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# The airline transport regulation and development of public health crisis in megacities of China

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ABSTRACT

*Background:* The Civil Aviation Administration of China (CAAC) declares the airline transport regulation in January 2020 to help retard the spread of the novel coronavirus disease in China. This study is to examine the effect of airline transport regulation on confirmed cases of the novel coronavirus disease in megacities in China.
*Methods:* This study combines the multi-source data from the health data platform DXY, the airline data platform Airsavvi, the China Economic Internet Statistical Database and the China Railway website. The megacities whose airports have a passenger throughput of over 30 million per year (11 megacities: Wuhan, Beijing, Shanghai, Guangzhou, Chengdu, Shenzhen, Kunming, Xi'an, Chongqing, Hangzhou, Nanjing) are included in the analysis. The regression analysis is conducted in this study.
*Results:* The curvilinear relationship between the limitation on air traffic and confirmed cases of the novel coronavirus disease is identified (coefficient of the linear term = −4.650, $p$-value < 0.01; coefficient of the quadratic term = 4.089, $p$-value < 0.01).
*Conclusions:* This study confirms the effectiveness of airline transport regulation in suppressing the development of this pandemic. The limitation on air traffic is found to negatively affect the confirmed cases in China's megacities. However, such effect marginally recedes as the strength of limitation intensifies. It suggests that comprehensive policy intervention is in need and air traffic can be one of important determinants that affect the epidemic development.

## 1. Introduction

In order to retard the fast spread of novel coronavirus disease in China, the Civil Aviation Administration of China (CAAC) made prompt responses to the epidemic emergency and announced the implementation of temporary regulation since Jan. 23rd, 2020 (CAAC, 2020a). On the same day, the CAAC reminded all airline companies to keep close watch on the epidemic development in Hubei, and urged them to gradually reduce the number of flights arriving in or leaving airports in Hubei province (CAAC, 2020b). In the flowing day, the CAAC declared the escalation of prevention measure and further urged airline companies to reduce the number of flights nationwide (CAAC, 2020c). Currently, the transport administration proposes higher demand for entry and exit screening

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**Fig. 1.** The study area in China.

measures at the transport station, for the capability of trained crews to identify suspected signs of getting infected, and for the knowledge of ground crews to quarantine individual passengers on an aircraft.

Since decades before, the global transport network continues to expand in reach, speed of travel, and volume of passengers carried. The pathogens and their vectors can now travel in a farther and faster way, leading to the vector-borne pathogen importation (Tatem et al., 2006). The most typical example is the severe acute respiratory syndrome (SARS), with small fatalities (Skowronski et al., 2005), but great speed and extent of proliferation. This variation suggests that the globalized economic activity and an ever-expanding traffic network can potentially spread infectious diseases (Tatem et al., 2006). The spread of infectious diseases has become much more facilitated by air traffic. In the past, the Ebola was brought to the US and the UK through undiagnosed infected airline passengers aboard (Bogoch et al., 2015; Gulland, 2014). A delayed influenza season was identified to be accompanied with the airline restriction subsequent to the 9–11 attack (Brownstein et al., 2006). Insects-borne infectious diseases, such as West Nile virus and malaria, are substantially facilitated by intercontinental flights for infected mosquitos carried by aircrafts (Brown et al., 2012; Gratz, Steff en, & Cocksedge, 2012). The spread of Zika virus to the American continent is found coincided with the upsurge of air travel to Brazil from countries suffering from epidemic in 2013 (Lowe et al., 2018). The outbreak of H1N1 that spreads along international airlines in 2009 (Khan et al., 2009), also highlighted the important role of human transportation in the global spread of infectious diseases (Nakata & Röst, 2015). The transmission can occur not only aboard airplanes, but also at the destination and airports (Browne et al., 2016), which can amplify influenza propagation (Browne et al., 2016). A systematic review shows that the air transport speeds up the importation of community-acquired influenza to new areas (Català et al., 2012; Khan et al., 2009; Kim et al., 2010) and that in-flight transmission has occurred on multiple occasions (Baker et al., 2010;Foxwell et al., 2011).

