacific region recording a 5.9% decrease in January 2020 on a year-on-year basis, compared to a 3.3% decline worldwide. These performance trends are particularly significant because the Asia Pacific region now serves the largest number of passengers, as airline companies based in this region transported 34.7% of all air travelers globally in February 2020⁷.

A contributing factor to this industry's sensitivity to economic downturns, especially in the Asia Pacific region, is the access to reasonable transport alternatives. High speed passenger rail has been shown to be a close substitute for airline transport along land routes, particularly in Asia⁸. Hence, operations during and following the COVID-19 recovery in air passenger transport face competitive pressure from passenger rail. The challenge for airline

¹ IATA April 2020 Survey: Airline Business Confidence Index. <https://www.iata.org/en/iata-repository/publications/economic-reports/business-confidence-survey---april-2020/>

² Air passenger market analysis, IATA March 2020. <https://www.iata.org/en/iata-repository/publications/economic-reports/air-passenger-monthly-analysis---mar-2020/>

³ Revenue passenger kilometers (RPK) is a metric that monetizes actual passenger demand.

Information sources: IATA's economic chart of the week. <https://www.iata.org/en/iata-repository/publications/economic-reports/what-can-we-learn-from-past-pandemic-episodes/>

⁴ IATA's economic chart of the week. <https://www.iata.org/en/iata-repository/publications/economic-reports/what-can-we-learn-from-past-pandemic-episodes/>

⁵ Air passenger market analysis, IATA February 2020. <https://www.iata.org/en/iata-repository/publications/economic-reports/air-passenger-monthly-analysis---feb-2020/>

⁶ Air passenger market analysis, IATA February 2020. <https://www.iata.org/en/iata-repository/publications/economic-reports/air-passenger-monthly-analysis---feb-2020/>

⁷ The next largest share of passengers is served by companies based in Europe as 26.8 percent of all passengers flew from this region in February 2020, Air passenger market analysis, IATA February 2020. <https://www.iata.org/en/iata-repository/publications/economic-reports/air-passenger-monthly-analysis---feb-2020/>

⁸ Xia *et al.* (2019) observe that government investment in high speed rail service in China has facilitated intermodal passenger competition such that air fares have been suppressed and demand for air transport services has been constrained.

companies based in the Asia Pacific region in competing for passengers during a pandemic is heightened in part because rail carriers can provide frequent service with a larger number of cars per train, which allows them to provide physical distancing while transporting significant numbers of passengers. Air transport companies are much more limited in the use of large aircraft carriers to transport a large number of passengers while practicing social distancing. This service limitation arises because many airports are ill-equipped to accommodate jumbo jets. In addition to competition from rail service airline companies, the air transport industry also faces increasing market pressure from the improved availability of internet connectivity. In contrast to rail, video conferencing presents a viable alternative to transport across sea lanes. Furthermore, such connectivity does not present the health risks associated with passenger transport⁹. Thus, analysis of the performance effect of COVID-19 needs to include an examination of air transport operations that minimizes passenger contact and considers the potential for the long-term erosion of passenger demand for this type of transport service.

While past research has examined airline companies' ability to survive economic recessions, there is a dearth of research examining the industry's ability to recover from a downturn caused by health risks. This study contributes to the body of work in this area by including performance indicators such as percentage of seats filled on flights, airline alliances and airline companies' use of contract workers for this analysis. These factors are critical as airline companies must make difficult decisions regarding the configuration of passenger seating, choice of cost-effective network configurations such as those used by alliances, and choice of contracting out work to reduce labor costs in a post COVID-19 business environment. In addition, this study will use contemporary estimation techniques to identify the profile of carriers that remain relatively productive and that achieve high levels of technical efficiency during an economic downturn and examines whether these carriers are able to build on their efficiency advantage over other airline companies following a severe economic downturn. Such an analysis is particularly important during the COVID-19 recession, which has the potential to rival the economic contraction of the great recession.

Airline operation in the Asia Pacific region

The last decade has witnessed significantly changing dynamics in the air transport sector in the Asia Pacific region. Essential to these changing dynamics are several key developments associated with the enforcement of government policies liberalizing airport operations in this region. Such policies relaxed entry restrictions from foreign airline companies and privatized airline services in this region. This enhanced competition along routes previously restricted to domestic carriers and a few foreign carriers and promoted lower fares and an expanded network. Nontrivial growth in passenger demand for air transport services in the Asia Pacific region reveals evidence of the success of this policy (ICAO, 2016). For instance, during the current decade the percentage year-on-year change of available seat kilometers (ASK) for this region increased in a range from a low of 4.5% in 2019 to a high of 10.1% in 2016¹⁰.

An understanding of the underlying contributing factors to this healthy growth following liberalization policies in the Asia Pacific region provides insight on the potential challenges for airline companies in this region when facing health crises. It is a source of growth, through cost-saving techniques, that can actually create challenges associated with health crises. By providing access to larger global markets, airlines can derive cost savings in this less restrictive business environment due to companies' access to a larger passenger base. This example of economies of scale allows companies to fly with a large percentage of seats filled. Operating cost per passenger will decline since the major cost associated with air transport is the cost of the aircraft and such cost is essentially fixed. Cost savings also arise from economies of network size and use of the hub and spoke model to transport passengers, following the liberalization of air transport operations in the Asia Pacific region. Flight coordination in a hub and spoke network system further allows companies to save costs by increasing the percentage of seats filled per flight. Consequently, liberalization of airline operations enhances carriers' ability to generate greater profits as long as they remain competitive globally¹¹.

⁹ Recent data on video conferencing application Zoom reports that usage increased 67% between January and mid-March 2020, during the COVID-19 pandemic (<https://www.businessofapps.com/data/zoom-statistics/>)

¹⁰ The relatively small increase in passenger demand in 2019 for the Asia Pacific region is consistent with ASK year-on-year percentage changes for all geographic regions around the globe.

¹¹ Evidence of the financial benefits of air liberalization from different regions are provided by, among others, Abate (2016); Inglada *et al.* (2006), Huderak-Glapska (2010), and Gillen *et al.* (2002).

The expansion of operations facilitated by liberalization policies can have unintended consequences associated with regional and global health crises. For example, following liberalization policies, expansive networks servicing larger numbers of passengers from all regions of the world make Asia Pacific airlines more vulnerable to health risks such as SARS and COVID-19. This vulnerability arises because a large network means greater dependence on international traffic. Hence, airlines have more routes that are at risk of a declining passenger demand due to the greater possibility of these passengers contracting airborne transmitted diseases. The risk of transmission is further exacerbated by servicing passengers on hub and spoke routes that are characterized by high percentages of seats filled on flights. Airline company vulnerabilities to health crises are evident in examining the effect of the 2003 SARS virus on the economic growth of airline companies operating out of Asia Pacific. The International Air Transport Association (2020c) reports revenue seat kilometers (RSK) for Asia Pacific airlines declining by 40% three months immediately following the SARS outbreak¹². This measure of airline growth took close to eight months to return to pre-SARS levels.

The economic challenges associated with health-related crises reported above for companies operating out of the Asia Pacific region places greater pressure on these companies sustaining efficient operations. Low costs derived from efficient and productive operations contribute to carriers' ability to avoid significantly increasing fares during a period of low passenger demand. Achieving these managerial objectives may be even more significant during the current COVID-19 outbreak. While SARS was primarily a regional health-crisis, COVID-19 is a global pandemic. The potential economic damage to airlines in this region is highlighted by forecasts predicting a 53.8% year-on-year decline of revenue passenger kilometers for 2020¹³. The predicted severity of the economic effect on airlines is due in part to global border closures and travel restrictions. Nonetheless, despite facing declines in passenger demand due to pandemics such as SARS and COVID-19, liberalization of the air transport market in Asia Pacific has served as an incentive for airlines based in this region to maintain efficient and productive operations. At issue, however, is the likelihood these companies are able to operate at high performance levels during and following a pandemic.

Airline performance under capacity constraints

The modeling of airline companies' ability to achieve high levels of efficiency and productivity is heavily influenced by the vehicle used to transport passengers. For instance, aircraft size caps the number of passengers that can be transported on a given flight due to space limitations. The percentage of seats used by passengers indicates whether a carrier is making full use of seating capacity, and this percentage is known as a flight's load factor. Flying at full passenger capacity generates a load factor of one, while load factors decline as the percentage of seats with passengers decline. Hence, the value of this measure varies from a low of zero to a high of one. Exogenous factors, such as a pandemic, limit the percentage of seats filled per flight and act as a capacity constraint and therefore influences carriers' operating performance. Indeed, management's ability to service as many passengers as possible per flight given a set number of crew members, and a given consumption level of fuel dictates the cost of flight operations. Attaining high performance depends heavily on attaining high load factor levels especially during and following a pandemic.

