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The impact of COVID-19 on airline passenger travel behavior: An exploratory analysis on the Chinese aviation market

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ABSTRACT

China was the first airline market in the world to be hit hard by the COVID-19 pandemic. It has been gradually recovering as the pandemic is largely contained domestically. However, with the global pandemic spread and great uncertainty, there has been a remarkable change in airline passengers' travel behavior. This paper collected air passenger-level data from TravelSky in the Chinese market. In addition to the analyses on aggregate passenger flow patterns, this paper explores changes in airline passenger travel behavior, such as ticket booking time, age distribution of passengers, refunds and ticket changes, and passenger arrival time at airports. This is one of the first studies to focus on micro-level changes in airline passenger travel behavior by using objective passenger-level data. The pandemic-induced psychological changes in air travelers are explored, providing useful managerial and policymaking implications for the normalization of the pandemic and the recovery of the airline market in the post-pandemic era.

1. Introduction

In recent years, air traffic travel has grown significantly with the rapid development of the global economy and the improvement of air transport infrastructure. Taking the Chinese market as an example, since the reform and opening up in 1978, China's civil aviation transportation has maintained an average annual growth rate of 16.3% over the past two decades, much higher than other modes of transportation (Wang et al., 2018). In 2019, China's airline market traffic reached 1.29 billion passengers and 1.2 trillion revenue passenger kilometers (RPKs) (CAAC, 2020). As an important strategic industry in China, civil aviation is changing the way people travel, driving the progress of cities and even the country, and becoming a powerful engine to fuel high-quality development (Wang et al., 2020).

However, in 2020, COVID-19 disrupted global economic development. Similar to SARS, COVID-19 is an airborne disease that can spread rapidly in populations (Yang et al., 2020). On January 30, 2020, the COVID-19 outbreak was declared a public health emergency of international concern (PHEIC). On March 11, 2020, the WHO Director, Dr. Ghebreyesus, declared that COVID-19 constituted a global pandemic.

The COVID-19 outbreak has hit many industries, especially the aviation market. Both the number of flights and passengers has dropped significantly. The GDP of the global economy is expected to shrink by 3%, which is worse than the contraction caused by the financial crisis in 2008–2009 (Währungsfonds, 2020). In comparison, the volume of global merchandise trade decreases by 13–32%. 2020 saw a US\$330 billion and US\$59 billion decrease in the international travel market, largely due to travel restrictions imposed in nearly 96% of destinations (ICAO, 2020).

Many scholars have conducted studies on the relationship between the pandemic and civil aviation from two main aspects.¹ The first aspect is the inhibitory effect of the occurrence of the pandemic on traffic. For example, Iacus et al. (2020) analyzed the dramatic implications for global passenger traffic. Graham et al. (2020) focused on older passengers (65+) who were severely affected by COVID-19. The study shows that a significant proportion of older passengers still plan to travel by air in the next year, however, their travel patterns may change, with fewer trips than before, more domestic trips, and more trips by different modes of transport. In particular, the shift from public transport to cars (especially in Korea and China) exceeded 60%. Czerny et al. (2021)

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¹ Sun et al. (2021) offered an excellent survey over 110 papers on COVID-19 and air transport, which were published in 2020. Tanriverdi et al. (2020) provided a bibliometric and visualization analysis of the air transport literature prior to COVID-19 and how this literature might define and guide the future of aviation post COVID-19.

reviewed the airline traffic changes around the world and focused more on the Chinese market. They suggested that China's airline domestic market traffic rebounded very fast because of the strict pandemic control. Most countries adopted the "curve flattening" strategy to combat the pandemic, leading to a slow recovery in airline traffic. Hensher et al. (2021) found through their study that the pandemic led to a greater shift in travel from public transportation to cars, such that many short-haul air travels are substituted by driving. Sun et al. (2020) conducted a comprehensive empirical analysis on the impact of the COVID-19 pandemic on the air transportation system through multi-grain network analysis. The authors found that the impact of the COVID-19 pandemic on international flights was much greater than that on domestic flights and the southern hemisphere was more affected than the northern hemisphere. Dube et al. (2021) reviewed the adverse impact of the pandemic on airlines' financial conditions, and also suggested potential recovery pathways for global airline industries. Choi (2021) examined the impact of COVID-19 on airport operating procedures and found the most obvious difference was the enhanced procedures for verifying the health status of passengers. Miani et al. (2021) studied the effect of COVID-19 on tertiary aviation education in Australian universities. They found that students were seeking further support to develop non-technical skills to better prepare them to compete after graduation. Hou et al. (2021) built an integrated economic model to examine how the previous international flight slots can be reallocated to the domestic routes at the hub airports. They analyzed the market competition and airline strategy changes with such airport slot reallocation.

The second stream of literature focuses on how airline travel can contribute to the spread of the virus. Gilbert et al. (2020) quantified the imported risk of COVID-19 faced by African countries by studying their international connectivity with China. Tang et al. (2020) calibrated the random transmission model of COVID-19 to predict the spread of the virus in China by using the population outflow of different modes of transportation (e.g., air, rail, and coach) from Wuhan to other regions of China. Lau et al. (2020) assessed the role of the air travel ban in containing the pandemic and found that the air travel ban significantly slowed the spread of COVID-19 in China. Chinazzi et al. (2020) applied the global population transmission model to predict the impact of Wuhan lockdown on curbing the spread of the virus. They noted that the embargo would only delay the development of the outbreak in China by 3–5 days, while international travel restrictions would more effectively help delay the spread of the outbreak from China to the rest of the world. Zhang et al. (2020a) compared the effects of different modes of transportation on the spread of COVID-19 in China. They found that air transport was more strongly associated with virus transmission than high-speed trains. Zhang et al. (2020b) proposed a method to integrate the real-time global flight information and pandemic data to calculate the risk of imported cases of COVID-19 via international air transport. The method is applied to the Chinese contexts to calculate the COVID-19 import risk for particular Chinese provinces and some important international routes.

In the Chinese airline market, the domestic passenger volumes were greatly affected by COVID-19 in the short term after the outbreak. As shown in Fig. 1 at the aggregated level, there is a slight increase in January 2020 compared to 2019. After mid-February, the domestic passengers steadily increased until the peak of the National Day holiday in early October 2020, as the domestic pandemic has been effectively controlled and domestic flight control was gradually liberalized. With the onset of winter and the emergence of imported and domestic cases in several cities, the number of flights and passengers declined from mid-October to December 2020.

Unlike the previous studies that focused on aggregated airline traffic flow or airline/airport operations, this paper examines how the pandemic affects airline passenger-specific travel behaviors in the context of the Chinese airline market.² For example, airline passengers would change their ticket booking and airport dwell time in response to the infection risk and changes of airline/airport operations. To the best of our knowledge, this is one of the first studies to investigate airline passenger's travel behaviors using passenger-specific ticket booking and airport check-in time. Understanding such micro-level passenger travel behavior changes has meaningful managerial implications for airlines and airports, and useful for government policymaking as well.