Some studies try to explain why mass transport systems are involved in amplifying and accelerating the spread of influenza and coronaviruses globally. The high crowd densities and enclosed spaces in public transport system provide prime conditions for person-to-person transmission via inhalation of virus in aerosols and droplets (Gupta et al., 2012). Between 1969 and 1999, 87 suspected cases of airport malaria, which is acquired through the bite of infected tropical Anopheline mosquitos, were recorded in the proximity of Paris, Brussels and London airports (Giacomini and Brumpt, 1989;Isaacson, 1989; Danis et al., 1996; Giacomini, 1998; Gratz et al., 2000), although the geographical history of these infected individuals showed that they had never been exposed to the natural habitat of tropical Anopheline mosquito (Isaacson, 1989). In addition to the high frequency of social contacts, the increase in global travel is another key determinant of epidemics. Aircrafts are believed to be directly responsible for the rapid expansion in the range of many plants and animals via inadvertent transport (Lounibos, 2002; Perrings et al., 2005).

Prior simulation studies also suggest that the early enhancement of transport restriction can be essential for controlling the spread of infectious disease (Nagatani, 2019; Wan and Cui, 2007). In the 2009 H1N1 epidemic crisis, simulation research displays an additional decline in travel flows above the existing level would provide an additional benefit in slowing down the propagation of the H1N1 virus from the American continent to the rest of the world (Bajardi et al., 2011). The restricted migration of population can mitigate the potential risk of infection in patchy environments, especially in the highly exposed migration process such as vehicle and transport stations (Denphedtnong et al., 2013). The risk of infectious disease transmission through air traffic is not just owed to the post-flight facilitation of population mobility among megacities, but also to the inflight facilitation of virus transmission in the cabin of a single-aisle aircraft (Hertzberg et al., 2018). Thus, a growing number of studies call for the enhancement of traffic control as the policy measure of interrupting novel coronavirus disease transmission (Lau et al., 2020; Yen et al., 2020).

However, the effectiveness of the airline transport regulation in containing the coronavirus disease transmission has not been empirically examined, particularly in megacities of China where the substantial population movement is documented after the lunar new year normally (Chen et al., 2020). This study tries to advance the existing literature by providing a preliminary empirical assessment of temporary airline transport regulation in affecting the development of novel coronavirus disease.

## 2. Materials and method

### 2.1. Data source

This study combines multisource data from the third party health data platform DXY (the real-time data can be accessed on https://ncov.dxy.cn/ncovh5/view/pneumonia) and from the airline data platform Airsavvi (a brief website version of air traffic data during the pandemic can be accessed via http://covid.airsavvi.com/). The data of Chinese megacities whose airports have a passenger throughput of over 30 million a year are analyzed in this study. As a result, the sample includes Wuhan, Beijing, Shanghai (both the Pudong and Hongqiao Airports are included), Guangzhou, Chengdu, Shenzhen, Kunming, Xi'an, Chongqing, Hangzhou, and Nanjing (please see Fig. 1). The time span of the data is from Jan. 23rd, 2020 to Mar. 13th, 2020. The two separate datasets are matched to each other, and form an unbalanced panel dataset given that the available data of different cities may have slightly different time spans.

### 2.2. Variables

#### 2.2.1. Independent variable

The independent variable is "limitation on air traffic" (data at a daily frequency, Jan. 23rd, 2020–Mar. 13th, 2020), which is defined as follows

$$Limitation\ on\ air\ traffic_{\ Day\ t} = 1 - \frac{Number\ of\ flights_{\ Day\ t}}{Number\ of\ flights_{\ the\ reference\ date\ of\ Day\ t}} \tag{1}$$

In the above equation, the reference week is set to be "Jan. 6th, 2020 (Monday) - Jan. 12th, 2020 (Sunday)", considering that this time span is before the official announcement of airline transport regulation.

