RESEARCH ARTICLE

REVISED COVID-19 and Airline Performance in the Asia Pacific region [version 2; peer review: 1 approved, 1 approved with reservations, 1 not approved]

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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)

This article is included in the Coronavirus (COVID-19) collection.

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> **REVISED** **Amendments from Version 1**
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> This revised version of the article entitled, "COVID-19 and Airline Performance in the Asia Pacific Region," incorporates responses to the reviewers' comments and suggestions. Making these changes enhanced the quality of the manuscript without changing the overall story that low load factors associated with the COVID-19 crisis exacerbates the disconnect between technical efficiency and productivity. 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. Empirically, the article incorporates this more recent information by computing technical efficiency and productivity changes when using information on changing levels of load factors arising during the recent Omicron surge. Findings derived from making these computations are presented in Table 6 (which is a new addition to the article) and a discussion of these new findings are provided in the 2nd to last paragraph of the *Results* section and the second to last paragraph of the *Conclusion*. In addition, a full discussion on the study's potential limitations as well as further examination of modal competition is now presented in the third paragraph in the *Conclusion*.
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> **Any further responses from the reviewers can be found at the end of the article**

Introduction

Following liberalization polices starting in the mid-1970s the global airlines industry has generally experienced significant increases in passenger demand. Declining air fares due in part to the influx of low-cost carriers (LCCs), 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 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 captured by the fact that in previous economic crises succeeding 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 increased passengers' post COVID-recession income supports enhanced demand for air transport services. Furthermore, survey findings from the International Air Transport Association (IATA) reveals that airline companies are expecting the recovery to take at least a year with some airlines believing it will take even longer[1]. This is consistent with the air traveler's confidence survey which reports that 30 percent of the respondents would not travel by air for at least six months[2]. 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 SARS outbreak in 2003 which took approximately 9 months for revenue passenger kilometer to return to its pre-crises 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 industry[4].

As 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

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[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] 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 in February

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/

a dramatic 41.3 percent decline in revenue passenger kilometers year-to-year for February 2020, compared to a 14.1 percent decline for all regions[5]. In addition, airline companies based in Asia Pacific experienced a 15.1 percent erosion of the percentage of seats filled by passengers for the same observation period compared to a 4.8 percent decline for the industry as a whole[6] largely due to widespread movement control orders. The negative impact was also recorded for airline's cargo section, with regional average cargo ton kilometers for airlines in Asia Pacific recording a 5.9 percent decrease in January 2020 on year-on-year basis, compared to a 3.3 percent 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 percent of all air travelers globally in February 2020[7].

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 Asia[8]. Hence, operations during and following the COVID-19 recovery in air passenger transport face competitive pressure from passenger rail. Asia Pacific airline companies challenge competing for passengers during a pandemic is heightened in part because rail carriers can provide frequent service with larger number of cars per train, which allows them to provide physical distancing while transporting significant numbers of passengers. Whereas air transport companies are much more limited in the use of large aircraft carriers to transport 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 also face increasing market pressure from the enhanced 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 risk associated with passenger transport[9]. Thus, analysis on the performance effect of COVID-19 needs to include examination of air transport operations that minimizes passenger contact and considers the potential for 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 recovery 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 fights, 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 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 is several key developments associated with the enforcement of government policies liberalizing airport operations in this region. Such policy relaxed entry restrictions from foreign airline companies and privatized airline services in this region. Thereby enhancing competition along routes previously restricted to domestic carriers and a few foreign carriers and promoting lower fares as well as expanding

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[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.

[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/)

the network of airports serving the region. Nontrivial growth in passenger demand for air transport service 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 kilometer (ASK) for this region increased in a range from a low of 4.5 percent in 2019 to a high of 10.1 percent in 2016[10].

Understanding 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 they face health crises. It is the 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 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 of hub and spoke model to transport passengers following liberalization of air transport operations in Asia Pacific. Flight coordination in a hub and spoke network system further allows companies to experience cost-saving 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 globally[11].

The expansion of operations facilitated by liberalization policies, though, 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 makes Asia Pacific airlines more vulnerable to health risks such as SARS and COVID-19. Vulnerability arises because a large network means greater dependence on international traffic. Hence, airlines have more routes that are at risk of declining passenger demand due greater possibility of these passenger 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. Evidence of airline company vulnerabilities to health crises is captured by examining the effect of the 2003 severe acute respiratory syndrome (SARS) virus on 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 decline by 40 percent three months immediately following the SARS outbreak[12]. 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 Asia Pacific 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-crises, COVID-19 is a global pandemic. The potential economic damage to airlines in this region is highlighted by forecasts predicting a 53.8 percent year-on-year decline of revenue passenger kilometers for 2020[13]. This 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 perform at high levels during and following a pandemic.