The operation performance outlined above is exemplified by the concept of technical efficiency. For example, airline management attain technical efficiency by using factor inputs such as fuel, workers and aircrafts in a manner that allows the servicing of the largest number of passengers given an aircraft's capacity limitations (Battese & Coelli, 1992). The achievement of technical efficiency is depicted graphically by airlines operating on the frontier of their production function. For the example illustrated in Figure 1, $q=q(K,NK)$ represents the frontier of the production function for the hypothetical Asia Pacific airline industry, where q depicts output, and K and NK depict capital (aircrafts) and non-capital (labor) inputs, respectively. Input combinations located outside the frontier of the production function, such as co-ordinate A , are unattainable with current technology and managerial techniques, whereas, input combinations distributed along the frontier of the production function denote the efficient use of inputs by companies. Hence, airline companies with input combinations B and D are producing efficiently, whereas companies using input combinations denoted by the co-ordinate C are producing inefficiently since they are transporting the same number of passengers, q_1 , as companies using input combination B . However, compared to efficient companies producing at co-ordinate B , inefficient companies producing at co-ordinate C are using more

¹² The effect of the SARS virus had an even greater impact on the Chinese domestic market as revenue seat kilometers fell by more than 80 percent in the three months immediately following the outbreak (IATA, 2020c).

¹³ IATA's economic chart of the week. <https://www.iata.org/en/iata-repository/publications/economic-reports/what-can-we-learn-from-past-pandemic-episodes/>

labor and capital to produce quantity q_1 . The distance along the horizontal line denoted by $\overline{B,C}$ measures the inefficiency deviation from the frontier for companies producing at co-ordinate C . The technical inefficiency ratio at output level q_1 and input combination C is illustrated by the ratio OB/OC . This measure considers productive inefficiency using the input combination denoted by co-ordinate B as the production reference and this approach used to measure inefficiency denotes the *input-oriented* inefficiency associated with producing output level q_1 with input combinations used at co-ordinate C (Yu, 2016). Since the distance OB is less than the distance OC the technical efficiency score is less than one indicating that the companies using this input ratio are operating inefficiently Farrell (1957). Whereas, companies operating at input ratio B attain a technical efficiency score equaling one, which indicates these companies are operating technically efficiently.

The disconnect of technical efficiency and productivity is exacerbated during an economic downturn that arises due to a health crisis. For example, a health crisis such as COVID-19 requires physical distancing so that load factors are held artificially low. Managers may employ workers efficiently, and managers may choose the most fuel-efficient aircrafts for a given route, which helps achieve technical efficiency. Yet, flying at less than capacity precludes managers from achieving maximum productivity levels even if they achieve technical efficiency. This disconnect between technical efficiency and productivity is illustrated by comparing the input combinations depicted by coordinates A and B in Figure 1. Output q_i , as measured by the number of passengers transported, remains the same for each of these two coordinates. However, the hypothetical Asia Pacific airline employs more labor and capital when using the input combination depicted by coordinate B relative to the combination used at coordinate A . Therefore, this airline is operating on a lower production function than the one that includes coordinate A . Since low load factors are associated with a downward shift of the production function, this hypothetical companies' operations can be depicted on Figure 1 as operating technically efficiently at coordinate B , while providing transport service at low productivity levels due to low load levels induced by enforcing physical distancing. Hence, within this theoretical framework air transport operations become more costly when an economic downturn is induced by a pandemic.

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productivity effects of the pandemic. Forming an alliance with other carriers can enhance airline companies' performance by facilitating productivity gains associated with the economics of passenger-traffic density (McMullen & Du, 2012). Gains arise from carriers transporting passengers from the same originating location to a hub airport regardless of passengers' final destination. Transporting passengers from several originating locations enhances carriers' ability to service a large group of customers from a central location (the hub). Thus, increasing productivity by increasing the number of passengers transported per flight. These productivity gains reduce the marginal cost of transporting customers on this more expansive network (Gayle & Le, 2014)¹⁴. Potential productivity gains associated with forming alliances, however, are likely limited during a pandemic due to safety requirements that impose physical distancing. Nonetheless, forming alliances would make it easier for airline companies to fly the maximum number of passengers, given pandemic induced capacity constraints.

In theory, outsourcing non-flight operations enhances productivity in part by allowing companies to focus on their core business (transporting customers and cargo). Gains from specializing on their core business operations contributes to airline companies' ability to service more customers without proportionally increasing factor inputs. In addition, companies who outsource non-core operations, such as maintenance, benefit from using contractors in order to operate in multiple time zones. Access to contractors dispersed over several time zones enhances the probability of workers servicing customers in a timely fashion (Abdullah & Satar, 2019)¹⁵. Past research, however, highlights potential risk factors that can limit the productivity effectiveness of outsourcing (Quinlan *et al.*, 2013), observing that subpar performance can arise from poor information and communications flow.

In sum, using the theoretical framework of airline performance under capacity constraint, this study poses three testable hypotheses on the potential influence of COVID-19. Those hypotheses are as follows: (1) the disconnect between technical efficiency and productivity growth is magnified when an economic downturn is accompanied by a pandemic; (2) health related disruption is more severe than a financial economic downturn due to tighter capacity constraints that artificially enforce flying with low load-factors; (3) companies can still potentially mitigate declining productivity growth by forming alliances, and outsourcing labor. However, gains from these managerial decisions are limited by health restrictions that impose physical distancing.

Data and empirical approach

Data

This study utilizes information from a total of 17 individual airline companies based in Asia and the Pacific region covering the period of 2003 to 2011, to measure the technical efficiency and productivity of airlines¹⁶. Inputs used in this study include fleet size (number of aircraft), fuel consumption (in gallons) and total number of employees. These input choices are consistent with the standard production theory posited by Heathfield (1971) and Salvatore (2009). Data on the quantity of fuel consumed by airlines is not reported by most airlines; hence we convert annual total fuel cost to total fuel consumed using information on annual jet fuel price provided by Index-Mundi¹⁷. These input data for size of fleets, total number of employees, and fuel cost are taken from the respective airline companies' annual reports. Two measures of output are used in this study. Passenger traffic output as measured by revenue passenger kilometer and overall output of an airline company as given by monetary value of operating revenue. Revenue passenger kilometer indicates the total annual distance traveled by passengers, which is derived by taking the total product of the number of passengers carried on each flight stage and stage distance (kilometers flown). Input and output data are sourced from the ICAO Digest of Statistics, Air Transport World Financial Reports, and supplemented by data obtained from a specific airline's annual report for various years.¹⁸ Additional information on airline character such as passenger load factors, alliance membership, outsourcing and available seat kilometers are also taken from airlines' annual reports. Inclusion of these variables allows the testing of whether forming alliances and outsourcing work actually contributes to airline companies attaining high levels of technical efficiency and productivity. Information on passenger load factors is especially important as it allows a simulation of the performance influence of low load factors occurring during the COVID-19 pandemic.

¹⁴ Findings by Gayle & Le (2014) support the notion that airline alliances decrease marginal cost, however they also find that this strategy is associated with higher recurrent fixed cost for alliance members.

¹⁵ See Abdullah & Satar (2019) for a more extensive review the potential productivity enhancing benefits of outsourcing in the airlines industry.

¹⁶ These airline companies were chosen based on data availability.

¹⁷ The URL link to Index Mundi is as follows: <https://www.indexmundi.com/commodities/?commodity=jet-fuel&months=30>

¹⁸ The link to the ATW Financial Reports is as follows <https://documents.worldbank.org/en/publication/documents-reports/documentdetail/364321491414311301/air-transport-annual-report-2016>

Descriptive statistics derived using this airline company information are presented in Table 1. Mean findings are grouped by sample observations covering pre-recession (2003–2006), recession (2007–2008) and post-recession (2009–2011) periods. Findings on mean input values reveal continuous increases in the investment and employment of these factors of production, even during the great recession. Mean values for industry outputs also show a continuous growth pattern as operating revenue and revenue passenger kilometers increased by 56.99% and 40.05% respectively over the entire sample observation. In contrast to the growth patterns for inputs and outputs, mean information on airline characteristics shows mixed results over time. For instance, while available seat miles and carriers belonging to an alliance have increased continuously and at a relatively healthy rate, passenger load factors only increased 5% for the entire observation sample, and mean findings on outsourcing actually show a declining use of workers from other countries during the years covered by this sample. Anemic load factor growth following the great recession explains the slow growth overall for this airline characteristic. Such muted growth indicates the difficulty airlines in the Asia Pacific region face flying at full capacity immediately following economic downturns. Findings revealing these airline companies' declining use of workers from locations outside their base location is consistent with the notion that greater cost-savings are achievable when employing labor from the local work force.