The remainder of this paper is organized as follows. First, Section 2 summarizes the methodology that has been used. Section 3 examines airline passenger travel behavior changes caused by the pandemic. Finally, Section 4 concludes and discusses some future research directions.

2. Data and methodology

2.1. Data and source

The data used in this paper mainly includes two parts. The first is the passenger-specific airline ticket booking data, which includes passenger-related information (e.g., age, gender, and ticket class) and ticket-related information (e.g., flight information). In addition, we also have the information on the time when the passenger passed the security checkpoint and got on board. Such passenger-specific airline ticket data was retrieved from TravelSky Departure Control System. As the most comprehensive and reliable ticket data source, the data covers all the passengers in the Chinese domestic market. The analysis of passenger travel choices based on the data in this paper can reflect the actual passenger travel situation in the aviation market to a large extent. This passenger-specific data enables the analysis of detailed passenger travel pattern changes, which has yet been well explored by previous studies.

The second part of our data is the dynamic flight data, which comes from UMETRIP, the largest aviation data service company in China. It provides daily air travel service information to more than 50 million passengers worldwide and monitors more than 12,000 domestic flights in China and 60,000 flights worldwide through AFTN messages and aircraft onboard ADS-B devices every day. All flights between January 1, 2018 and December 31, 2020 are included in the analysis.

2.2. Methodology

This study analyzes the passenger level air travel behavior and ticket booking pattern amid the COVID-19 pandemic. It utilizes the real and large volume of passenger ticket booking data. It focuses on the following aspects: i) the heterogeneous evolution of air passenger traffic in individual Chinese provinces; ii) the ticket booking time of air passengers; iii) the ticket refund and change rate; iv) the age distribution of air passengers; v) the arrival time of air passengers at the airport. The analysis is conducted mainly through descriptive statistics, supplemented by statistical tests.

Specifically, to examine air passengers' ticket booking behaviors, we define the temporary ticketing and planned ticketing as follows: the temporary ticketing is the purchasing within three days before the departure date and the planned ticketing as booking tickets more than 15 days before the departure date. The booking time can reflect the travel nature (leisure vs. business) and the psychology of passengers to a certain extent, which would be analyzed in detail later. Basically, the

² Lamb et al. (2021) interviewed 15 airline passengers in the US to examine the effects of COVID-19 on the social and emotional perspectives of passengers. In contrast, we focus on the impact of COVID-19 on the travel behavior of domestic airline passengers in China.

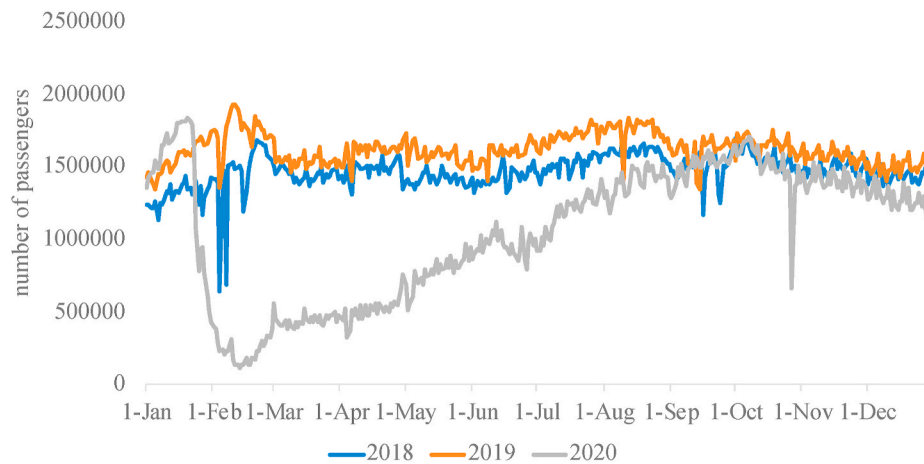


Fig. 1. The daily number of domestic passengers in 2018, 2019 and 2020. Source: calculated by the authors using data from TravelSky and UMETRIP.

shorter the booking time in advance, the travel nature is more inclined to business travel, and the more conservative the travel psychology is. On the contrary, the longer the time to purchase tickets in advance, the more the nature of their trips will be returning home on holidays and leisure travel. Meanwhile, COVID-19 disrupted people’s travel plans and could force people to cancel or adjust travel schedules due to sudden local outbreaks. We then use the ticket refund and change rate to analyze the impact of COVID-19 on passenger’s ticket refund and cancellation behaviors. In addition, we categorize the passenger ages into “young”, “middle-aged”, and “elderly”. Among them, the “young” is defined as less than 16 years old, and the “elderly” are those over 65 years. Such analysis on each individual age group would better shed light on the heterogeneous impact of COVID-19 on passenger groups.

Last, passengers could also change their arrival time at the airport during the pandemic. On the one hand, the airports carried out more stringent pandemic prevention and control (EPC), such that the passengers may need to arrive earlier to undergo such additional measures. For example, many airports set up “EPC teams” to strictly enforce EPC sweeps, temperature measurements, and disinfection. Airports are required to check passengers’ body temperature, travel history, health code, and nucleic acid reports. On the other hand, passengers would like to shorten the exposure in the public space to reduce the infection risk, so that they may arrive later purposely. Many airport shops have also been closed during the pandemic, limiting passengers’ shopping in the terminal. This would also discourage passengers’ dwell time at the airport. Therefore, the impact of the pandemic on passengers’ airport arrival time is unclear without formal analysis. We analyze passengers’ arrival time distribution at the security checkpoint in 2019 and 2020 for comparison, with data collected from the TravelSky Departure Control System.

3. Impact of COVID-19 on airline passenger travel behaviors

The pandemic has led to significant changes in the travel behavior of passengers in the aviation market. These changes have important implications for the demand characteristics of travelers and may also gradually change the landscape of the aviation market in the coming years, with profound implications for the development and planning of the air transportation industry. During the pandemic, which kind of passengers are still traveling and what changes have occurred in their travel psychology and behavior? In order to grasp the changes in the passenger travel characteristics, this section mainly analyzes air passengers’ traffic change at the provincial level and the detailed air ticket booking patterns during the pandemic.