Airline performance under capacity constraints

Modeling 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

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[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); Huderek-Glapska (2010), and Gillen *et al.* (2002).

[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/

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. As Zhang *et al.* (2019, 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. 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 acts 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, then depends heavily on attaining high load factor levels especially during and following a pandemic.

The operation performance outlined above is captured by the concept of technical efficiency. For example, airline management attains technical efficiency by using factor inputs such as fuel, workers and aircrafts in a manner that allows servicing the largest number of passengers given an aircraft's capacity limitations (Battese & Coelli, 1992). Achieving 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 Asian airline industry, where q depicts output, and K and NK depict capital (aircrafts) and non-capital inputs (labor), 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 using input combinations denoted by the co-ordinate *C* is 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 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.

Even if an airline company satisfies the condition for technical efficiency as depicted by co-ordinate *B*, it may also experience low or declining productivity growth. During economic recessions passenger demand declines such that the number of passengers per flight declines in the near term contributing to declining load factors. Airline companies may be able to mitigate productivity losses by reducing flight frequency and laying-off
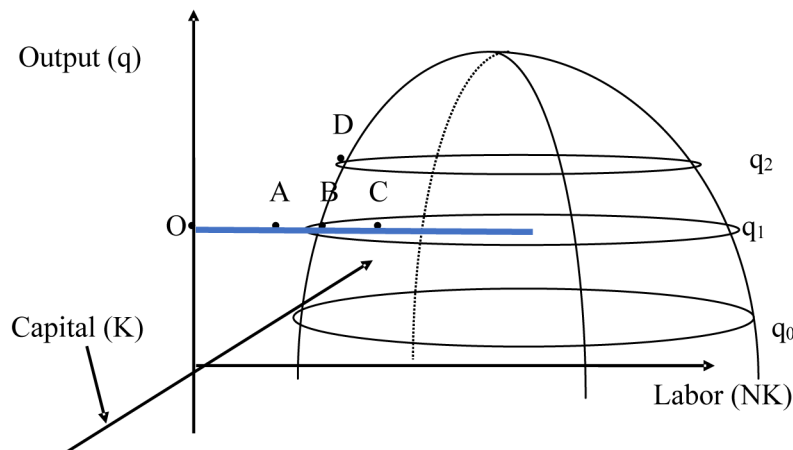

Figure 1. The ellipses depicted by q_0, q_1 and q_2 represent isoquants for their respective output levels.

crews in the short-term. However, in the short-term these companies still maintain their fleet size and thus sustain high fixed cost without the benefit of offsetting revenue due to the erosion of passenger demand. It isn't until companies are able to meet the definition of long term by eliminating excess capital, such as idle aircrafts that airline carriers are positioned to offset declining revenue associated with an economic contraction. Nonetheless, in the near term even if airline companies exhibit effective managerial skills by attaining technical efficiency, during a recession they can still experience cost enhancement due to productivity declines.

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_1, as measured by the number of passengers transported, remains the same for each of these two coordinates. However, the hypothetical Asian 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 company's 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 physically distancing. Hence, within this theoretical framework air transport operations become more costly when an economic downturn is induced by a pandemic.

Even though physical distancing constrains airline companies' ability to attain high productivity levels, other productivity activities such as forming alliances, and outsourcing maintenance work can help offset the negative productivity effects of the pandemic. Forming an alliance with other carriers can enhance airline companies' performance by facilitating productivity gains associate with 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, though is likely limited during a pandemic due to safety requirement 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 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, highlight potential risk factors that can limit the productivity effectiveness of outsourcing (Quinlan et al., 2013). That research observes subpar performance can arise from poor information and communications flow. 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 could also add expenses to the purchased services, making its net impact on the total factor productivity (TFP) is unclear. Thus, *a priori*, outsourcing's influence on productivity and technical efficiency is not obvious and requires further empirical investigation for airline companies based in the Asia Pacific region.

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[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.

In sum using the theoretical framework of airline performance under capacity constraint, this study poses three testable hypotheses on the potential influence of the 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; and (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 a period 2003 to 2011 to measure the technical efficiency and productivity of airlines[16]. 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-Mundi[17]. 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). Inputs and outputs 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 testing whether forming alliances and outsourcing work actually contributes to airline companies attaining high the levels of technical efficiency and productivity. Information on passenger load factors is especially important as it allows simulating the performance influence of low load factors occurring during the COVID-19 pandemic.

Descriptive statistics derived using this airline company information are presented in Table 1. Mean findings are grouped by sample observations covering pre-recession, recession and post-recession 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 percent, 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 has increased continuously and at a relatively healthy rate, passenger load factors only increased 5 percent for the entire observation sample, and mean findings on outsourcing actually show 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 Asia Pacific 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 workforce.