For example, the limitation on air traffic on Feb. 3rd, 2020 (Monday) is calculated as "1 – dividing the number of flights on Feb. 3rd, 2020 (Monday) by that on Jan. 6th, 2020 (Monday)". Similarly, the limitation on air traffic on Feb. 4th, 2020 (Tuesday) is calculated as "1 – dividing the number of flights on Feb. 4th, 2020 (Tuesday) by that on Jan. 7th, 2020 (Tuesday)".

As mentioned above, the data of air traffic can be accessed on the airline data platform Airsavvi (a brief website version of air traffic data during the pandemic can be accessed via http://covid.airsavvi.com/).

#### 2.2.2. Control variables

Control variables based on annual frequency (that is *bus/tram passenger volume, railway transport capacity, and* GDP growth) are included in the regression analysis for robustness check.

In the past, the road traffic within and between towns and cities is shown to affect the epidemic transmission (Xiao et al., 2011; Xu et al., 2019). Familial cluster of coronavirus disease infection associated with a railway journey is reported (Qiu et al., 2020). Thus, the effects of Bus/tram passenger volume and railway transport capacity are controlled.

*Bus/tram passenger volume (municipal district, 2018, data at an annual frequency).* The data are collected from the China Economic Internet Statistical Database (https://db.cei.cn/). The latest data available are of year 2018. It is expected that the higher passenger volume is associated with more confirmed cases.

*Railway transport capacity (2019, data at an annual frequency).* The data are collected on the official website of China Railway (https://www.12306.cn/index/) in 2019. The variable "railway transport capacity" is yielded according to the procedure below. (1) To organize the operation timetable that is based on the railway transport network of 37 core cities in China (i.e., Hong Kong SAR, four central government administered municipalities, 27 provincial capital cities, five national independent planning cities). (2) To add two points to both two cities if there exists the through-train headed with G/C/D (i.e., high-speed railways/urban rails/multiple units of bullet trains) linking them. Further, to add additional one and a half points to the city if it is the departure/destination station and the through-train is headed with G (i.e., high-speed railways). Moreover, to add additional one point to the city if it is the departure/

**Table 1**
The overview of the confirmed cases of novel coronavirus disease and the limitation on air traffic (Jan. 23rd, 2020–Mar. 13th, 2020).

| | ln [Confirmed cases] | | The limitation on air traffic | |
|---|---|---|---|---|
| | Mean | S.D. | Mean | S.D. |
| Wuhan | 9.671 | 1.466 | 0.982 | 0.023 |
| Beijing | 5.554 | 0.742 | 0.427 | 0.218 |
| Shanghai | 5.377 | 0.798 | 0.368 | 0.199 |
| Guangzhou | 5.361 | 0.940 | 0.373 | 0.191 |
| Chengdu | 4.585 | 0.660 | 0.374 | 0.165 |
| Shenzhen | 5.560 | 0.881 | 0.378 | 0.183 |
| Kunming | 3.561 | 0.742 | 0.430 | 0.194 |
| Xi'an | 4.229 | 0.981 | 0.493 | 0.214 |
| Chongqing | 5.855 | 0.885 | 0.399 | 0.202 |
| Hangzhou | 4.772 | 0.748 | 0.456 | 0.202 |
| Nanjing | 3.981 | 0.929 | 0.456 | 0.218 |
| Overall | 5.320 | 1.787 | 0.467 | 0.252 |