Empirical approach

To investigate the impacts of COVID-19 pandemic on technical efficiency and productivity of airlines, we apply the output orientation based on the standard Data Envelopment Analysis (DEA) model as introduced by Charnes

Table 1. Descriptive statistics for inputs, outputs and airline company characteristics for sample observation covering the years from 2003–2006, 2007–2008 and 2009–2011*

Years	2003–2006	2007–2008	2009–2011
Inputs:			
Operating fleet	91.897	106.677	117.94
	(53.901)	(65.773)	(79.718)
Fuel (Gallons, 1000)	762,000	905,000	1,120,000
	(782,000)	(823,000)	(927,000)
Total employees	16179.52	18962.57	213890.65
	(9854.30)	(12464.57)	(16367.85)
Outputs:			
Operating revenue	4,930,000	7,040,000	7,740,000
('000)	(4,970,000)	(5,830,000)	(5,950,000)
Revenue passenger	36,200,000	45,400,000	50,700,000
kilometers ('000)	(26,700,000)	(31,800,000)	(34,600,000)
Airline characteristics:			
Passenger load factor	0.716	0.745	0.751
	(0.049)	(0.044)	(0.048)
Outsourcing	0.397	0.288	0.288
	(0.181)	(0.134)	(0.117)
Available seat	53,000,000	63,100,000	69,000,000
kilometers ('000,000)	(34,100,000)	(38,400,000)	(41,200,000)
Alliance membership	0.38	0.47	0.53
	(0.49)	(0.51)	(0.51)

Mean values and (*Standard deviations) are presented

et al. (1978) or later called CCR constant return to scale model. This model allows each decision-making unit (DMU)¹⁹ to select optimal weights of input and output using mathematical programming. This model takes the basic form specified in Equation (1) when calculating technical efficiency scores for each airline company.

$$\text{Max}_{\phi, \lambda} \phi \quad (1)$$

Subject to:

$$-\phi q_i + Q\lambda \geq 0,$$

$$x_i - X\lambda \geq 0,$$

$$\lambda \geq 0$$

Where, $1 \leq \phi \leq \infty$, and $\phi - 1$ is the proportional increase in output achievable by the *i*th firm, holding that input quantities are constant and, λ is a $I \times 1$ vector of weights.

This constrained maximization problem depicted by Equation (1) and the succeeding inequalities implies that *i*th number firms seek a radial contraction of input vectors x_i to attain the maximum output level while still restricted within the feasible input set. The radial contraction of the input vector, x_i produces a projected point $(X\lambda, Q\lambda)$, on the surface of this technology. In addition, the constraints ensure that the projected technical efficiency scores cannot lie outside the feasible set bounded by one at the maximum and zero at the minimum (Coelli *et al.*, 2005, p163). Hence, the benchmark high performance decision-making unit achieves a technical efficiency score of 1. These scores are derived empirically using a DEA linear programming technique to solve the constrained maximization problem for Equation (1). The benefits derived from estimating Equation (1) in this manner is it satisfies the axioms of convexity, constant return to scale and strong disposability (Fare *et al.*, 1994).

To allow for comparative analysis of technical efficiency and productivity in the Asia Pacific airline industry the DEA model is also used to calculate productivity for each airline company. Following Fare *et al.* (1994), this study applies the Malmquist output distance function to calculate the Malmquist productivity index (MPI). The MPI measures productivity change with respect to period *t* and period *t*+1 technologies. Based on Fare *et al.* (1994), assuming there are *i* panel of firms denoted by the subscripts $i = 1, \dots, K$. The number of periods observed are $t = 1, \dots, T$ periods. This assumes that each firm uses *N* inputs, $x \in R_+^N$ to produces *M* outputs, $y \in R_+^M$. The production possibility set which defines the technology applied in this case is given by:

$P = \{(x, y) | x \text{ can produce } y\}$ with $\lambda P = P, \lambda > 0$. It is also assumed that there are *J* different groups in the panels which use different technologies.

The output orientated MPI based on DEA approach takes the form of geometric mean which is defined as follows:

$$M_{t,t+1}(x_t, y_t, x_{t+1}, y_{t+1}) = \left[\frac{D_t(x_{t+1}, y_{t+1})}{D_t(x_t, y_t)} X \frac{D_{t+1}(x_{t+1}, y_{t+1})}{D_{t+1}(x_t, y_t)} \right]^{1/2} \quad (2)$$

The MPI index is computed by solving six linear programming problems as indicated below.

$$M_{t,t+1}(x_t, y_t, x_{t+1}, y_{t+1}) = \frac{D_{t+1}(x_{t+1}, y_{t+1})}{D_t(x_t, y_t)} \left[\frac{D_t(x_{t+1}, y_{t+1})}{D_{t+1}(x_{t+1}, y_{t+1})} X \frac{D_t(x_t, y_t)}{D_{t+1}(x_t, y_t)} \right]^{1/2} \quad (3)$$

EC × TEC

Where, the first fraction from the left-hand side refers to technical efficiency change, and the second fraction on the right refers to technical change.

¹⁹ Airline carriers are the decision-making units for this analysis.

The output distance function for $K' \in R_j$ in this study is calculated using a linear programming approach which is outlined below. The productivity of producer K' between time period t and $t + 1$ is given by the distance function:

$$[D^s(x^{k',s}, y^{k',s})]^{-1} = \max \phi_c^{k',s} \quad (4)$$

Subject to

$$\sum_{k \in R_j} \lambda^k y_m^{k,s} \geq \phi_c^{k',s} y_m^{k',s}, \quad m = 1, \dots, M$$

$$\sum_{k \in R_j} \lambda^k x_n^{k,s} \leq x_n^{k',s}, \quad n = 1, \dots, N$$

$$Z^{k,s} \geq 0$$

Where λ^k , which refers to the intensity of an airline activity used in providing this service. The productivity scores are obtained by using the DEA linear programming technique to solve the constrained maximization problem depicted by Equation (4) and the succeeding inequalities. The solution to this problem gives an MPI score for each airline company with values bounded from below at a value of zero.

Performance predictions derived from computing technical efficiency and productivity scores are used to test the influence of airline characteristics on these performance measures. Following empirical approaches used in past research examining technical efficiency in transportation sectors, this study uses the Tobit estimation procedure to examine the technical efficiency influence of airline characteristics (Fethi *et al.*, 2006; Gillen & Lall, 1997). The benefit of using this approach to predict technical efficiency scores is it censors prediction between the values of 0 and 1, which is the range of values for this performance measure. The specification used for this study is as follows:

$$TE_{it}^* = \phi_{1it} + \phi_2 x_{2it} + \phi_3 x_{3it} + \phi_4 x_{4it} + \phi_5 x_{5it} + \phi_6 x_{6it} + \phi_7 x_{7it} + \phi_8 x_{8it} + \phi_9 x_{9it} + \phi_{10} x_{10it} + \phi_{11} x_{11it} + \phi_{12} x_{12it} + u_{it}; \quad (5)$$

Where,

$$y_i = y_i^*, \text{ if } y_i^* > 0 \text{ and}$$

and $y_i = 0$, otherwise

Where x_i and ϕ are vectors of explanatory variables and unknown parameters respectively, whilst y_i^* and y_i are the latent variable and the DEA derived technical efficiency score, respectively. The random error u_{it} is independent and normally distributed with zero mean and variance, $N(0, \sigma^2)$. TE_{it}^* denotes the unobserved technical efficiency value as a function of a set of explanatory variables, namely the extent of outsourcing (x_{2it}), available seat kilometer (x_{3it}), revenue passenger kilometer (x_{4it}), alliance dummy (x_{5it}), passenger load factor (x_{6it}), pre-recession dummy (x_{7it}), recession 2007/2008 dummy (x_{8it}), the interaction between the logarithm of available seat kilometers and the recession dummy 2007/2008 (x_{9it}), the interaction between the logarithm of passenger load factor and the recession dummy 2007/2008 (x_{10it}), the interaction between the logarithm of passenger load factor and the pre-recession dummy 2003/2006 (x_{11it}), and the interaction between outsourcing intensity and the recession dummy 2007/2008 (x_{12it}). Special attention is given to the parameter estimates on passenger load factor since this airline characteristics captures the influence of social distancing on airline performance.