Empirical approach
To investigate the impacts of the 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 *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

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[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

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

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

programming. This model takes the basic form specified in Equation (1) when calculating technical efficiency scores for each airline company.

$$Max_{\phi,\lambda} \; \phi \qquad (1)$$

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 *ith* firm, holding input quantities constant and, λ is a I x1 vector of weights.

This constrained maximization problem depicted by Equation (1) and the succeeding inequalities implies that *ith* 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 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 programing 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 $i = 1,...,K$ firms. The number of periods observed are $t = 1,... .,T$ periods and each firm uses N inputs, $x \epsilon R_+^N$ to produces M outputs, $y \epsilon R_+^M$. The production possibility set which defines the technology applied in this case is given by:

$P = \{(x,y)|\ x$ 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:

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

The MPI index is computed by solving 6 linear programming problems as indicated below.

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

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.

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:

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

Subject to

$$\sum_{k \epsilon R_J} \lambda^k y_m^{k,s} \geq \phi_c^{k',s} y_m^{k',s}, \qquad m = 1,...., M$$

$$\sum_{k \epsilon R_J} \lambda^k x_n^{k,s} \leq x_n^{k',s}, \qquad n = 1,...., N$$

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

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:

$$TE_{it}^* = \phi_{1it} + \phi_2 x_{2it} + \phi_3 x_{3it} + \phi_4 x_{4it} + \phi_5 x_{5it} + \phi_6 x_{6it} + \phi_7 x_{7it} + \phi_8 x_{8it} + \phi_9 x_{9it} +$$

$$\phi_{10} x_{10it} + \phi_{11} x_{11it} + \phi_{12} x_{12it} + u_{it};$$

(5)

Where,

$$y_i = y_i^*, \ \ if \ y_i^* > 0 \ \ and$$

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, $N(O,\sigma^2)$. 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 dummy2007/2008(x_{10it}) the interaction between the logarithm of passenger load factor and the pre-recession dummy2003/2006 (x_{11it}), and the interaction between outsourcing intensity and the recession dummy2007/2008(x_{12it}). Special attention is given to the parameter estimates on passenger load factor since this airline characteristic 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 presents, as it fully utilizes past information on airline performance to form the moment conditions. The specification of airlines' productivity model based on difference GMM estimators is as follows:

$$MPI_{it}^* = \phi_1 MPI_{it-1}^* + \phi_2 y_{2it} + \phi_3 y_{3it} + \phi_4 y_{4it} + \phi_5 y_{5it} + \phi_6 y_{6it} + \phi_7 y_{7it} + \phi_8 y_{8it} + \phi_9 y_{9it} +$$

$$\phi_{10} y_{10it} + \phi_{11} y_{11it} + \phi_{12} y_{12it} + v_{it}$$

(6)

The model of 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.

The choice of explanatory variables for the technical efficiency and productivity equations flows directly from this study's modeling of airline performance under capacity constraints. These determinants are grouped into the two following categories: (1) determinants whose usage influences air company performance (belongs to an alliance, load factor level and out-sources part of the company's operation). The other category includes determinants that identify the size of the company's operations and the annual macroeconomic conditions under which the company operates (available seat kilometers, revenue passenger miles and recession dummies)[20]. The inclusion of the lagged Malmquist productivity index in Equation (6) allows the use of past performance information to form the moment condition.

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[20] While 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. Even though 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.

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 that recession 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. Apparently, 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 efficient 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 in section IV is used to derive this performance measure. The means of these productivity scores differ by 13.5 percent 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 percent above levels achieved prior to the 2008–2007 downturn. Findings indicating differing technical efficiency and productivity patterns is 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 respectively present estimations of the performance equations as specified by Equation (5) and Equation (6). 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 estimations 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 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 shows the effect 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. Productivity findings reported in Table 4 generally mirror the technical efficiency finding with one notable difference. The great recession dummy is negative and statistically significant suggesting productivity declined during the great recession. This finding further supports the notion of a disconnect between productivity and technical efficiency during an economic downturn. 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.

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	
Psuedo 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.

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 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

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.

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 comparing productivity and technical efficiency for different load factor rates 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 0.1828 for the pre-recession sample. This reduction accounts for a predicted 23.09 percent decline in technical efficiency at the mean (0.1828/0.792). This reduction closely resembles the simulated COVID induced technical efficiency reduction of 23.93 percent (0.2019/0.844) for the great recession sample observation. Hence, these simulations presented in column (2) predict a negligible negative influence of COVID-19 induced capacity changes on technical efficiency during an economic crisis. We interpret this finding to suggest that passenger airline companies operating out of the Asia Pacific use managerial techniques that allow them to continue operating without notable loss of efficiency even during periods when demand for

Table 5. Simulated changes in performance scores[21].