3.1. The impact on different Chinese provinces

The changes in the travel behavior of air passengers will affect the passenger volumes in various provinces in mainland China. We specify the impact of the pandemic on different Chinese provinces or major cities at first. Due to the pandemic, air passenger volumes in various provinces in mainland China have declined significantly compared to the previous years. According to our drawn heat map of the year-on-year percentage decline in passenger volume by province in 2020 shown in Fig. 2, the decline is relatively large in Hubei, Xinjiang, Heilongjiang, Beijing, and Shanghai. Furthermore, Fig. 3 shows the cumulative num-

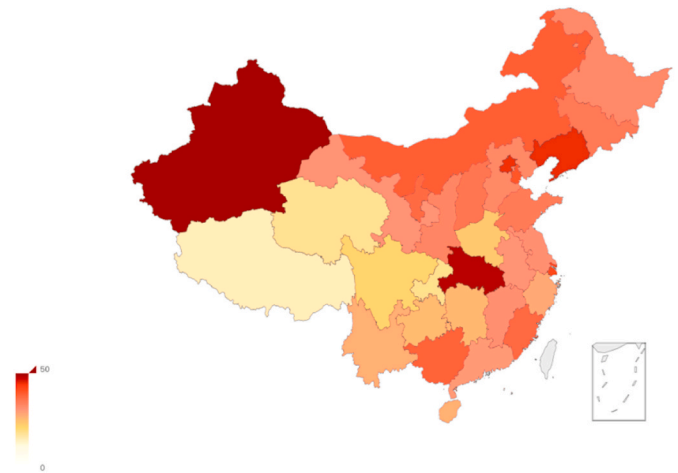


Fig. 2. The year-on-year decrease of passenger volume in 2020.

ber of confirmed cases in China. It can be seen that the provinces with the highest cumulative number of confirmed cases throughout the year are concentrated in Hubei and the surrounding provinces. But Xinjiang, Beijing, Shanghai, and Heilongjiang have also seen a serious drop in air passenger traffic, mainly because of the subsequent sudden local break

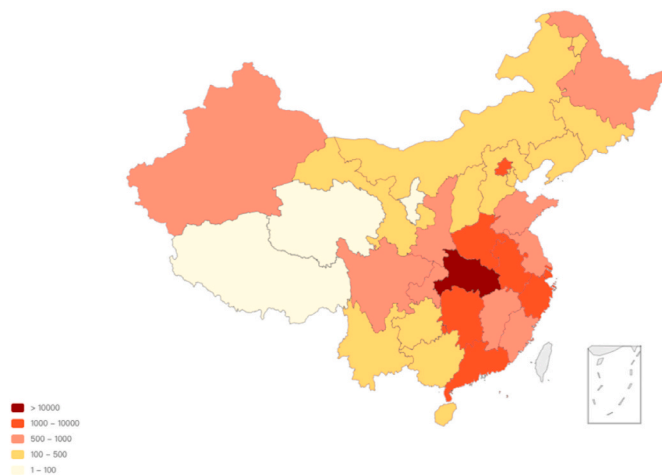


Fig. 3. China's cumulative confirmed cases in 2020.

due to imported cases.³ Therefore, we may conclude that the pandemic greatly affected air passengers' travels in regions with more confirmed cases or experienced sudden local outbreaks. This shows significant heterogeneity of pandemic's adverse impacts on airline travels within one large country. It also indicates the government's ability to implement stricter travel restrictions only on the targeted regions while not affecting other parts of the country.

3.2. Impact on passengers' ticket booking time

Booking time can reflect the travel psychology of air passengers. Fig. 4 shows the more detailed dynamic trend of the proportion of temporary tickets from 2018 to 2020. The proportion of temporary booking in January 2020 was basically the same as that in the previous two years. However, the proportion of temporary booking from February to December in 2020 was higher than in previous years. Starting in February 2020, the percentage of temporary ticket purchases increased month by month, peaking in April, when 70% of people booked tickets within three days before travel. During this period, travel uncertainty caused by the pandemic was the most significant and most cities and companies were unable to determine the time of return to work. At the same time, the travelers with outbound travel and entertainment activities were also hindered by the pandemic, thus making it more difficult to pre-sell and book tickets in advance.

The time of return to work and the travel restriction policy are closely related to the control of pandemic domestically. With the gradual liberalization of travel restrictions, the time of return to work in the country is gradually determined, and people have started to book recent air tickets to start traveling, so that there may be the occurrence of a relatively large proportion of passengers who purchase tickets temporarily. As the outbreak was gradually brought under control, people began to plan their travel well in advance again, with the proportion of temporary ticket purchases gradually decreased. In

³ Although China has largely controlled the pandemic since April 2020, the country continue to experience sudden, small-scale local outbreaks due to imported cases. Taking Xinjiang province for example, Fig. A1 in the Appendix shows the monthly passenger flow in Xinjiang in 2019 and 2020. The tourism and air passenger flow peak in Xinjiang was the third quarter of 2019. However, the local outbreak began on July 17, 2020, with more than 900 cases confirmed. China immediately suspended a large number of flights flying into or out of Xinjiang, resulting in a dramatic drop in the number of air passengers. One reviewer also pointed out that the border in northeastern China (i.e., Heilongjiang, Jilin, and Liaoning provinces) is particularly hard to control illegal immigration. Therefore, even without air transport, there is a significant risk of case importation.

September and October 2020, the percentage of temporary ticket purchases reached the trough, and the difference with the same period in previous years reached the minimum, mainly because air travel gradually picked up during the National Day holiday week. People began to book tickets in advance to plan their trips after a long period of travel restrictions. The proportion of tourism travel trips began to rebound and people even conducted "retaliatory consumption and travels". The domestic tourism industry suffered a heavy blow in the first half of 2020, with only 1.168 billion domestic tourists (Ministry of Culture and Tourism of China, 2020). During the National Day holiday week of 2020, many travelers' long-deferred travel plans were put back on the agenda. According to estimates of the China Tourism Research Institute, there were 637 million domestic tourists during the holiday, which is about 79% of the pre-pandemic level.⁴ As a result, the proportion of temporary ticket booking was even lower in 2020. Overall, we have seen the convergence in the proportion of temporary ticket bookings, which suggests air passengers quickly adjusted their ticket bookings with the successful control of pandemic (Figs. 5 and 6 show a similar conclusion).

Fig. 5 shows that the pandemic significantly shortens the average booking time, with an increase in the proportion of passengers with temporary bookings and a decrease in the proportion of passengers with planned bookings. As shown in Fig. 6, the standard deviation of advance booking time in 2020 is much smaller than that in 2018 and 2019, except for January. In May 2020, the standard deviation of advance booking time is only 5.5 days. In October 2020, it rebounded to 11 days, which is still lower than the standard deviation of 16.6 days in October 2019. In December 2020, the standard deviation was still less than 10 days, down 38.5% year-on-year. This shows that the outbreak reduced the average time for travelers to purchase tickets in advance, deepening the bottom-line psychology of travelers and bringing people's travel psychology into line. Therefore, we believe that the pandemic caused a fundamental change in the travel psychology of many passengers. People are becoming more conservative in their travel psychology. It will be difficult for the booking time in 2021 to return to the pre-pandemic level.