The Generalized Method of Moments (GMM) approach is used to test the influence of airline characteristics on airline productivity. This approach is a superior technique of estimation compared to the instrumental variables technique when heteroscedasticity is present, as it fully utilizes past information on airline performance to form the moment conditions. The specification of airline's productivity model based on difference GMM estimators is as follows:

$$MPI_{it}^* = \phi_1 MPI_{it-1}^* + \phi_2 y_{2it} + \phi_3 y_{3it} + \phi_4 y_{4it} + \phi_5 y_{5it} + \phi_6 y_{6it} + \phi_7 y_{7it} + \phi_8 y_{8it} + \phi_9 y_{9it} + \phi_{10} y_{10it} + \phi_{11} y_{11it} + \phi_{12} y_{12it} + v_{it} \quad (6)$$

The model of an airline's productivity in Equation (6) is regarded as a function of predictive variables such as the extent of outsourcing (y_{2it}), available seat kilometer (y_{3it}), revenue passenger kilometer (y_{4it}), alliance dummy (y_{5it}), passenger load factor (y_{6it}), pre-crisis dummy (y_{7it}), recession 2007/2008 dummy (y_{8it}) and the interaction between the logarithm of ASK and the recession dummy 2007/2008 (y_{9it}), the interaction between outsourcing extent and recession dummy 2007/2008 (y_{10it}), the interaction between alliance and the recession dummy 2007/2008 (y_{11it}) and the interaction between passenger load factor and the recession dummy 2007/2008 (y_{12it}). As with the findings for technical efficiency, special attention is given to the parameter estimates on passenger load factor.

Results

Findings for technical efficiency and productivity

The second column of Table 2 provides mean information on technical efficiency trends for the observation periods preceding the great recession of 2007–2008, during and immediately following that recession. These technical efficiency measures are obtained from using the Data Envelopment Approach (DEA) outlined in the previous section to derive technical efficiency scores for each of the 17 companies included in this study. On average these companies have been able to attain higher levels of efficiency, even during the great recession, as the mean of these scores suggests continued improvements in technical efficiency throughout the entire sample observation period. For example, the technical efficiency score increases from a low of 0.792 for the pre-recession sample period to 0.844 for the period covering the great recession. This score increases further to a value of 0.883 for the post-recession observation sample. This pattern of enhanced efficiency in the Asia Pacific airline industry contrasts with productivity patterns for the same observation period. Mean information on these productivity patterns are presented in the third column of Table 2. The productivity measures are derived from using the DEA procedure to derive Malmquist Productivity Indexes (MPI) scores for each company included in the sample population. The Generalized Methods of Moments (GMM) procedure presented previously is used to derive this performance measure. The means of these productivity scores differ by 13.5% from a value of 1.083 prior to the great recession to 0.937 for the period covering the great recession. Immediately following the great recession productivity increases to levels 9% above levels achieved prior to the 2008–2008 downturn. Findings indicating differing technical efficiency and productivity patterns are consistent with this study's hypothesis on the potential efficiency-productivity disconnect that can arise when industries characterized by capacity constraints face economic downturns.

Table 3 and Table 4 present estimations of the performance equations as specified by Equation (5) and Equation (6), respectively. These estimations use the technical efficiency and productivity scores derived above as the dependent variables. Findings presented in Table 2 suggest available seat kilometers and load-factors contribute to enhanced technical estimated for the pre and post recessionary periods as the parameter estimates on LRPK and LPLF are statistically significantly greater than zero. The lack of statistical significance on the pre-recession dummy 'PRECR' indicates technical efficiency does not differ appreciably for the non-recessionary observation periods. Findings in Table 3 also reveal that outsourcing is associated with lower levels of technical efficiency, as the parameter estimate on the outsourcing variable 'OSRC' is positive and statistically significant. This result is consistent with the notion that coordination challenges limit the effectiveness of outsourcing as an efficiency enhancing activity. Parameter estimates depicting the change in technical efficiency during the great recession show that the effects of outsourcing and load-factors are even stronger during an economic downturn, as the sign on the interaction terms for these parameter estimates are the same as the sign on the parameter of the noninteraction outsourcing and load factor variables. The signs on the parameter estimates for the productivity findings reported in Table 4 generally mirror the signs reported for the technical efficiency findings with one notable difference. The great recession dummy is negative and statistically significant suggesting productivity declined during the great

Table 2. Mean values of performance measures of airline companies based in the Asia Pacific region.

Observation sample	Technical efficiency score	Productivity score
2003–2006	0.792	1.083
2007–2008	0.844	0.937
2009–2011	0.883	1.183
Overall (2003–2011)	0.834	1.073

Table 3. Technical efficiency (Tobit) estimation results (t-statistics in parentheses).

Variable	Technical efficiency estimation using Tobit regression technique	Marginal effects
Constant, ($\hat{\phi}_1$)	-0.8607 (-1.36)	0.011
Outsourcing extent, OSRC ($\hat{\phi}_2$)	1.44*** (5.03)	0.9265
(log) Available seat kilometer, LASK ($\hat{\phi}_3$)	0.1257*** (3.79)	0.5517
(log) Revenue Passenger Kilometer, LRPK ($\hat{\phi}_4$)	-0.054** (-2.61)	0.4801
Alliance dummy, ($\hat{\phi}_5$)	0.0264 (0.058)	0.5120
(log) Passenger Load Factor, LPLF ($\hat{\phi}_6$)	0.728* (1.76)	0.7642
Pre-Crisis dummy, PRECR ($\hat{\phi}_7$)	0.088 (0.49)	0.8106
Crisis 2007/2008 dummy, CR0708DUM ($\hat{\phi}_8$)	3.966*** (2.84)	-0.999
(Log) LASK x Crisis dummy 2007/2008, LASKCR2007/2008 ($\hat{\phi}_9$)	-0.144** (-2.62)	0.6252
(Log) LPLF x Crisis dummy 2007/2008, LPLFCR ($\hat{\phi}_{10}$)	1.93** (2.43)	0.9748
(Log) LPLF x Pre-Crisis dummy, LPLFPRECR ($\hat{\phi}_{11}$)	0.472 (0.86)	0.6808
Outsourcing x Crisis dummy, OSRCR ($\hat{\phi}_{12}$)	1.419** (2.00)	0.9222
Number of observations	153	
Number of airlines	17	
Pseudo R-squared	1.02	
Log Likelihood ratio chi-squared	126.69	

Note: *, ** and *** indicate that the corresponding estimates are statistically significant at ten, five and one percent level of significance respectively.

depression. This finding further supports the notion of a disconnect between productivity and technical efficiency during an economic downturn.

COVID-19 simulations

The theoretical model used in this study hypothesizes that capacity limitations associated with COVID-19 are likely to further exacerbate this disconnect as well as depress the performance of airline companies. We test these hypotheses by simulating changes in technical efficiency and productivity attributable to changes in the load factor of airline companies. A focus on load factors is critical because this measure of capacity usage is directly affected by the health risks associated with COVID-19. Adhering to physical distancing guidelines requires companies to seat smaller percentages of passengers per flight. As reported earlier in this study load factors have declined 15% year-to-year for February 2020, which marks the early stages of the COVID-19 crises. We use parameter estimates on the load-factor coefficients and the actual February 2019 and 2020 mean values of load factors

Table 4. MPI Productivity (GMM) estimation results (z-statistics in parentheses).

Variable	Productivity estimation using GMM estimator
Lag Malmquist Productivity Index, MPI ($\hat{\phi}_1$)	-0.310*** (-2.71)
Outsourcing extent, OSRC ($\hat{\phi}_2$)	0.048 (0.22)
(log) Available seat kilometer, LASK ($\hat{\phi}_3$)	1.091** (2.24)
(log) Revenue Passenger Kilometer, LRPK ($\hat{\phi}_4$)	-0.959* (-1.87)
Alliance Dummy, ($\hat{\phi}_5$)	0.423 (0.89)
(log) Passenger Load Factor, LPLF ($\hat{\phi}_6$)	2.986** (2.17)
Pre-Crisis dummy, PRECR ($\hat{\phi}_7$)	0.136 (1.00)
Crisis dummy 2007/2008 ($\hat{\phi}_8$)	-9.476** (-2.02)
LASK x Crisis dummy 2007/2008, ($\hat{\phi}_9$)	0.426** (2.13)
OSCR x Crisis dummy 2007/2008, ($\hat{\phi}_{10}$)	-2.294** (-2.16)
Alliance dummy x Crisis dummy 2007/2008, ($\hat{\phi}_{11}$)	-0.762** (-2.38)
LPFL x Crisis dummy 2007/2008, ($\hat{\phi}_{12}$)	2.126 (1.54)
Number of observations	102
Number of airlines	17
Number of instruments	15
Hansen test (p-value)	0.516
Arrelano-Bond test, AR (2) (p-value)	0.221

Note: *, ** and *** indicate that the corresponding estimates are statistically significant at ten, five and one percent level of significance respectively.