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	-23.09%	-33.47%
2007–2008	-23.93%	-63.35%
2009–2011	-10.05%	-29.31%

[21] Source for November 2021 load factor: (IATA, 2022 Passenger Market Analysis).

their service declines. Further, simulated findings for the post-recession sample suggest a nontrivial improvement in the technical efficiency attributable to operating with simulated low load factors as this differential that technical efficiency differential (10.05) is less than half the differential projected for the pre-recession sample.

Findings presented in column (3) shows the predicted COVID-19 influence on productivity attributable to declining load factors. These findings reveal a more consistent COVID effect on productivity during non-recessionary periods compared to the findings for technical efficiency. For instance, the simulated non-recessionary decline in productivity is 33.47 percent (0.3625/1.083) and 29.31 (0.3467/1.183) percent for the pre and post recessionary periods, respectively. Further, COVID-19 level load factors have a much harsher 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 simulate productivity declines 63.35 percent for the recession sample compared to the 33.47 percent decline for the pre-recession sample when imposing the February 2019–November 2021 load factor differential. In comparison, the pre-recession technical efficiency differential is only 0.8 percentage points smaller than the recession differential.

In sum, these COVID-19 simulations reveal two important findings. (1) Low load factors associated with the COVID-19 crisis exacerbates the disconnect between technical efficiency and productivity during a recession. (2) Regardless of economic conditions social distancing that requires airline companies in Asia Pacific to fly with low load-factors weakens the productivity performance of airline companies, without weakening managers' ability to operate technically efficiently.

While these simulations examine scenarios using the actual low load factors for Asia Pacific passenger airline companies for November 2021 during the onset of the Omicron pandemic, China's economy, which was the first economy to be hit by the epidemic, was also one of the initial countries to contain the initial pandemic, and to resume work and production (Sun *et al.*, 2021) prior to Omicron. In conjunction with this early recovery by July 2020 it is reported that flight capacity in China increased to levels reaching close to 80 percent of their 2019 levels by Czerny *et al.* (2020)[22]. China's gains domestically provide some insight on future airline performance in this region. Indeed, prior to the spread of the Omicron variant load factors in Asia Pacific reached 65.7 percent by July 2020. Presumably, if passenger airline companies in this region were able to reach this load factor rate prior to the onset of the Omicron variant, it is conceivable that they would be able to attain this rate following the decline in its global health effect. Hence, we use this July 2020 load factor value to forecast potential performance outcomes post COVID-19.

Performance simulations using the approach to derive findings in Table 5 are used to compute different performance scenarios using the 65.7 percent load factor value. These findings are presented in Table 6 and suggest marked performance improvements associated with attaining load factors reached prior to the Omicron surge. Now technical efficiency differentials are less than 20 percent for all three sample populations, and the productivity differential for the great recession sample falls from 63.45 when using the Omicron load factor to 40.66 when using the July 2020 pre-Omicron load factor. These simulated improvements reveal the performance enhancing potential of Asia Pacific Airline companies who are able to regain their pre-pandemic load factor levels.

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[22] Even though the domestic market in Mainland China enjoyed a quick recovery to about 80% of the pre COVID-19 level by July 2020, the recovery of international services has been much slower due to the bilateral route and flight frequency/capacity control and strict requirement for health check and quarantine (Czerny *et al.*, 2020). For instance, Sun *et al.* (2021) report that at the end of March 2020, China initiated the continuation of its Five Ones Flight restriction policy, which stipulates that each country can only have one airline to and from China via one route and one flight per week.

Table 6. Simulated Changes in Performance Scores for Asia Pacific Airline Companies When Comparing February 2019 pre-pandemic and February 2020 pandemic load factor levels (0.78 and 0.678 rates for 2019 and 2020, respectively).

Observation Sample	Change in Technical Efficiency Using COVID-19 Load Factor Levels	Change in Productivity (MPI) Using COVID-19 Load Factor Levels
2003–2006	-14.82%	-21.48%
2007–2008	-15.35%	-40.66%
2009–2011	-6.45%	-18.81%

Concluding remarks

The current pandemic creates a challenge for business and industry operating successfully. This challenge is especially acute in industries whose business is characterized as serving 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 emphasizing physical distancing, airline companies struggle to operate a profitable business. These challenges faced by airline companies not only influence 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 connective by air transport is more evident than the Asia Pacific 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 reveal significant declines in passenger service, which was nearly exclusively limited to the Asia Pacific region.