3.3. Impact on domestic airline ticket refunds and changes

COVID-19 hindered people from traveling and many planned trips had to be changed. Fig. 7 shows the daily refund and change rates in 2019 and 2020. The refund and change rates from January to May 2020 were significantly higher than the same period in 2019, with the highest refund and change rates reached in February. This is mainly due to the outbreak of the pandemic that happened in January and passengers had to cancel or change their travel plans. Later in the year, the uncertainty of the pandemic and frequent policy changes resulted in a higher refund and change rate.

Policies issued by CAAC have had a significant impact on refunds and ticket changes. On January 23, 2020, CAAC announced a policy to provide free refunds for passengers who purchased tickets. On February 10, CAAC issued another policy that provided free refunds and ticket changes for students until March 31. These policies led to a significant increase in the number of refunds and ticket changes. People's psychological changes also greatly affected ticket refunds and changes. As the pandemic gradually got under control and people slowly adapted to the way they traveled during the pandemic. As a result, the refund and change rate gradually decreased and stabilized in May 2020.

However, there were still several periods with high refund rates from May to December 2020, which is shown in Fig. 8. To analyze this phenomenon, this paper combines the analysis of several unexpected pandemic time points in China during this period and finds that most of the days following these pandemic points coincide with the time points

⁴ Please see the link: http://www.gov.cn/shuju/2020-10/09/content_5549822.htm.

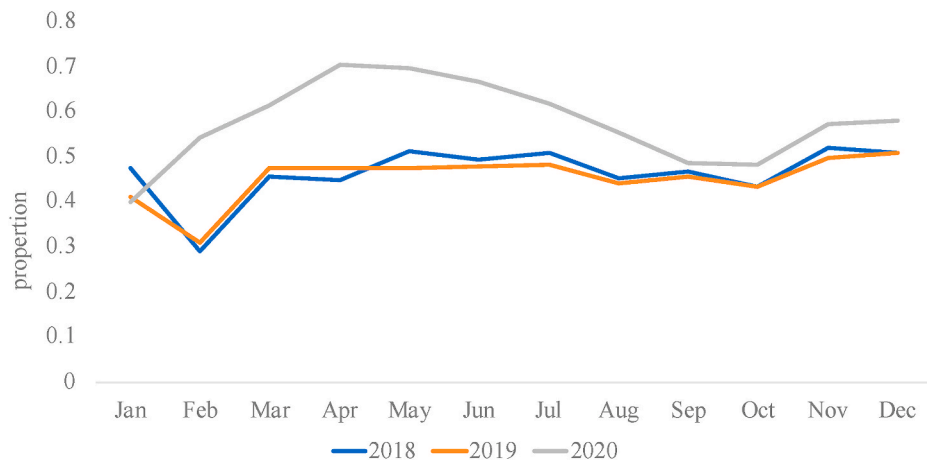


Fig. 4. The proportion of temporary ticket from 2018 to 2020.

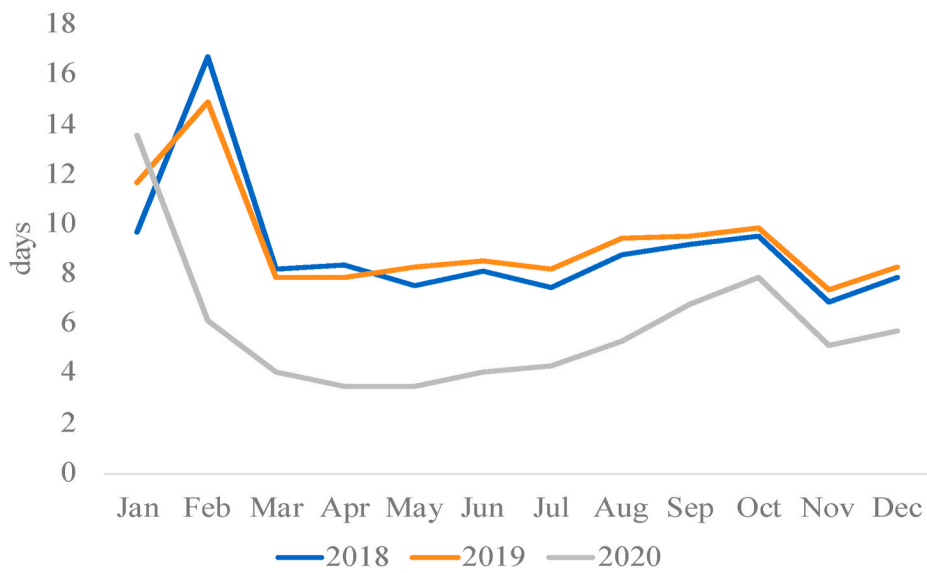


Fig. 5. Monthly average booking time from 2018 to 2020.

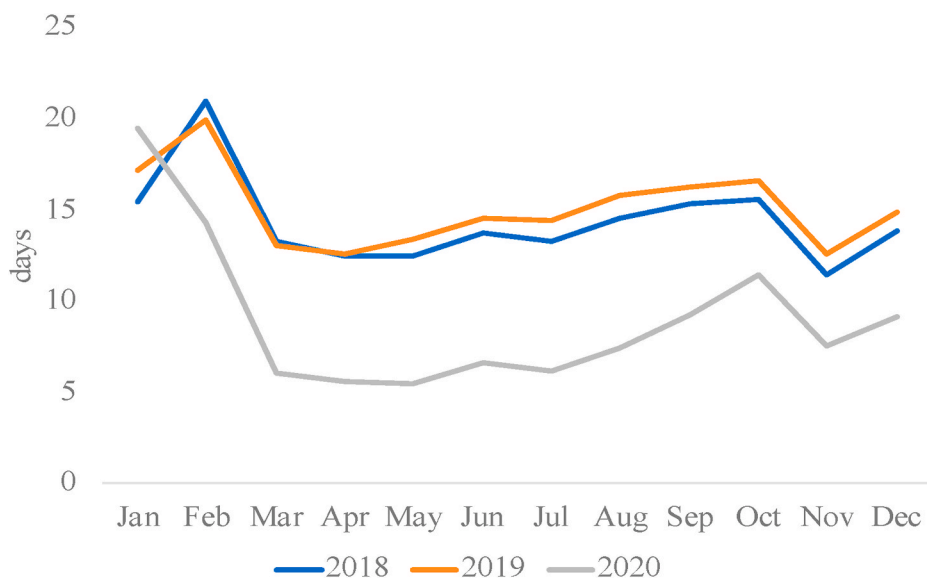


Fig. 6. Standard deviation of monthly advance booking time.