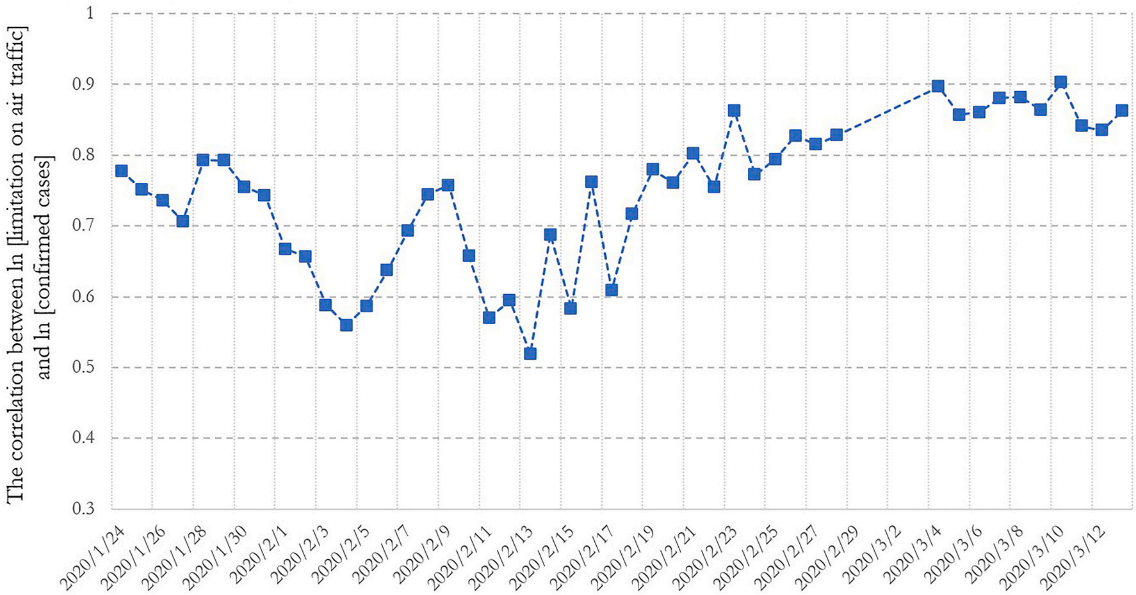


**Fig. 2.** The correlation between ln [limitation on air traffic] and ln [confirmed cases] (both variables are taken the average of the eleven megacities).

destination station and the through-train is headed with C/D (i.e., urban rails/multiple units of bullet trains). (3) To add one point to both two cities if there exists the through-train linking them and headed with Z/K/T (i.e., non-stop express/normal express/special express). Further, to add additional one point to the city if it is the departure/destination station and the through-train is headed with Z/K/T (i.e., non-stop express/normal express/special express). It is expected that the higher railway transport capacity is associated with more confirmed cases.

*GDP growth (in %) (2018, data at an annual frequency).* The data of each megacity is collected from the China Economic Internet Statistical Database (https://db.cei.cn/). The latest data available are of year 2018. As the higher GDP growth implies more active business and population mobility, it is expected that the higher GDP growth is associated with more confirmed cases (Zhang Y, Zhang A, & Wang, 2020).

### *2.3. Statistical analysis*

The regression analysis is performed in this study and is shown as follows.

Ln [Confirmed cases] $_{it} = \beta_0 + \beta_1$ Limitation on air traffic $_{it} + \beta_2$ Limitation on air traffic $^2{}_{it} + \beta_3$ Bus/tram passenger volume $_i + \beta_4$ Railway transport capacity $_i + \beta_5$ GDP growth $_i + \Sigma\, \beta_6$ Unobservable City effect (dummy) $_i + \Sigma\, \beta_7$ Time effect (dummy) $_t + \varepsilon_{it}$

In which, the subscript $i$ indicates the $i$-th city and the subscript $t$ indicates the $t$-th day.

In practice, the city effect and time effect serve as dummy variables (i.e., 0–1 variable). The value of 1 means the observation is corresponding to the specific city or date. For example, for the city of Wuhan, the dummy indicator "Wuhan" would take the value of 1,