This study contributes to our understanding of health-related disruption of 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, health-related disruptions may exacerbate this distortion of performance measures due to tighter capacity constrains attributable to flying with low passenger load factors. Simulations using estimation results on technical efficiency and productivity support these hypotheses. The simulations using actual load factor values before the global enactment of COVID-19 mandates (February 2019 compared to load factor value during the beginning of the Omicron surge (November 2021) suggest a 23.09 percent decline in the average technical efficiency score prior to the great recession, which did not change appreciably during the great recession. In contrast, productivity simulations indicate a 34.47 percent decline prior to the great recession, which increased dramatically to 66.79 percent during the great recession. Simulated efficiency and productivity declines were smaller for the post-recession sample, however, these performance differences remained large especially for productivity. The differing COVID-19 effects on technical efficiency and productivity supports this study's hypothesis suggesting capacity constraints create a business environment that contributes to a disconnect between productivity and technical efficiency. We interpret these results as predicting airline companies in this region potentially face significant challenges operating profitably during the current COVID-19 crises. Estimation results also suggest forming alliances and effectively using the local workforce can contribute to cost-savings associated with enhanced 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.

While findings from this study presents new insights on the potential effect of COVID-19 on air companies operation performance, we acknowledge the potential limitations of our analysis. First, the paper was initiated early in 2020 when the crisis just hit the economy. Therefore, we are not able to directly test COVID-19's performance effect because data on individual airline statistics were not readily available. Secondly, as we also mention earlier in this study, modal competition between airlines and other modes of transportation, particularly the highspeed rail is acute in many Asian countries and in China in particular (Borsati & Albalate, 2020; Zhang et al., 2019). With greater capacity, highspeed rails could better cope with requirement for physical distancing

than airlines. Accounting for modal substitutability could further explain challenges air transport companies in this region face when attempting to maintain high levels of productivity. Furthermore, physical meetings are being replaced more frequently with either fully virtual or hybrid meetings. This communications model lessens businesses reliance on international travel, creating additional challenges for air transport companies.

In the immediate time frame, airline companies could consider reducing the number of flights offered between cities and consider providing more frequent cargo transport service as a strategy to generate greater revenue. Government intervention can also play a role to assist air transport companies navigating the challenges associated with COVID-19 health risks. For instance, China has eased domestic travel restrictions in coordination with intensive monitoring of infections, increased vaccination rates and the imposition of travel bubbles. Such easing of travel restriction, though has not been extended to international travel to and from China, which allows for a comparison of domestic and international air transport performance. Indeed, evidence of an effective domestic policy is reported by the IATA (2020e) revealing international revenue per kilometer growth in December 2020 equaling -85.3% while domestic was a much smaller -42.9% year-on-year. In addition, for the entirety of 2021, global international and domestic load factors for Asia Pacific were 61.6 and 73 percent, respectively. These desperate performance results indicate effective public policy towards airline performance during a the COVID-19 pandemic. Further, airline companies 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.

Finally, as the pandemic has lasted for a couple of years, more company performance and operations information for the COVID-19 sample will become available for public use. Indeed, data limitation, as highlighted by Sun *et al.* (2021) and Andreana *et al.* (2021) remains the largest hurdle to research the impact of COVID-19 on the aviation industry.

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://www1.nseindia.com/corporates/shldInformation/shldinfo_annualReports.html?radio_btn=company&param=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/doLLG5ufYkCy-EPjF1tpgyw/file/annual-reports/2019-Annual-Report-ASX.pdf

o. Singapore Airlines https://www.singaporeair.com/saar5/pdf/Investor-Relations/Annual-Report/annualre-port1920.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.xslx

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)

References

Abdullah MA, Satar NM: **The impact of outsourcing on airlines' performance: empirical evidence from Asia and Countries in the Pacific.** In: Peoples, J. and Fu X. (eds). *Advances in Airline Economics: Airline Economics in Asia.* Emerald Publishing, 2019; **7**: 195–220.
Publisher Full Text

Abate M: **Economic effects of air transport market liberalization in Africa.** *Transp Res Part A Policy Pract.* 2016; **92**: 326–337.
Publisher Full Text

Albertson D: **Outsourcing shows limited impact for strategic HR.** Employee Benefit News, 2000; **14**(10): 70.

Andreana G, Gualini A, Martini G, *et al.*: **The disruptive impact of COVID-19 on air transportation: An ITS econometric analysis.** *Research in Transportation Economics.* 2021; **90**: 101042.
Publisher Full Text

Battese GE, Coelli TJ: **Frontier production functions, technical efficiency and panel data: with application to paddy farmers in India.** *J Product Anal.* 1992; **3**(1–2): 153–169.
Publisher Full Text

Borsati M, Albalate D: **On the modal shift from motorway to high-speed rail: evidence from Italy.** *Transp Res Part A.* 2020; **137**: 145–164.
Publisher Full Text

Charnes A, Cooper WW, Rhodes E: **Measuring the efficiency of decision making units.** *Eur J Oper Res.* 1978; **2**(6): 429–444.
Publisher Full Text

Coelli TJ, Rao DSP, O'Donnel CJ, *et al.*: **An Introduction to Efficiency and Productivity Analysis**. New York: Springer Science & Business Media, 2005.
Publisher Full Text