Table 5. Simulated changes in performance scores.

Observation Sample	Change in technical efficiency using coronavirus disease 2019 (COVID-19) load factor levels	Change in productivity levels using coronavirus disease 2019 (COVID-19) load factor levels
2003–2006	44.05%	33.73%
2007–2008	34.33%	66.79%
2009–2011	18.34%	30.08%

for airline companies in the Asia Pacific region to simulate the potential influence of COVID-19 on company performance in this industry. For instance, to examine the marginal effects of COVID-19 load factor changes on technical efficiency during the post-recession sample period we take the product of the marginal effect of the parameter LPLF (0.7642) and the log of the change in the mean load factor from February 2019 to February 2020 ($.1226 = \log(0.78) - \log(0.678)$). This product indicates a change in the post-recession technical efficiency score equaling -0.153. Given the mean technical efficiency score for this sample period is 0.883, this simulation predicts an 18.34% reduction in technical efficiency.

The remaining COVID simulation results are presented in Table 5. Findings presented in column (2) show the simulated COVID influence on technical efficiency attributable to an erosion of load factor levels. These findings suggest a nontrivial reduction of the technical efficiency score of 0.3489 for the pre-recession sample. This reduction accounts for a predicted 44% decline in technical efficiency at the mean ($0.3489/0.792$). This reduction even exceeds the simulated COVID induced technical efficiency reduction of 34.33% ($0.2892/0.844$) for the great recession sample observation. Hence, these simulations presented in column (2) predict a declining influence of COVID-19 induced capacity changes on technical efficiency as the economy recovers from an economic crisis.

Findings presented in column (3) of Table 5 show the predicted influence of COVID-19 on productivity attributable to declining load factors. These findings reveal a smaller effect on productivity during non-recessionary periods compared to the findings for technical efficiency. For instance, the simulated non-recessionary decline in productivity is 33.73 ($0.3653/1.083$) and 30.087% ($0.3653/1.183$) for the pre and post recessionary periods, respectively. In contrast to the non-recessionary findings, COVID-19 level load factors have a much larger effect on productivity compared to the technical efficiency findings for the sample covering the great recession (2007–2008). The contents in column 3 of Table 5 simulates productivity declines 66.79% when imposing the year-to-year February decline in load factors.

In sum, these COVID-19 simulations reveal two important findings; (1) low load factors associated with the COVID-19 crisis exacerbate the disconnect between technical efficiency and productivity during a recession; (2) regardless of economic conditions social distancing that requires airline companies in the Asia Pacific region to fly with low load-factors weakens the performance of airline companies, and especially productivity performance of these firms.

Concluding remarks

The current pandemic makes it challenging for businesses and industries to operate successfully. This challenge is especially acute in industries whose business is characterized by the serving of customers in a confined space. Airline transport is a prime example of just such an industry because passengers are transported in vehicles that often require close physical proximity. Now, in the current environment which emphasizes physical distancing, airline companies struggle to operate a profitable business. These challenges faced by airline companies not only influences their industry, but also has wide ranging implications for the global economy. This service contributes significantly to the connectivity of people from all corners of the globe. There are few other places where the example of connections by air transport is more evident than the Asia Pacific region, as this region now serves the largest share of passengers globally. Airline passenger growth in the region, however, makes it especially susceptible to health-related economic disruptions. Evidence from the SARS outbreak reveals significant declines in passenger service, which was nearly exclusively limited to the Asia Pacific region.

This study contributes to our understanding of health-related disruptions to airline transport services by examining factors influencing industry performance in the Asia Pacific region. The theoretical model used in this study suggests the following two key hypotheses regarding firm performance during economic crises. Due to the uniqueness of the transport vehicle in this industry, operating efficiently may not necessarily contribute to productivity growth, because physical distancing caps the percentage of seats airline companies can fill on their flights. Also, the effects of health-related disruptions are more severe than a financial downturn due to tighter capacity constraints attributable to flying with low passenger load factors. Simulations using estimation results on technical efficiency and productivity support these hypotheses. The simulations suggest a 44% decline in the average technical efficiency score prior to the great recession compared to a 33.37% decline in productivity in non-recessionary years when using the low COVID-19 levels of passenger load factors for calculations. Simulations also indicate a 34.33% technical efficiency decline during the great recession compared to a 66.79% productivity decline for the same period when using the low COVID-19 levels of passenger load factors for calculations. We interpret these results as predicting airline companies in this region will potentially face significant challenges operating profitably during the current COVID-19 crises. Performance findings reported in this study suggest the

formation of alliances and effectively using the local workforce can contribute to cost-savings associated with enhance productivity. Nonetheless, the potential for nontrivial performance erosion due to physical distancing may require increasing fares to offset the cost of flying with unfilled seats. However, in a region where airline companies compete with rail and online communications services, setting high fares could also harm the profit margins of these companies.

Data availability

Underlying data

Source data was obtained from:

1. ICAO Digest of Statistics: <https://www.icao.int/sustainability/Pages/Statistics.aspx>
 - a. Fuel cost, number of employees, are taken from the ICAO data base, which requires a login and subscription. This information is not presented in the attached EXCEL file to avoid violating third party restrictions on data dissemination.
2. Air Transport World Financial Reports: <https://documents.worldbank.org/en/publication/documents-reports/documentdetail/364321491414311301/air-transport-annual-report-2016>
 - a. Information on fleet size is taken from this source. Access to this data requires a subscription fee. Hence, this information is not presented in the attached excel spread sheet to avoid violating third party restriction on data dissemination.
3. Index Mundi: <https://www.indexmundi.com/commodities/?commodity=jet-fuel&months=30>
 - a. Provides additional information on fuel costs. This information is not presented in the attached EXCEL file to avoid violating third party restrictions on data dissemination.
4. Annual reports of airlines provide information on operating revenue, revenue passenger kilometers (RPK), total labor cost, available seat kilometers (ASK) and load factor (PLF)
 - a. Air Asia <https://ir.airasia.com/ar.html>
 - b. SriLankan Airlines https://www.srilankan.com/pdf/annual-report/SriLankan_Airlines_Annual_Report_2018-19_English.pdf
 - c. All Nippon Airlines https://www.ana.co.jp/group/en/investors/irdata/annual/pdf/17/17_E_00.pdf
 - d. China Airlines <https://www.china-airlines.com/de/en/investor-relations/annual-report>
 - e. China Eastern Airlines <https://webb-site.com/dbpub/docs.asp?p=4794&s=typup>
 - f. Cathay Pacific Airlines https://www.cathaypacific.com/cx/en_US/about-us/investor-relations/interim-annual-reports.html
 - g. China Southern Airlines <https://www.csair.com/en/about/investor/yejibaogao/all/>
 - h. Garuda Indonesia Airlines <https://www.garuda-indonesia.com/id/en/investor-relations/annual-report-dan-sustainability-report/annual-report>
 - i. Jet Airways https://www.lnseindia.com/corporates/shldInformation/shldinfo_annualReports.html?radio_btn=company¶m=JETAIRWAYS
 - j. Japan Airlines <https://www.jal.com/en/investor/library/finance/>
 - k. Korean Airlines https://www.koreanair.com/global/en/about/economic-responsibility-investor-relations/investor-relations/annual_reports/
 - l. Malaysia Airlines http://ir.chartnexus.com/mas/website_HTML/attachments/attachment_18596_1321343066.pdf
 - m. Pakistan International Airlines <https://www.piac.com.pk/corporate/management/corporate-reports>
 - n. Qantas Airways https://investor.qantas.com/FormBuilder/_Resource/_module/doLLG5ufYkCyEP-jF1tpgyw/file/annual-reports/2019-Annual-Report-ASX.pdf

- o. Singapore Airlines <https://www.singaporeair.com/saar5/pdf/Investor-Relations/Annual-Report/annualreport1920.pdf>
- p. Thai Airlines <http://investor.thaiairways.com/en/downloads/annual-report>
- q. Virgin Australia <https://www.virginaustralia.com/us/en/about-us/company-overview/investor-information/annual-reports/>