**Table 2**
The effect of airline transport regulation on the confirmed cases of novel coronavirus disease.

| | Dependent variable: ln [Confirmed cases] | | | | |
|---|---|---|---|---|---|
| | Estimates | S.E. | | Estimates | S.E. |
| Limitation on air traffic | −4.650 ** | 0.336 | 2020/2/6 | 4.442 ** | 0.176 |
| Limitation on air traffic - square | 4.089 ** | 0.414 | 2020/2/7 | 4.500 ** | 0.175 |
| ln [Bus/tram passenger volume] | 1.819 ** | 0.437 | 2020/2/8 | 4.537 ** | 0.175 |
| ln [Railway transport capacity] | 38.154 ** | 2.365 | 2020/2/9 | 4.550 ** | 0.174 |
| GDP growth (in %) | 1.349 ** | 0.147 | 2020/2/10 | 4.678 ** | 0.176 |
| Intercept | −212.218 ** | 7.681 | 2020/2/11 | 4.736 ** | 0.178 |
| **City effect** | | | 2020/2/12 | 4.768 ** | 0.179 |
| Wuhan | Reference | | 2020/2/13 | 4.822 ** | 0.180 |
| Beijing | −12.436 ** | 0.545 | 2020/2/14 | 4.868 ** | 0.179 |
| Shanghai | −10.384 ** | 0.576 | 2020/2/15 | 4.878 ** | 0.179 |
| Guangzhou | −4.993 ** | 0.269 | 2020/2/16 | 4.910 ** | 0.178 |
| Chengdu | −2.680 ** | 0.241 | 2020/2/17 | 4.904 ** | 0.179 |
| Shenzhen | 2.427 ** | 0.407 | 2020/2/18 | 4.902 ** | 0.180 |
| Kunming | 2.899 ** | 0.146 | 2020/2/19 | 4.933 ** | 0.179 |
| Xi'an | −4.736 ** | 0.162 | 2020/2/20 | 4.934 ** | 0.179 |
| Chongqing | −0.213 ** | 0.319 | 2020/2/21 | 4.949 ** | 0.179 |
| Hangzhou | Omitted for collinearity | | 2020/2/22 | 4.943 ** | 0.179 |
| Nanjing | Omitted for collinearity | | 2020/2/23 | 4.947 ** | 0.178 |
| **Time effect** | Reference | | 2020/2/24 | 4.942 ** | 0.178 |
| 2020/1/23 | | | 2020/2/25 | 4.945 ** | 0.178 |
| 2020/1/24 | 0.530 ** | 0.153 | 2020/2/26 | 4.941 ** | 0.178 |
| 2020/1/25 | 1.074 ** | 0.152 | 2020/2/27 | 4.949 ** | 0.178 |
| 2020/1/26 | 1.422 ** | 0.152 | 2020/2/28 | 4.934 ** | 0.177 |
| 2020/1/27 | 1.560 ** | 0.150 | 2020/3/4 | 4.886 ** | 0.175 |
| 2020/1/28 | 2.058 ** | 0.152 | 2020/3/5 | 4.922 ** | 0.177 |
| 2020/1/29 | 2.377 ** | 0.153 | 2020/3/6 | 4.900 ** | 0.176 |
| 2020/1/30 | 2.670 ** | 0.154 | 2020/3/7 | 4.947 ** | 0.177 |
| 2020/1/31 | 3.142 ** | 0.160 | 2020/3/8 | 4.910 ** | 0.176 |
| 2020/2/1 | 3.549 ** | 0.166 | 2020/3/9 | 4.916 ** | 0.176 |
| 2020/2/2 | 3.755 ** | 0.168 | 2020/3/10 | 4.942 ** | 0.177 |
| 2020/2/3 | 3.972 ** | 0.170 | 2020/3/11 | 4.908 ** | 0.176 |
| 2020/2/4 | 4.255 ** | 0.176 | 2020/3/12 | 4.942 ** | 0.177 |
| 2020/2/5 | 4.329 ** | 0.175 | 2020/3/13 | 4.924 ** | 0.176 |
| Number of obs. | 509 | | | | |
| Wald $\chi^2$ statistics | 31139.41 [p-value = 0.000] | | | | |

Notes: The data of 2020/2/29–2020/3/03 are not published. The city effect (dummy variable) is used for controlling the unobserved heterogeneity across cities. The data of bus/tram passenger volume (2018), railway transport capacity (2019) and GDP growth (2018) are based on annual frequency, and thus they are invariant when included in the regression which uses data with a daily frequency.

and meanwhile, the other city-specific dummy indicators such as "Beijing" and "Shanghai" would take the value of 0. The main purpose of controlling the city effect and time effect is to control unobservable heterogeneity across cities and dates, as not all determinants can be controlled in practice (for data availability) and the omitted variables are almost inevitable. The omitted variables would be the components of unobservable heterogeneity across cities, and the control for city effect and time effect would alleviate this problem to some extent.