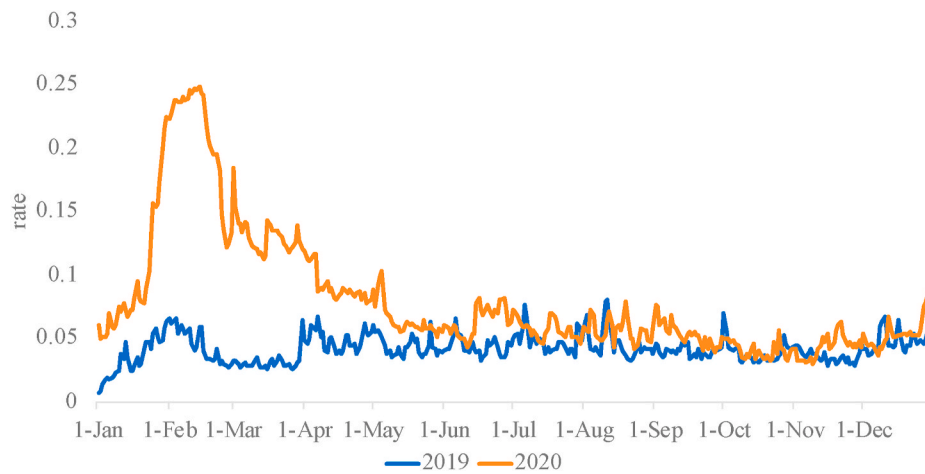


Fig. 7. Refund and change rates in 2019 and 2020.

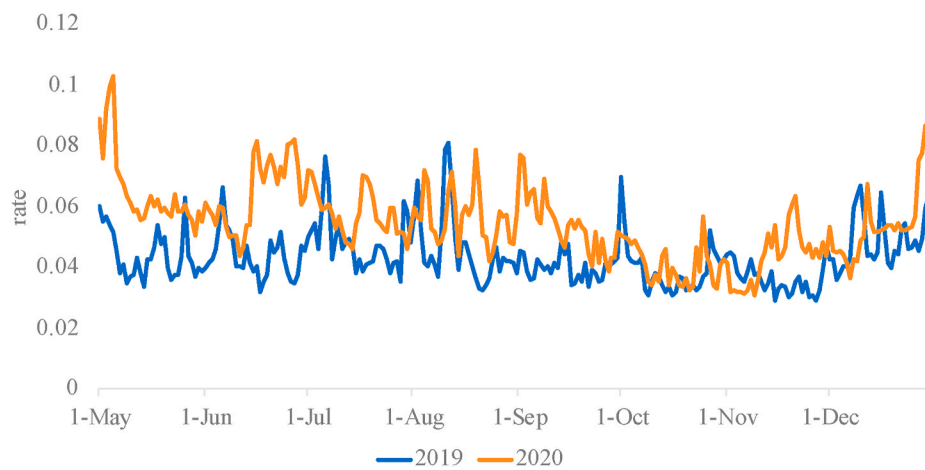


Fig. 8. Refund and change rates from May to December in 2019 and 2020.

of high refund rates. Therefore, some sudden revival of the pandemic in the local communities primarily affected people’s travel plans and increased the refund rate. This suggests the Chinese passengers are also very risk-averse to the infection risk. Even the airlines were not forced to cancel. The passengers might voluntarily change the original travel plans. This finding is also consistent with the observation in subsection 3.1 that passengers are more likely to book temporary tickets (within 3

days before departure), as passengers expect that their trips might be canceled given the uncertainty of pandemic evolution. Tables A1 and A2 in the Appendix show key COVID-19-related policies and significant time points of the COVID-19 outbreak in China.

Next, we look into more details on the ticket refunds and changes at both route and province levels. As shown in Figs. 9 and 10, routes with the highest refund and change rates in 2020 include Harbin-Shanghai

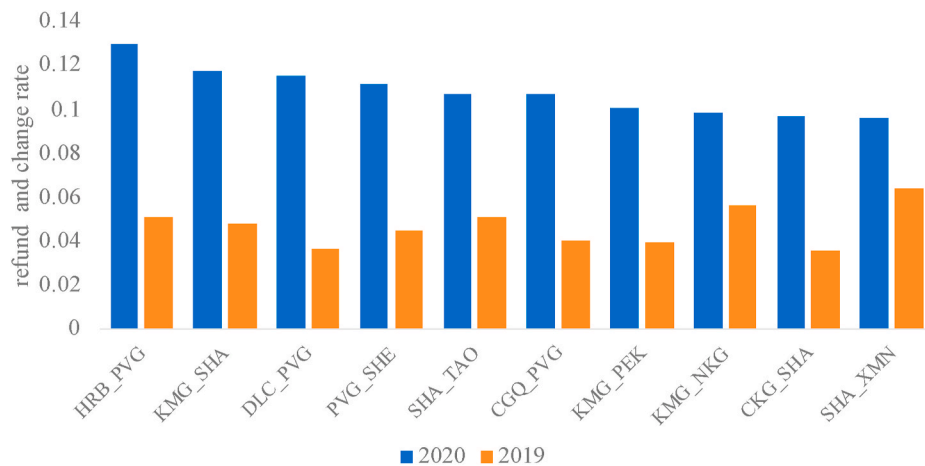


Fig. 9. Top 10 domestic routes in terms of refund and change rate.



Fig. 10. Top 20 domestic routes in terms of refund and change rate.

Pudong, Kunming-Shanghai Hongqiao, Dalian-Shanghai Pudong, Shenyang-Shanghai Pudong, Qingdao-Shanghai Hongqiao, Chongqing-Shanghai Hongqiao, Kunming-Beijing Capital, and Kunming-Nanjing. Among them, the highest refund rate of the Harbin-Shanghai Pudong route reached 13%. Compared with 2019, the routes with the highest year-on-year growth in refund and change rates are those between Dalian-Shanghai Pudong, Guangzhou-Haikou, Guangzhou-Xi'an, Chongqing-Sanya, and Chongqing-Shanghai Hongqiao. The most affected by the pandemic are the routes connecting first-tier cities and tourist cities.

Figs. 11 and 12 show the total refund and change rates of all routes departing from and arriving at each province in mainland China respectively. In 2020, the three provinces and municipalities with the highest outbound refund and change rates were Hebei (9.2%), Shanghai (9%), and Fujian (6.7%), and with the highest inbound refund and change rates are Shanghai (9.9%), Hebei (8.9%), and Beijing (8.7%). There is an imbalance between the refund and change rates at the departure and arrival points in some provinces. For example, when Beijing, Shanghai, and Tianjin are served as departure points, their flight refund and change rates are much lower than when they are destinations.