Zenodo: COVID-19 Airline Data

<https://doi.org/10.5281/zenodo.4015344> (Peoples *et al.*, 2020)

This project contains the following underlying data:

Dataset_Emerald Open Research.xlsx

1. Output spread sheet contains airline information on airline ID, observation, operating revenue, revenue passenger kilometers (RPK), total labor cost, available seat kilometers (ASK) and load factor (PLF)
2. Productivity spreadsheet: airline ID, Alliance dummy, outsourcing (osrc), operating revenue, revenue passenger kilometers (RPK) productivity index (MPI), pre-crises dummy and crises dummy. Note the 2011 sample observations for productivity are not listed because the productivity measure is given by the change in productivity. Since the dataset covers the period 2003-2011, there therefore are 8 years of observations rather than 9 years. The last observation is given by the change of productivity from 2010-2011.
3. Technical efficiency spreadsheet: airline ID, Alliance dummy, Operating Revenue, revenue passenger kilometers (RPK), outsourcing (osrc), technical efficiency index (TEFF), pre-crises dummy and crises dummy

Data are available under the terms of the [Creative Commons Attribution 4.0 International license](#) (CC BY 4.0)

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This article examines the role of airline technical efficiency and productivity on airline stability before, during, and after the Great Recession of 2007-2008. The authors are then able to use this analysis to simulate the impact of COVID-19, and the associated social distancing requirements, on airline performance. As such, this article is timely and important, as the authors correctly note that there is a "dearth of research examining the industry's ability to recover from a downturn caused by health risks." Further, the authors should be commended for their creativity given that their simulation results give us some estimates of the impact of COVID-19 on the airline industry at a time when data to directly study this impact is just starting to become available.

Using data on 17 airlines located in Asia and the Pacific region from 2003-2011, the authors first use Data Envelopment Analysis to estimate the technical efficiency and productivity of these airlines. The authors then use a Generalized Method of Moments model to estimate the impact of airline characteristics on productivity. These results are then used to simulate the impact of capacity restrictions, due to social distancing requirements, on airline technical efficiency and productivity, finding that the social distancing requirements "exacerbate the disconnect between technical efficiency and productivity during a recession" and "weakens the performance of airline companies, and especially the productivity performance of these firms." These data and models are appropriate, well documented, and their use for this type of analysis is well cited by the authors.

While I commend the authors on their aforementioned creativity in using older data to estimate the impact of the COVID-19 social distancing requirements on airline performance, I do wonder if more discussion is needed regarding the limitations of this work. Specifically, my instincts are that the estimates derived in this analysis should be treated as the lower bound (given that the estimates are decreases in productivity, or alternatively the upper bound of the absolute value of the impact) of the impact of COVID-19 social distancing restrictions on firm performance. The reason I feel this way is because running a simulation in this way ignores (to my mind) the ability of airlines to adjust to this new shock to the industry in new ways, limiting the impacts of the pandemic.

For example, there is ample evidence that the number of flights during the majority of 2020 decreased significantly from previous years, something that I don't believe to be true of the Great Recession (at least at no where near the same magnitude). Indeed, the story behind the decrease of demand during the Great Recession is more of an income/economic activity explanation, while for COVID-19 it is both an income/economic activity story as well as an attitudes/preferences story in which travelers did not feel as safe flying as they did previously or are now able to telecommute (the authors do a good job of noting this in the introduction). As such, this should have allowed airlines to alter their operations in ways that I would assume would improve productivity and efficiency relative to the estimates in the paper. Examples of this behavior include: re-optimizing the number of flights offered between cities, re-optimizing what planes are being used on what routes, removing the least efficient planes from the sky until demand recovers, and creating new revenue forms such as an increased emphasis on transporting cargo (where passengers' bags would have likely been previously).

I do not bring these factors up to discredit the authors findings, but rather to add context to these results. If everything were identical between the Great Recession and the COVID-19 pandemic except the social distancing requirements' impact on airline load factors, I think the provided estimates are correct. However, given that the pandemic changed the attitudes of travelers and allowed airlines to re-optimize their operations, I feel that the authors estimates that COVID-19 social distancing requirements led to a "44% decline in the average technical efficiency" and a "66.79% productivity decline" are valid, but likely lower bounds (again, considering that the estimates show decreases), and that the true impacts on both technical efficiency and productivity are likely to be less extreme. As such, I think more context towards the end of the paper, perhaps right before the conclusion section, highlighting the limitations of this research is warranted.

At the end of the day, I feel that this paper does make a significant, timely, contribution to the literature, but also feel that the approach taken has some limitations and that these should be noted in the text for the reader to understand how to interpret the results and where future research can add to the results of this paper.

Other Notes:

- For some reason, in the PDF file I had access to, there are numerous erroneous -s on page 8 ("employ-ment", "infor-mation", "car-riers", "follow-ing", "indi-cates", etc.). I am unsure whether these are typos in the authors work (I kind of doubt this given that I only noticed them in this one section) or are something from the typesetting stage of production.
- On page 14, the parentheses are not closed when you write: " $(.1226=\log(0.78)-\log(0.678))$ ". You either want a second) at the end or to eliminate the first (and make this equation part of the sentence itself.

Is the work clearly and accurately presented and does it cite the current literature?

Yes

Is the study design appropriate and is the work technically sound?

Yes

Are sufficient details of methods and analysis provided to allow replication by others?

Yes

If applicable, is the statistical analysis and its interpretation appropriate?

Yes

Are all the source data underlying the results available to ensure full reproducibility?

Yes

Are the conclusions drawn adequately supported by the results?

Partly

Is the argument information presented in such a way that it can be understood by a non-academic audience?

Partly

Does the piece present solutions to actual real world challenges?

Partly

Is real-world evidence provided to support any conclusions made?

Partly

Could any solutions being offered be effectively implemented in practice?

Partly

Competing Interests: No competing interests were disclosed.

Reviewer Expertise: Airline demand, competition, and pricing

I confirm that I have read this submission and believe that I have an appropriate level of expertise to confirm that it is of an acceptable scientific standard, however I have significant reservations, as outlined above.

Author Response 03 Feb 2022

James Peoples, University of Wisconsin, Milwaukee, Milwaukee, United States

Authors' Response to Reviewer-2's comments

1. Reviewer's comment: "While I commend the authors on their aforementioned creativity using older data to estimate the impact of the Covid-19 social distancing requirement on airline performance, I do wonder if more discussion is needed regarding the limitations of this work. Specifically the estimates derived in this analysis should be treated as the lower bound of the absolute value of the impact.
2. 1. **Response: This comment fits with the other reviewer's comment to use recent higher load factors as a predictor of post COVID-19 performance. We also include a presentation of the study's limitations in the third to last paragraph of the "concluding" section. In addition, we have also**

included in our conclusion this reviewer's observation that airlines can re-optimize the number of flights offered between cities and re-optimize what planes are being used on what routes, by removing the least efficient planes from the sky until demand recovers and creating new revenue forms such as an increased emphasis on transporting cargo in the belly of the planes.

Competing Interests: No competing interests were disclosed.

Reviewer Report 04 November 2020

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This paper examines the airline industry's ability to recover from an economic crisis caused by and coupled with a health crisis. It notes that previous research looked at its ability to recover solely from economic crises. This ability is evaluated by performance measures of technical efficiency and productivity scores, which are based on a handful of variables. The present paper applies COVID-19 capacity constraints to the mean technical efficiency and productivity scores of airlines based in the Asia Pacific region during both the non-recessionary and recessionary periods of the years 2003-2011. By doing this, the authors are able to show how these airlines would have performed when faced with the physical distancing constraints of a health crisis on top of an economic crisis.

Their findings suggest that by applying COVID-19 constraints, technical efficiency and productivity become further disconnected than they already were with the recession and that social distancing requirements, regardless of economic conditions, weaken the performance of airlines. In this study, using the COVID-19 levels of passenger load factors, there is a 44% decline in the average technical efficiency score and a 33.37% decline in productivity in non-recessionary years. During the recession period, there is a 34.33% technical efficiency decline and a 66.79% productivity decline with the COVID-19 load factors.

The sources of the underlying data used are very clearly outlined. They have included a section entitled "Data Availability" where all the source material for the general subject matter as well as the links for all the 17 airlines studied are listed. Furthermore, there is a link to their dataset. Additionally, with any data that the authors have calculated themselves, such as the quantity of

fuel consumed by airlines, they explain their methods and the data sources used in its production.