## 3. Empirical results

Table 1 shows the overview of the confirmed cases and the limitation on air traffic (Jan. 23rd, 2020–Mar. 13th, 2020, data at a daily frequency). The results show that the epicenter Wuhan has experienced the most stringent limitation on air traffic among all the megacities whose airports have a passenger throughput of over 30 million a year. Besides, the correlation between limitation on air traffic and confirmed cases of the eleven megacities during this time span is demonstrated in Fig. 2.

Results of Table 2 show that, after controlling the city and time effect and the effects of bus/tram passenger volume (coefficient = 1.819, $p$-value $< 0.01$), railway transport capacity (coefficient = 38.154, $p$-value $< 0.01$), and GDP growth (coefficient = 1.349, $p$-value $< 0.01$) on confirmed cases, the limitation on air traffic has a negative effect on confirmed cases (coefficient of linear term = −4.650, $p$-value $< 0.01$), and such effect marginally recedes as the strength of limitation intensifies (coefficient of quadratic term = 4.089, $p$-value $< 0.01$). Further, when taking the city of Wuhan as a reference point, the measures of most other megacities have a significantly negative effect on confirmed cases (Beijing, −12.436; Shanghai, −10.384; Guangzhou, −4.993; Chengdu, −2.680; Xi'an, −4.736; Chongqing, −0.213, $p$-value $< 0.01$).

## 4. Discussion and conclusion

This study empirically confirms the effectiveness of airline transport regulation in suppressing confirmed cases of novel coronavirus disease in megacities of China. The impact of airline transport regulation on confirmed cases is found to be negative, yet marginally recedes as the strength of regulation intensifies.

The findings of this study examine the airline transport regulation as a possible solution in the short term to containing the fast spreading. The examination of this short-term policy is important especially under the circumstance where it might take a very long time to develop a vaccine. The prior study has confirmed that an airline network which unveils the ubiquitous presence of connectivity patterns can be used as a prediction tool of epidemic risk (Colizza et al., 2006). The pattern of annual inter-regional dissemination of influenza and pneumonia in the US is found to be associated with the domestic airline volume (Brownstein et al., 2006). However, the actual use of airline transport regulation as the policy tool to contain the spread of a pandemic is very rare since its implementation would inevitably bring huge economic costs. Thus, the effectiveness of this policy lacks sufficient empirical evidence in the history. This finding also suggests that the mere reliance on the air traffic limitation policy would not have a long and lasting effect in containing the development of the pandemic. The policy effectiveness would marginally recede as the policy strength intensifies. It implies that the development of the pandemic may not be just determined by air traffic or even interregional population migration. Thus, comprehensive policies are needed to contain the epidemic development.

This study still has some limitations. For the availability of data, this study just examines the effect of airline transport regulation on the spread of novel coronavirus disease in China's megacities whose airports have a passenger throughput of over 30 million a year. When more data are available, more comprehensive analysis can be conducted to examine this policy on a larger scale. Besides, as the data of confirmed cases are released daily and the railway and highway transport are just available on annual based, the analysis that reflects the daily dynamics between railway transport (and bus/tram transport) and confirmed cases has not been provided. Instead, this study controls the influence of railway (and bus/tram) transport on annual based, but this could still not capture the full picture of daily situation. With the daily data of railway and highway transport available in the future, more fine-grained analysis about the effect of the regulation of railway (and bus/tram) transport on the spread of novel coronavirus disease in China will be exhibited.

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## CRediT authorship contribution statement

**Jiannan Li:** Conceptualization, Writing - original draft, Investigation. **Chulan Huang:** Data curation, Writing - original draft. **Zhaoguo Wang:** Visualization, Writing - review & editing, (partial). **Bocong Yuan:** Conceptualization, Methodology, Formal analysis. **Fei Peng:** Writing - review & editing, (partial), Supervision, Funding acquisition.

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