The ten provinces with the largest year-on-year increase in refund and change rates for outbound and inbound flights compared to 2019 are shown in Table 1. Jilin, Liaoning, and Heilongjiang had the highest year-on-year growth rates for both outbound and inbound flights. This is mainly due to the frequent recurrence of pandemics in the northeastern region in the second half of 2020. For example, on May 7, 2020, an

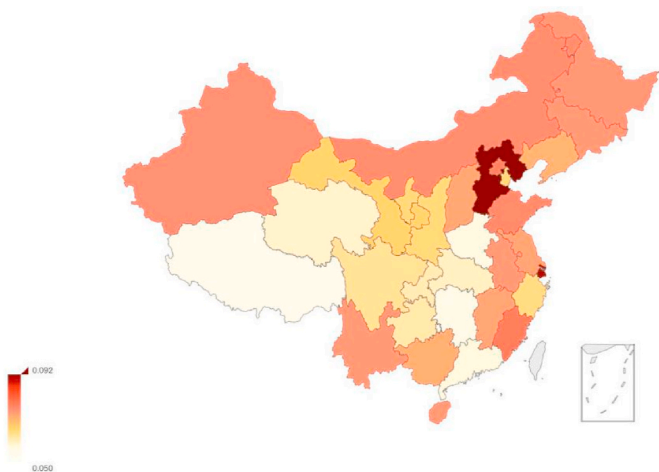


Fig. 11. Refund and change rates for flights departing from each province in 2020.

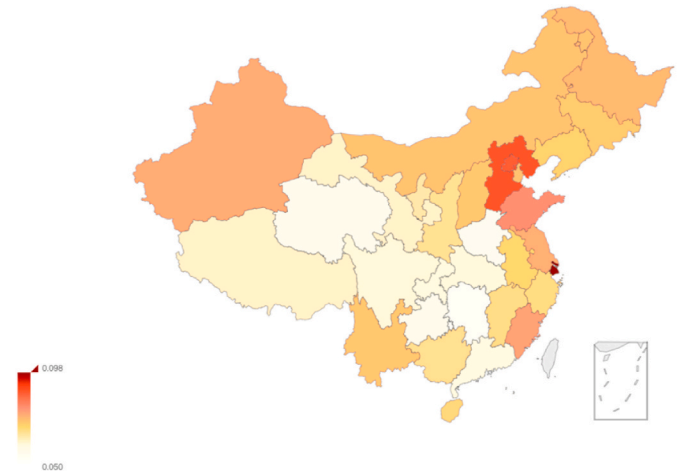


Fig. 12. Refund and change rates for flights arriving in each province in 2020.

outbreak occurred in Shulan, Jilin, resulting in 49 confirmed cases. On July 22, a new round of outbreak occurred in Dalian, Liaoning, with 118 confirmed cases reported.

The outbreak of the pandemic and the various refund policies introduced by CAAC made the refund rate in 2020 significantly higher than in previous years. The refund rate from January to May 2020 was significantly higher than that of the same period in 2019, with the highest rate in February. The refund rate was relatively high from June to December, a period that mostly coincided with the outbreak of small-scale domestic pandemics. Therefore, it indicates that the recurrence of the pandemic largely affected people's travel plans and raised the refund rate.

3.4. Impact on age distribution of domestic passengers and airport arrival time

3.4.1. Age distribution of domestic passengers

Fig. 13 shows the age distribution of domestic airline passengers in 2020. It shows an upward trend in the middle and a downward trend on the two sides of the age groups (young and elderly). The proportion of passengers over 65 years old decreased by 18.2% year-on-year, and that of passengers under 16 years old decreased by 25.4% year-on-year. Air travel is most adversely affected in people under 16 and over 65, as they are the most vulnerable to COVID-19 infection. In addition, these people travel mainly for leisure purposes, thus more flexible to cancel or re-schedule. The proportion of young passengers increased and became the main travel force. The group aged 30–45 still accounted for the largest proportion of travelers, accounting for 40.2% of the total number of travelers. However, this group's proportion did not change much due to the pandemic, with a year-on-year change of only 1.6%. The proportion of people aged 16–30 increased by 13.6% year-on-year. The age structure of air passengers traveling mainly shifted from older to younger people.

Since Fig. 13 did not show a significant change in the age distribution, we performed further statistical analysis to verify whether the proportion of young and elderly passengers changed in 2019 and 2020. The *t*-test shows that the proportion of young and elderly passengers decreased with statistical significance.

3.4.2. Arrival time at the airport

As shown in Fig. 14, the arrival time of passengers at the security checkpoint is relatively longer in 2020 compared to 2019. The percentage of passengers arriving at the security checkpoint within 80 min before flight scheduled departure time declined, while the percentage of passengers arriving at the airport 100 min earlier than the departure time increased. In 2020, the percentage of passengers arriving at the

Table 1

Top 10 provinces in terms of year-on-year increase in ticket refunds and ticket changes for outbound and inbound flights.

Outbound flights refund and change rates				Inbound flights refund and change rates			
province	2020	2019	year-on-year increase	province	2020	2019	year-on-year increase
Jilin	7.45%	3.65%	104.39%	Liaoning	6.99%	3.48%	100.81%
Liaoning	7.14%	3.61%	98.23%	Shanghai	9.88%	4.96%	99.34%
Heilongjiang	7.49%	3.84%	94.95%	Jilin	7.09%	3.62%	95.78%
Hainan	7.46%	3.97%	87.99%	Heilongjiang	7.37%	3.98%	85.05%
Shanghai	9.03%	4.87%	85.57%	Shanxi	7.15%	3.87%	84.83%
Sichuan	6.39%	3.45%	84.92%	Xinjiang	7.55%	4.18%	80.84%
Chongqing	6.18%	3.51%	76.07%	Sichuan	6.01%	3.36%	79.01%
Shandong	7.66%	4.36%	75.81%	Guangdong	5.90%	3.34%	76.66%
Shanxi	7.30%	4.19%	74.04%	Jiangsu	7.52%	4.31%	74.42%

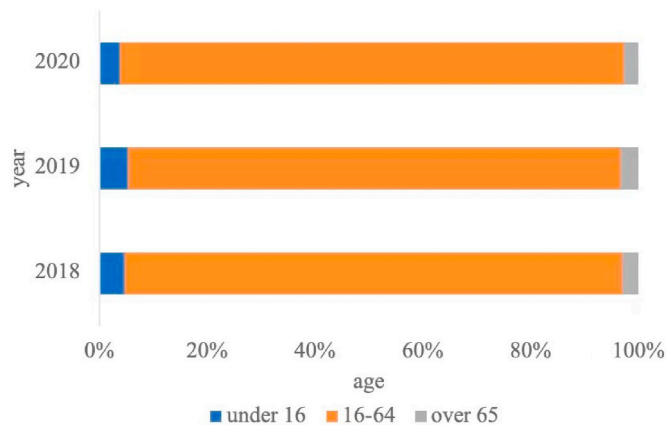


Fig. 13. The age distribution of domestic passengers from 2018 to 2020.