Each method of analysis is first explained plainly and then, its application in the study is introduced. All the formulas and functions are presented clearly with descriptions of each of their variables. However, the variables chosen for the Tobit estimation and the Generalized Method of Moments (GMM) approach are simply listed, rather than providing the reader with some rationale for the selection. In particular, there are no variables related to the post-recession period but the reason for this is not mentioned. As this study considers a period of 2003-2011, it is suggested that a dynamic DEA model can be adopted to capture the intertemporal efficiency changes more accurately.

The interpretation of the mean values of performance measures derived by the authors is reasonable. They show that in a recession period, there are discrepancies between technical efficiency and productivity. The values produced make it clear to see that the two measures act out of sync with each other when they are being used in an industry facing major capacity constraints in an economic downturn. They do not attempt to stretch the occurrence of this notion by acknowledging that in the non-recession periods examined, there is no noteworthy disconnect between the measures. The interpretation of the COVID-19 simulation findings is reasonable but quite broad, perhaps there could be a deeper dive into what these results suggest and implications they may have as the industry makes its way through these health and economic crises.

It appears somewhat inconsistent how the authors represent their view of outsourcing labor. First, in one of their hypotheses and throughout the first six pages, they say that airlines can potentially mitigate productivity declines by outsourcing labor and they speak primarily of the positive benefits, which is the mainstream view. The authors only briefly mention that there are potential risk factors that can lead to a different outcome. However, in the "Data and empirical approach" section, they show that their findings are "consistent with the notion that greater cost-savings are achievable when employing labor from the local work force," and then this is also re-confirmed by later results. The possibility of this notion as an alternative to the notion that outsourcing will aid productivity should be fully discussed earlier in the previous section, perhaps along with some supporting studies. Or at least, the implications of this finding and its clash with the mainstream view should be elaborated upon. Second, perhaps more importantly, while labor outsourcing will raise labor productivity, it would add expenses to the purchased services, and its net impact on the total factor productivity (TFP) is unclear.

The conclusions drawn are broad but seem to be adequately supported by the results of the study. The COVID-19 simulation results offer a simple and clear summary. There is a limit to the level in which the operation can efficiently contribute to productivity gains due to the physical distancing constraint on the number of seats that can be sold. The effects of a health-related disruptions wreak greater damage than those of solely a financial downturn. This is again due to the capacity constraint on seats. The authors offer some suggestions for airlines in navigating through the recession and post-recession periods, which are limited to the formation of alliances, effectively using the local workforce, and raising fares.

A main innovation of the paper is to examine the implications of the physical distancing constraint for technical efficiency and productivity. The authors are right in pointing out that the cost per passenger falls as the percent of seats sold on a flight (the so-called "load factor") rises, since

much of a flight's cost is fixed regardless of the number of passengers flown. Some further elaboration, including the relevant literature, would be helpful here (e.g. Zhang and Zhang, 2018¹). Second, the authors have motivated the study by emphasizing that "... the challenge posed by this pandemic is especially pronounced for airline companies based in the Asia Pacific region. Indeed, airline companies based in this region have experienced a dramatic 41.3% decline in revenue passenger kilometers year-to-year for February 2020, compared to a 14.1% decline for all regions ..." and "... in part because COVID-19 has significantly affected the Chinese airline industry ...". While China and the Asia Pacific region went into the COVID-19 crisis earlier (the first quarter of 2020) than the other regions, in general they also came out of the crisis earlier than the others (Sun *et al.*, 2020²). For instance, a recent study by Czerny *et al.* (2020³) reported that China's flight capacity in July was at about 80% of 2019 levels at its major airports, its domestic passenger at 60% of 2019 levels (with load factors being 70%), and the ratio of domestic actual to scheduled flights is in range of 60 to 90%. The number of passengers carried by domestic flights in September 2020 was 47.75 million, at 98% of the pre-pandemic level. A key to recovery is that China has been reporting near zero new cases of COVID-19 since March 2020.

There is no discussion surrounding any of the paper's potential limitations, and no suggestions given for how this research may be built upon or improved in the future. For example, the paper could further examine the extent in which airlines are competing, *and cooperating*, with high-speed rail (e.g. Zhang *et al.*, 2019⁴) or motorway driving (e.g. Borsati and Albalade, 2020⁵). As another example, the authors noted in the introduction that "... consumer demand post COVID-19 will likely require in-flight changes that limit carriers' ability to fly at capacity, even if an increase in passengers' post COVID-recession income supports enhanced demand for air transport services." The paper's analysis is based primarily on this scenario. While this scenario may be highly likely, the other scenario is that the constraint is not needed (e.g. the recent experience in Chinese domestic market where physical distancing is no longer required with many flights being fully packed with passengers). It will be interesting to assign probabilities to both scenarios and offer a more complete analysis of COVID-19 and airline performance.

There are a very few typos in the writing, which we list below:

- "and productivity, Information on passenger load factors is especially important as it allows a simulation of the performance influence of low load factors occurring during the COVID-19 pandemic." (page 7) – there is a comma in place of what should be a period.
- "Should we explain that in this study we use the 2007/2008 recession to represent crises period." (page 8) – this sentence is phrased as a question rather than a statement.
- "Immediately following the great recession productivity increases to levels 9% above levels achieved prior to the 2008–2008 downturn." (page 11) – should be 2007.
- "Findings presented in Table 2 suggest available seat kilometers and load-factors contribute to enhanced technical estimated for the pre and post recessionary periods" (page 11) – should be estimations.
- "Special attention is given to the parameter estimates on passenger load factor since this airline characteristics captures the influence of social distancing on airline performance."

(page 10) – should be made singular.

References

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Is the work clearly and accurately presented and does it cite the current literature?

Partly

Is the study design appropriate and is the work technically sound?

Yes

Are sufficient details of methods and analysis provided to allow replication by others?

Yes

If applicable, is the statistical analysis and its interpretation appropriate?

Yes

Are all the source data underlying the results available to ensure full reproducibility?

Yes

Are the conclusions drawn adequately supported by the results?

Yes

Is the argument information presented in such a way that it can be understood by a non-academic audience?

Yes

Does the piece present solutions to actual real world challenges?

Yes

Is real-world evidence provided to support any conclusions made?

Yes

Could any solutions being offered be effectively implemented in practice?

Yes

Competing Interests: No competing interests were disclosed.

We confirm that we have read this submission and believe that we have an appropriate level of expertise to confirm that it is of an acceptable scientific standard, however we have significant reservations, as outlined above.

Author Response 03 Feb 2022

James Peoples, University of Wisconsin, Milwaukee, Milwaukee, United States

Authors' Responses to Reviewer 1's comments

This paper examines the airline industry's ability to recover from an economic crisis caused by and coupled with a health crisis. It notes that previous research looked at its ability to recover solely from economic crises. This ability is evaluated by performance measures of technical efficiency and productivity scores, which are based on a handful of variables. The present paper applies COVID-19 capacity constraints to the mean technical efficiency and productivity scores of airlines based in the Asia Pacific region during both the non-recessionary and recessionary periods of the years 2003-2011. By doing this, the authors are able to show how these airlines would have performed when faced with the physical distancing constraints of a health crisis on top of an economic crisis.

Their findings suggest that by applying COVID-19 constraints, technical efficiency and productivity become further disconnected than they already were with the recession and that social distancing requirements, regardless of economic conditions, weaken the performance of airlines. In this study, using the COVID-19 levels of passenger load factors, there is a 44% decline in the average technical efficiency score and a 33.37% decline in productivity in non-recessionary years. During the recession period, there is a 34.33% technical efficiency decline and a 66.79% productivity decline with the COVID-19 load factors.

The sources of the underlying data used are very clearly outlined. They have included a section entitled "Data Availability" where all the source material for the general subject matter as well as the links for all the 17 airlines studied are listed. Furthermore, there is a link to their dataset. Additionally, with any data that the authors have calculated themselves, such as the quantity of fuel consumed by airlines, they explain their methods and the data sources used in its production.

Each method of analysis is first explained plainly and then, its application in the study is introduced. All the formulas and functions are presented clearly with descriptions of each of their variables. However, the variables chosen for the Tobit estimation and the Generalized Method of Moments (GMM) approach are simply listed, rather than providing the reader with some rationale for the selection.

Response:

The revised version of the manuscript now provides rationale for the selection of explanatory variables. This presentation is reported in the last paragraph of section IV.

In particular, there are no variables related to the post-recession period but the reason for this is not mentioned. As this study considers a period of 2003-2011, it is suggested that a dynamic DEA model can be adopted to capture the intertemporal efficiency changes more accurately.