Czerny A, Fu X, Lei Z, *et al.*: **Post Pandemic Aviation Market Recovery: Focus on Changes in China**. Institute of Transport and Logistics Studies, The University of Sydney, working paper ITLS-WP-20-20. 2020.
Reference Source

Fare R, Grosskopf S, Norris M, *et al.*: **Productivity growth, technical progress, and efficiency change in industrialized countries.** *Am Econ Rev.* 1994; **84**(1): 66–83.
Reference Source

Farrell MJ: **The measurement of productive efficiency.** *J R Stat Soc Ser A.* 1957; **120**(3): 253–290.
Publisher Full Text

Fethi MD, Jackson PM, Weyman-Jones TG: **Measuring the efficiency of European airlines: an application of DEA and Tobit analysis**. Efficiency and Productivity Research Unit, University of Leicester, 2006.

Gillen D, Harris R, Oum TH: **Measuring the Economic Effects of Bilateral Liberalization Air Transport.** *Transport Res E.* 2002; **38**(3–4): 155–174.
Publisher Full Text

Gillen D, Lall A: **Developing measures of airport productivity and performance: an application of data envelopment analysis.** *Transport Res E-Log.* 1997; **33**(4): 261–273.
Publisher Full Text

Gayle P, Le HB: **Airline Alliances and Their Effects on Costs.** *Kansas State University working paper series.* 2014.
Reference Source

Heathfield DF: **Production Functions**. London: Macmillan, 1971.
Publisher Full Text

Huderek-Glapska S: **Economic benefits of market liberalization: evidence from air transport in Poland.** *J Int Stud.* 2010; **3**(1): 49–58.
Publisher Full Text

IATA: **IATA's What we can learn from past pandemic episodes**. 2020c.
Reference Source

ICAO: **Air transport liberalization and the economic development of the countries.** *International Civil Aviation Organization Working Paper A39–WP/189.* 2016.
Reference Source

Inglada V, Rey B, Rodriguez-Alvarez A, *et al.*: **Liberalisation and efficiency in international air transport.** *Transportation Research Part A 40.* 2006; **40**(2): 95–105.
Publisher Full Text

McMullen S, Du Y: **Determinants of successful code-sharing: a case study on Continental and American West airlines alliances – a discrete longitudinal analysis**. In: Peoples, J. (ed). *Advances in Airline Economics vol. 3: Pricing Behaviour and Non-Price Characteristics in the Airline Industry*. United Kingdom: Emerald Group Publishing Ltd, 2012.
Publisher Full Text

Peoples J, Abdullah M, Satar N: **Covid-19 airline data.** [Data set], *Zenodo.* 2020.
http://www.doi.org/10.5281/zenodo.4015344

Quinlan M, Hampson I, Gregson S: **Outsourcing and offshoring aircraft maintenance in the US: implications for safety.** *Safety Science.* 2013; **57**: 283–292.
Publisher Full Text

Salvatore D: **Principles of Microeconomics**. New York: Oxford University Press, 2009.
Reference Source

Savage I: **Trends in transportation employee injuries since economic deregulation.** In: James Peoples and Wayne Talley (eds). *Research in Economics Volume 10: Transportation Labor Issues and Regulatory Reform.* Volume. Elsevier Publishing, 2004; 11–33.
Publisher Full Text

Sun X, Wandelt S, Zhang C, *et al.*: **COVID-19 pandemic and air transportation: Successfully navigating the paper hurricane.** *J Air Transp Manag.* 2021; **94**(2): 102062.
PubMed Abstract | **Publisher Full Text** | **Free Full Text**

Winston C: **US industry adjustment to economic deregulation.** *J Econ Perspect.* 1998; **12**(3): 89–110.
Publisher Full Text

Xia W, Wang K, Zhang A: **Air transport and high-speed rail interactions in China: review on impacts of low-cost carriers, rail speed, and modal integration**. In: Fu X., & Peoples, J. (eds). *Advances in Airline Economics Volume 7: Airline Economics in Asia.* Emerald Publishing, 2019; 103–122.
Publisher Full Text

Yu C: **Airline productivity and efficiency: concept, measurement, and applications.** In: Peoples Bitzan, J.D., Peoples, J., and Wilson, W.W. (eds). *Airline Efficiency (Advances in Airlines Economics* . Volume 5). Emerald Group Publishing Limited, 2016; 11–53.
Publisher Full Text

Zhang A, Wan Y, Yang H: **Impacts of high-speed rail on airlines, airports and regional economies: A survey of recent research.** *Transp Policy.* 2019; **81**: A1–A19.
Publisher Full Text

Open Peer Review

Current Peer Review Status: ✔ ❓ ✘

Version 2

Reviewer Report 03 July 2023

✘
Lázaro Florido-Benítez 🆔

Department of Economics and Business Administration, University of Málaga, Malaga, Spain

Dear authors, for me is a pleasure to review this study, but I recommend you improve some point of views.