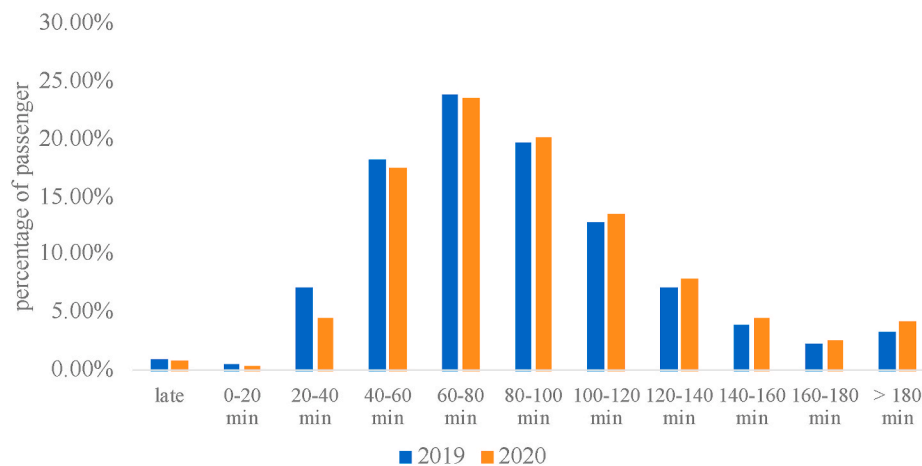


Fig. 14. Distribution of passengers arriving early at the security checkpoints.

security checkpoint 100–140 min earlier than departure time was 21.5%, an increase of 7.9% year-on-year; the percentage of passengers arriving at the security checkpoint 140–180 min earlier than departure time was 7.2%, an increase of 15.3% year-on-year. The proportion of passengers arriving at the security checkpoint 180 min earlier than departure time was 4.2%, an increase of 24% year-on-year. Compared with 2019, passengers are more inclined to arrive at the airport earlier and tend to be more conservative in 2020.

However, the overall increase in passenger’s dwell time at the airport (early arrival) is not very significant. This is because staying longer at the terminal (a closed indoor space) would also increase the risk of infection. The shops, restaurants and entertainment facilities have also

been closed during the pandemic, thus discouraging passengers to arrive earlier to make consumptions within the terminals.⁵

To analyze the arrival times of passengers at different airports, we selected China’s top 10 large airports in terms of passenger volume in 2020 and 10 medium-sized airports ranked 41st to 50th in terms of passenger volume. Then the average duration that passengers arrive at the security checkpoint in advance at the above airports was calculated. The results are shown in Figs. 15 and 16. In 2020, the average time for passengers to arrive early at the security checkpoint has increased for both large and medium-sized airports. In other words, under the influence of the pandemic, passengers are more willing to arrive at the airport earlier than in previous years. The average duration for passengers to arrive at the security checkpoint early at large airports is relatively longer than that at medium-sized airports.

4. Conclusion and discussion

The impact of COVID-19 is enormous, especially in the global aviation market. Although vaccination is underway in many countries, given

the current global prevalence of COVID-19, the virus has a long time to coexist with the aviation market. To analyze the impact of the COVID-19 pandemic on airline passengers’ travel behavior and to inform the aviation market in 2021, we collected three years of passenger named records (PNR) data and passenger security data from TravelSky for the 2018–2020 period, and illustrated the changes in air passengers’ travel behavior since the outbreak.

The following conclusions are obtained. First, the domestic air

⁵ Choi et al. (2020) found evidence of passengers arriving at airports earlier (i.e., a longer dwell time) in order to do shopping prior to COVID-19.

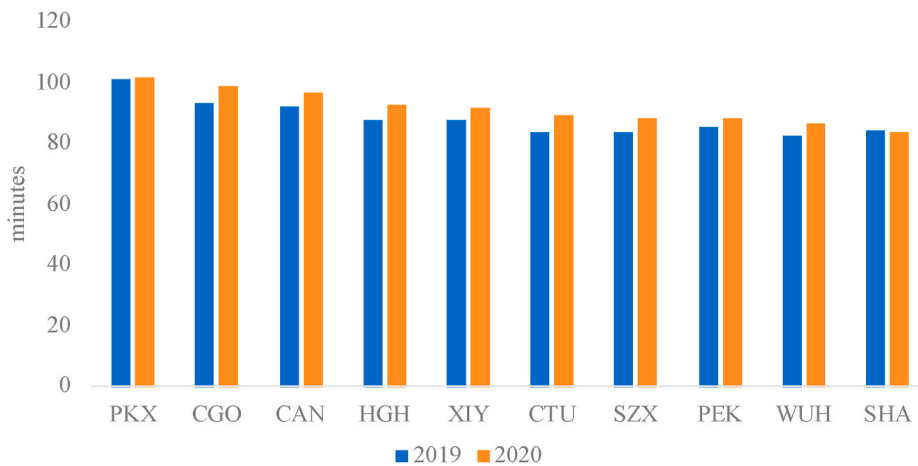


Fig. 15. Average duration for passengers to stay at the large airport early.

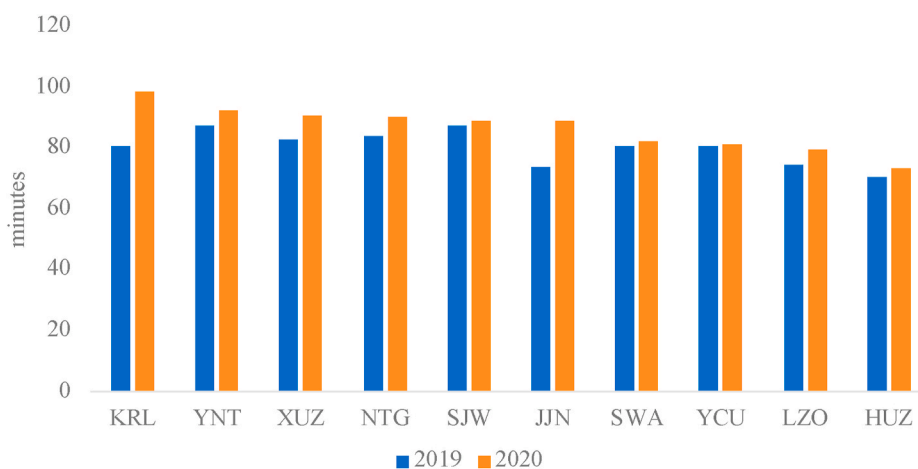


Fig. 16. Average duration for passengers to stay at the mid-sized airport early.

passenger travel volume showed an L-shaped reversal after reaching the bottom in February 2020 and recovered to 90% of the 2019 level during the National Day holiday period. Second, the net inflows of the domestic aviation market were strictly controlled. The demand from international passengers was greatly suppressed by CAAC’s strict controls on inbound and outbound flights. Third, the domestic market saw a significant decline in the proportion of air travel of elderly passengers and children. In contrast, the travel of young and middle-aged passengers remained strong. Fourth, the small-scale local outbreak of the pandemic caused a significant increase in the percentage of refunds and changes in the short term. Fifth, the percentage of temporary tickets increased significantly, while the percentage of passengers who bought tickets more than 15 days in advance dropped sharply. Finally, we also found that passengers arrived at the airport earlier in 2020 than in previous years. Our empirical evidence on the passenger-level travel behavior changes complements existing studies that mainly focused on aggregate level air traffic flow, and thus are useful for better industry management and regulatory policymaking.