Response: Both specifications include a recession (crisis) dummy and a prerecession (precrisis) dummy, the post-recession (post crisis) dummy is excluded to avoid singularity in the estimated covariance matrix in errors. While post-recession interaction terms could be included, the inclusion of those terms did not convey meaningful results due to the small sample size constraint and collinearity issue. We now describe the rationale for the exclusion of these dummies in footnote-11.

Response:

We agree with the reviewer that the efficiency score estimated using the dynamic DEA provides a more accurate measure of efficiency scores for airlines. Nonetheless, applying the dynamic DEA model would require additional variables such as intermediate inputs and carry over variable which require an access to ICAO database. Given the present condition where movement is restricted, we unable to travel to the DCA Kuala Lumpur to collect each of airline's additional data such as the number of departures, flying hours and network size (number of destinations served).

The interpretation of the mean values of performance measures derived by the authors is reasonable. They show that in a recession period, there are discrepancies between technical efficiency and productivity. The values produced make it clear to see that the two measures act out of sync with each other when they are being used in an industry facing major capacity constraints in an economic downturn. They do not attempt to stretch the occurrence of this notion by acknowledging that in the non-recession periods examined, there is no noteworthy disconnect between the measures.

Response:

This response to this comment is presented at the end of the second paragraph of the 'Results' section and reads as follows:

The capacity constraint-economic downturn disconnect is further supported by the lack of a disconnect for productivity and technical efficiency during the pre- and post-recession sample. As noted above, there is an absence of a pre-recession change in both technical efficiency and productivity, and both those performance measures resemble their post-recession levels. Thus, the technical efficiency-productivity disconnect found for the great recession sample is unique to the 2007-2008 economic downturn.

The interpretation of the COVID-19 simulation findings is reasonable but quite broad, perhaps there could be a deeper dive into what these results suggest and implications they may have as the industry makes its way through these health and economic crises.

Response: We now provided more details on the simulation results in the 3rd and 2nd

to last paragraphs in the concluding section address this issue.

In addition, the revised version of the manuscript now includes additional simulations that examine potential air transport performance when the industry makes it way through these health and economic crises. This presentation occurs in the last two paragraphs of the 'Results' section.

It appears somewhat inconsistent how the authors represent their view of outsourcing labor. First, in one of their hypotheses and throughout the first six pages, they say that airlines can potentially mitigate productivity declines by outsourcing labor and they speak primarily of the positive benefits, which is the mainstream view. The authors only briefly mention that there are potential risk factors that can lead to a different outcome. However, in the "Data and empirical approach" section, they show that their findings are "consistent with the notion that greater cost-savings are achievable when employing labor from the local work force," and then this is also re-confirmed by later results. The possibility of this notion as an alternative to the notion that outsourcing will aid productivity should be fully discussed earlier in the previous section, perhaps along with some supporting studies. Or at least, the implications of this finding and its clash with the mainstream view should be elaborated upon. Second, perhaps more importantly, while labor outsourcing will raise labor productivity, it would add expenses to the purchased services, and its net impact on the total factor productivity (TFP) is unclear.

Response:

This response to these two comments is presented at the end of the second to the last paragraph of the 'Airline Performance Under Capacity Constraints' section and reads as follows:

In addition, evidence indicating the potential shortcomings associated with outsourcing reveal that nearly 50% of the companies surveyed reported it was more expensive to manage the outsourced activity than originally expected and that service quality did not meet expectations (Albertson, 2000). Hence, while outsourcing labor activities can potentially raise labor productivity, it would add expenses to the purchased services, and its net impact on the total factor productivity (TFP) is unclear. Thus, *a priori*, outsourcing influence on productivity and technical efficiency is not obvious and requires further empirical investigation for airline companies based in the Asia Pacific region.

The conclusions drawn are broad but seem to be adequately supported by the results of the study. The COVID-19 simulation results offer a simple and clear summary. There is a limit to the level in which the operation can efficiently contribute to productivity gains due to the physical distancing constraint on the number of seats that can be sold. The effects of a health-related disruptions wreak greater damage than those of solely a financial downturn. This is again due to the capacity constraint on seats. The authors offer some suggestions for airlines in navigating through the recession and post-recession periods, which are limited to the formation of alliances, effectively using the local workforce, and raising fares.

A main innovation of the paper is to examine the implications of the physical distancing

constraint for technical efficiency and productivity. The authors are right in pointing out that the cost per passenger falls as the percent of seats sold on a flight (the so-called “load factor”) rises, since much of a flight’s cost is fixed regardless of the number of passengers flown. Some further elaboration, including the relevant literature, would be helpful here (e.g. Zhang and Zhang, 2018).

Response:

We now elaborate further on load factors by including the following passage in the first paragraph of the third section:

“As Zhang and Zhang (2018, page 172) observe, the cost per passenger falls as the load factor rises, since much of a flight’s cost is fixed regardless of the number of passengers flown..”

Second, the authors have motivated the study by emphasizing that “... the challenge posed by this pandemic is especially pronounced for airline companies based in the Asia Pacific region. Indeed, airline companies based in this region have experienced a dramatic 41.3% decline in revenue passenger kilometers year-to-year for February 2020, compared to a 14.1% decline for all regions ...” and “... in part because COVID-19 has significantly affected the Chinese airline industry ...”. While China and the Asia Pacific region went into the COVID-19 crisis earlier (the first quarter of 2020) than the other regions, in general they also came out of the crisis earlier than the others (Sun et al., 2020). For instance, a recent study by Czerny et al. (2020) reported that China’s flight capacity in July was at about 80% of 2019 levels at its major airports, its domestic passenger at 60% of 2019 levels (with load factors being 70%), and the ratio of domestic actual to scheduled flights is in range of 60 to 90%. The number of passengers carried by domestic flights in September 2020 was 47.75 million, at 98% of the pre-pandemic level. A key to recovery is that China has been reporting near zero new cases of COVID-19 since March 2020.

Response:

The revised version of the manuscript now includes additional information on China’s response to the initial surge of the pandemic and its implications for air transport service in this region. Please see the 2nd to last paragraph of the ‘Results’ section and the second to last paragraph of the ‘Conclusion’.

There is no discussion surrounding any of the paper’s potential limitations, and no suggestions given for how this research may be built upon or improved in the future. For example, the paper could further examine the extent in which airlines are competing, and cooperating, with highspeed rail (e.g. Zhang et al., 2019) or motorway driving (e.g. Borsati and Albalade, 2020).

Response:

A full discussion on the study’s potential limitations and further examination of modal competition is now presented in the third to last paragraph in the ‘Conclusion’.

As another example, the authors noted in the introduction that “... consumer demand post COVID-19 will likely require in-flight changes that limit carriers’ ability to fly at capacity, even if an increase in passengers’ post COVID-recession income supports enhanced demand for

air transport services.” The paper’s analysis is based primarily on this scenario. While this scenario may be highly likely, the other scenario is that the constraint is not needed (e.g. the recent experience in Chinese domestic market where physical distancing is no longer required with many flights being fully packed with passengers). It will be interesting to assign probabilities to both scenarios and offer a more complete analysis of COVID-19 and airline performance.

Response:

The revised version of the manuscript now includes simulations that include scenarios with low load factors (the more recent observation period that includes the surge of the Omicron variant) and relatively high load factors (the observation sample including domestic passenger growth in China following easing of domestic travel restrictions). See the last two paragraphs of the ‘results’ section.

There are a very few typos in the writing, which we list below:

“and productivity, Information on passenger load factors is especially important as it allows a simulation of the performance influence of low load factors occurring during the COVID19 pandemic.” (page 7) – there is a comma in place of what should be a period.

“Should we explain that in this study we use the 2007/2008 recession to represent crises period.” (page 8) – this sentence is phrased as a question rather than a statement. ○

“Immediately following the great recession productivity increases to levels 9% above levels Emerald Open Research Page 22 of 24 Emerald Open Research 2020, 2:62 Last updated: 27 APR 2021 achieved prior to the 2008–2008 downturn.” (page 11) – should be 2007. “Findings presented in Table 2 suggest available seat kilometers and load-factors contribute to enhanced technical estimated for the pre and post recessionary periods” (page 11) – should be estimations.

“Special attention is given to the parameter estimates on passenger load factor since this airline characteristics captures the influence of social distancing on airline performance.” (page 10) – should be made singular.

Response: Thanks for identifying these typos. We have now made the requested editing changes.

Competing Interests: No competing interests were disclosed.