1. The abstract section must tackle the main objectives, methods, findings, and the new contribution of this paper to scientific community.

2. The entire paper have to include updated studies, we are researchers and we are in 2023. Readers need to know the last information in this topic, please. Studies carry out in 2004, 1998, 1992, 1971, 2012... are very old to face a problem that took in 2020 like COVID-19.

3. Authors need to date the year in some reports like: survey findings from the International Air Transport Association (IATA) reveals--- It is plagiarism.

4. Introduction: there is a lack of motivation for this work, what is the research problem and the main gaps which authors have decided to work in this study, what is the goal and objective of this research, what is the novelty and contribution of this manuscript.

5. The entire paper need to be supported by updated studies. For instance, there is no discussion in introduction section. Furthermore, there is no literature review in this paper, why? It is so important for this type of study.

6. A lot of information needs to be removed in the entire paper because it is not relevant with the narrative of the topic and scope. For instance: Hence, operations during and following the COVID-19 recovery in air passenger transport face competitive pressure from passenger rail. Asia Pacific airline companies challenge competing for passengers during a pandemic is heightened in part because rail carriers can provide frequent service with larger number of cars per train, which allows them to provide physical distancing while transporting significant numbers of passengers. Whereas air transport companies are much more limited in the use of large aircraft carriers to transport 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 also face increasing market pressure from the enhanced 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 risk associated with passenger transport9. Thus, analysis on the performance effect of COVID-19 needs to include examination of air transport operations that minimizes passenger contact and considers the potential for long-term erosion of passenger demand for this type of transport service.

7. This study seems a report from a private organisation. There are a lot of sentences and paragraphs written only by authors, but not supported by other expert authors in this topic.

8. This manuscript add nothing new to scientific community.

9. Authors need to explain why you have done this study in Asia Pacific and not in US. Authors did not face the number of airlines in bankruptcy in this region, and how this affected to passengers and airports. Moreover, authors need to show real examples of airlines and airports which were considerably affected by the pandemic crisis.

10. Authors must notably improve the methodology section. Why authors selected the period 2003-2011. The COVID-19 took in 2020 I do not understand it.

11. Authors must show other updated studies and authors which used this method to support your study, so readers can compare your own results with other updated studies.

12. Authors wrote it: "his study utilises information from a total of 17 individual airline companies based in Asia and the Pacific..." We want to know which airlines were and data in a Table. I did not airlines and Table in this "study". And why authors selected these 17 airlines. Are these LCCs or Legacy carriers? It is very important to analyse and measure variables.

13. Authors cannot tackle COVID-19 impact and effect with data from 2011. In addition, there are a lot of authors that have worked with DEA methods in air transport.Why authors did not include authors to support your methodology and study?

14. The conclusion section did not tackle the main objectives and research questions because authors did not develop these. Indeed, the conclusion section add nothing new that we do not already know.

15. Authors wrote this sentence in conclusion section: The theoretical model used in this study suggests the following two key hypotheses regarding firm performance during economic crises. Please, if authors did not face research questions and hypotheses in this manuscript.

16. Authors need to consider and enhance the entire paper in objectives, research questions, updated studies, methods, findings, and conclusion terms. Besides, authors need to implement theoretical and managerial implications, limitations and future studies subsections. I am confident that authors a lot to say in these subsections.

17. I recommend authors these authors:

Florido-Benítez, L. (2021), "The effects of COVID-19 on Andalusian tourism and aviation sector", *Tourism Review*, Vol. 76 No. 4, pp. 829-857. https://doi.org/10.1108/TR-12-2020-0574[1].

Florido-Benítez, L. The Role of the Top 50 US Cargo Airports and 25 Air Cargo Airlines in the Logistics of E-Commerce Companies. *Logistics* **2023**, *7*, 8. https://doi.org/10.3390/logistics7010008[2].

Amankwah-Amoah, J. (2021). COVID-19 pandemic and innovation activities in the global airline industry: A review. *Environment International*, *156*, 106719[3].

Rita, P., Moro, S., & Cavalcanti, G. (2022). The impact of COVID-19 on tourism: Analysis of online reviews in the airlines sector. *Journal of Air Transport Management*, *104*, 102277[4].

Abdi, Y., Li, X., & Càmara-Turull, X. (2023). Firm value in the airline industry: perspectives on the impact of sustainability and Covid-19. *Humanities and Social Sciences Communications*, *10*(1), 1-24[5].