The airline market will face a major reshuffle under the normalization of the pandemic. The psychology of passengers is also changing subtly. First, if the pandemic is better controlled domestically, there will be a more rapid rebound in passenger volume. However, the psychology of passengers’ ticketing will not be restored in a short period of time, which is reflected in the fact that passengers are still conservative in booking tickets in advance and the proportion of middle-aged and elderly passengers and children traveling is suppressed. Airlines need to

focus on this change and make corresponding adjustments, especially to cultivate passengers’ travel confidence. Second, the local rebound of the pandemic does not have a significant change on the total number of passengers, but it does have a larger impact on the percentage of refunds and ticket changes. In fact, higher refund and change rates imply greater risk for airlines. In a normalized pandemic scenario in 2021, airlines should have plans for refunds and ticket changes due to a local pandemic rebound. Finally, due to strict pandemic prevention and control measures, passengers will also choose to arrive at the airport earlier for check-in in 2021. This means passengers will spend more time at the airport. The spending potential of passengers could be further exploited.

Our study also has some limitations. First, our passenger data is mainly from TravelSky. Although TravelSky has the most comprehensive passenger data in China, this data does not cover all domestic air passengers because some low-cost airlines are not connected to the TravelSky system. This part of missing data might have some influence on our findings. Second, the development of the pandemic is still ongoing, and the psychology of passengers and the policy of CAAC are still in continuous change. Third, starting in November 2020, China began a universal free COVID-19 vaccination campaign. As of May 2, 2021, 275.34 million doses have been vaccinated in China. Therefore, analyzing and understanding the role of vaccines on the psychology of travelers is crucial for the airline market. These are very important tasks, but they are beyond the scope of the current study.

CRedit authorship contribution statement

Linfeng Zhang: Conceptualization, Methodology, Software, Formal analysis, Writing – original draft. **Hangjun Yang:** Conceptualization, Methodology, Writing – original draft, Writing – review & editing, Supervision, Funding acquisition. **Kun Wang:** Conceptualization, Formal analysis, Writing – review & editing. **Lei Bian:** Conceptualization, Data curation, Writing – original draft. **Xian Zhang:** Conceptualization, Resources.

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Appendix

Table A1

Key COVID-19-related policies issued in China in 2020

Dates	Events	Affected
January 27, 2020	Free air ticket refund policy extended to January 28	Chinese airlines
February 10, 2020	Student passengers can cancel their tickets for free until March 31	Chinese airlines
February 21, 2020	CAAC opened a green channel to ensure fast and smooth travel for workers returning to work and production	Chinese airlines
March 19, 2020	Announcement on the entry of international flights destined for Beijing from designated first entry points (No. 1)	International flights
March 22, 2020	Announcement on the entry of international flights destined for Beijing from designated first entry points (No. 2)	International flights
March 26, 2020	Notice on continued adjustment and reduction of international passenger flights during the epidemic prevention and control period	International flights
April 7, 2020	Notice on further strengthening the management of international air ticket prices during the epidemic period	International flights
June 4, 2020	Notice on adjustment of meltdown measures for international passenger flights	International flights
July 20, 2020	Announcement on boarding of passengers on inbound flights with proof of negative nucleic acid test for COVID-19	International flights
September 1, 2020	Notice of further strict management of international passenger flights with high imported risk	International flights
September 15, 2020	Adjustment and relaxation of some domestic airline flight access policy	Chinese airlines

Table A2

Important time points of the COVID-19 pandemic in China

Dates	Events	Number of new confirmed cases
December 8, 2019	Wuhan reported the first confirmed case	1
January 23, 2020	Wuhan announced lockdown	131
May 7, 2020	Local outbreak in Shulan, Jilin	46
June 6, 2020	Local outbreak in the Xinfadi Market, Beijing	269
July 17, 2020	Local outbreak in Xinjiang	902
July 22, 2020	Local outbreak in Dalian, Liaoning	57
October 11, 2020	Local outbreak in Qingdao, Shandong	12
November 9, 2020	Local outbreak in Binhai, Tianjin	11
December 1, 2020	Local outbreak in Chengdu, Sichuan	13
December 15, 2020	Local outbreak in Dalian, Liaoning	47
December 23, 2020	Local outbreak in Shunyi, Beijing	17
December 24, 2020	Local outbreak in Shenyang, Liaoning	27

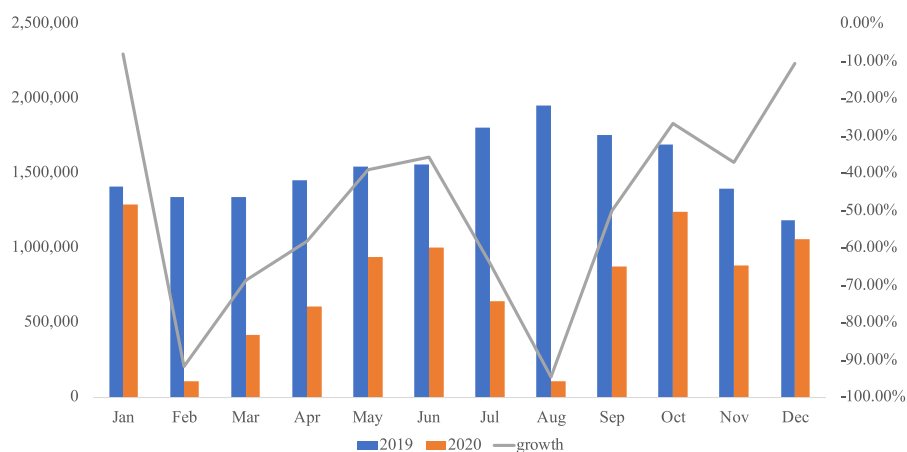


Fig. A1. Monthly passenger flow in Xinjiang in 2019 and 2020.

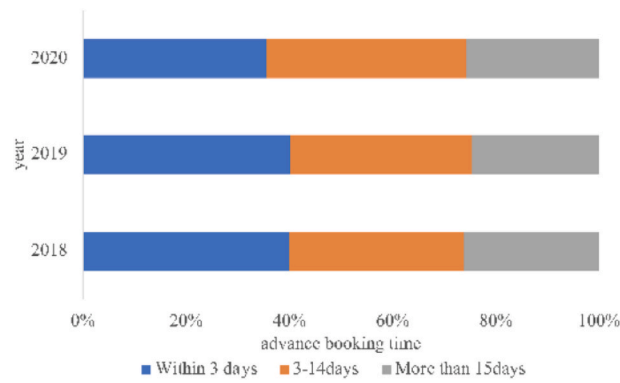


Fig. A2. The distribution of advance booking time for the National holiday (October 1st).

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