Yu, M. M., & See, K. F. (2023). Evaluating the efficiency of global airlines: A new weighted SBM-NDEA approach with non-uniform abatement factor. *Research in Transportation Business & Management*, *46*, 100860[6].

References
1. Florido-Benítez L: The effects of COVID-19 on Andalusian tourism and aviation sector. *Tourism Review*. 2021; **76** (4): 829-857 Publisher Full Text
2. Florido-Benítez L: The Role of the Top 50 US Cargo Airports and 25 Air Cargo Airlines in the Logistics of E-Commerce Companies. *Logistics*. 2023; **7** (1). Publisher Full Text
3. Amankwah-Amoah J: COVID-19 pandemic and innovation activities in the global airline industry: A review.*Environ Int*. 2021; **156**: 106719 PubMed Abstract | Publisher Full Text
4. Rita P, Moro S, Cavalcanti G: The impact of COVID-19 on tourism: Analysis of online reviews in the airlines sector. *Journal of Air Transport Management*. 2022; **104**. Publisher Full Text
5. Abdi Y, Li X, Càmara-Turull X: Firm value in the airline industry: perspectives on the impact of sustainability and Covid-19.*Humanit Soc Sci Commun*. 2023; **10** (1): 294 PubMed Abstract | Publisher Full Text
6. Yu M, See K: Evaluating the efficiency of global airlines: A new weighted SBM-NDEA approach with non-uniform abatement factor. *Research in Transportation Business & Management*. 2023; **46**. Publisher Full Text

Is the work clearly and accurately presented and does it cite the current literature?
No

Is the study design appropriate and is the work technically sound?
No

Are sufficient details of methods and analysis provided to allow replication by others?
No

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

No

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

No

Are the conclusions drawn adequately supported by the results?

No

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

No

Does the piece present solutions to actual real world challenges?

No

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

No

Could any solutions being offered be effectively implemented in practice?

Not applicable

Competing Interests: No competing interests were disclosed.

Reviewer Expertise: Tourism, air transport, and marketing.

I confirm that I have read this submission and believe that I have an appropriate level of expertise to state that I do not consider it to be of an acceptable scientific standard, for reasons outlined above.

Reviewer Report 14 April 2023

https://doi.org/10.21956/emeraldopenres.15666.r28732

Anming Zhang

Sauder School of Business, University of British Columbia, Vancouver, BC, Canada

I approve the revised version with no further comments.

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

Not applicable

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

Not applicable

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

Not applicable

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

Not applicable

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

Not applicable

Are the conclusions drawn adequately supported by the results?

Not applicable

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

Not applicable

Does the piece present solutions to actual real world challenges?

Not applicable

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

Not applicable

Could any solutions being offered be effectively implemented in practice?

Not applicable

Competing Interests: No competing interests were disclosed.

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.

Version 1

Reviewer Report 26 April 2021

https://doi.org/10.21956/emeraldopenres.14997.r27445

? **Kevin E. Henrickson**

Gonzaga University, Spokane, WA, United States

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

https://doi.org/10.21956/emeraldopenres.14997.r27212

?

Anming Zhang
Sauder School of Business, University of British Columbia, Vancouver, BC, Canada
Yahua Zhang
University of Southern Queensland, Toowoomba, Queensland, Australia

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, 2018[1]). 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[2]). For instance, a recent study by Czerny *et al.* (2020[3]) 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.*, 2019[4]) or motorway driving (e.g. Borsati and Albalate, 2020[5]). 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 <u>productivity, Information</u> 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 <u>2008</u>–2008 downturn." (page 11) – should be 2007.

○ "Findings presented in Table 2 suggest available seat kilometers and load-factors contribute to enhanced technical <u>estimated</u> 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 <u>characteristics</u> captures the influence of social distancing on airline performance." (page 10) – should be made singular.

References

1. Zhang A, Zhang Y: Airline economics and finance. In: A. Graham and N. Halpern (eds.), The Routledge Companion to Air Transport Management. *Routledge*. 2018; **1st Edition**: 171-188 Reference Source

2. Sun X, Wandelt S, Zhang A: How did COVID-19 impact air transportation? A first peek through the lens of complex networks. *J Air Transp Manag*. 2020; **89**: 101928 PubMed Abstract | Publisher Full Text

3. Czery A, Fu X, Lei Z, Oum T: Post pandemic aviation market recovery: Experience and lessons from China. *Unpublished manuscript*. 2020.

4. Zhang A, Wan Y, Yang H: Impacts of high-speed rail on airlines, airports and regional economies: A survey of recent research. *Transport Policy*. 2019; **81**: A1-A19 Publisher Full Text

5. Borsati M, Albalate D: On the modal shift from motorway to high-speed rail: evidence from Italy. *Transportation Research Part A: Policy and Practice*. 2020; **137**: 145-164 Publisher Full Text

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 prior*, 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 Albalate, 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.