Impact of different control policies for COVID-19 outbreak on the air transportation industry: A comparison between China, the U.S. and Singapore

- **Related award：**全国研究生统计建模大赛二等奖

- **Related publication:** Meng F, Gong W, Liang J, Li X, Zeng Y, Yang L (2021) Impact of different control policies for COVID-19 outbreak on the air transportation industry: A comparison between China, the U.S. and Singapore. Plos ONE 16(3): e0248361.

- **项目获奖：**全国研究生统计建模大赛二等奖

全国研究生统计建模大赛

获奖证书

获奖等级：二等奖

获奖作品：《不同管控措施下新型冠状病毒肺炎疫情对第三产业影响的研究》

获奖单位：南方科技大学

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中国统计教育学会

全国应用统计专业学位研究生教育指导委员会

二〇二〇年十二月

南科大学子在2020年全国研究生统计建模大赛中获佳绩

南方科技大学统计与数据科学系 2020-12-23

近日，2020年全国研究生统计建模大赛成绩公布，经过紧张激烈的角逐，南方科技大学统计与数据科学系的参赛学生龚文武、梁俊、李娴以参赛项目"不同管控措施下新型冠状病毒肺炎疫情对第三产业影响的研究"荣获全国二等奖，指导老师为统计与数据科学系教授杨丽丽和前沿与交叉科学研究院研究助理教授孟繁宇。

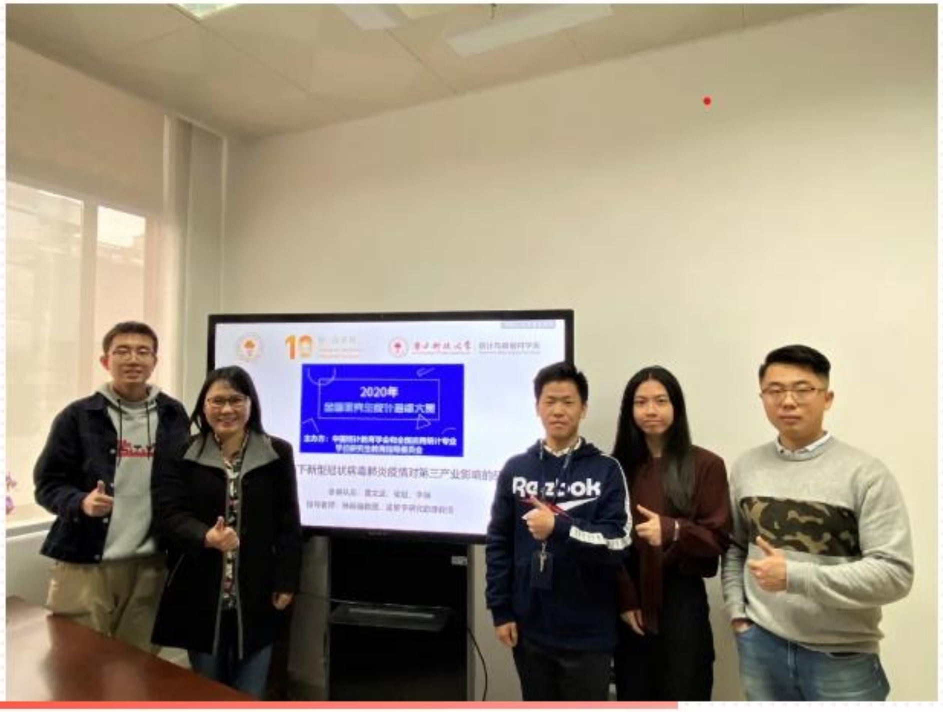


图 | 获奖学生与指导老师合影

1、Research Background and Data

Background

China

enforced quarantine

suspension of express delivery

slowly recovered economy since March,、stimulated economy and encouraged consumption but still took basic prevention measures (mask-wearing etc.)

1 2 3 4 5 6 7 8

[1/23]outbreak of COVID-19, lockdown of Wuhan， delay of return to work and to school, air ticket refund for cancellation
[1/24] the close of recreation places in the national scope

[3/26] Solely one international fight was kept for a country in a single week.

[4/8]the end of Wuhan lockdown
[4/13] Tourist attractions set bounds to the number of visitors.

[6/18] Domestic airlines management was back to normal.

[7/20}Cinemas resumed businesses.

Singapore

Enforced quarantine or other prevention measures, and violators might be imprisoned or fined for thousands of Singapore Dollar.

6/2-6/18 the first phase of ‘Economy Reboot’

1 2 3 4 5 6 7 8

[1/23]the first country in the world to suspend flights to and from China

[2/7] outbreak of COVIE-19

The authorities came up with prevention policy ‘Circuit Breaker’ in April， which required the close of unnecessary public workplaces. It was originally executed from 4/7 to 5/4

[6/3]Singaporean Foreign Ministry proposed to establish a ‘Fast Route’ between Singapore and China’s six cities, such as

6/18- by now the second phase of ‘Econo Reboot’, businesses resumed for restaura casinos, etc.

conducted nucleic acid tests and installed

Background

The United States

enforced curfews across the United States， quarantine conducted/public places closed in some states such as Ohio, without the emphasis on mask-wearing

1 2 3 4 5 6 7 8

[2/2] became the 39th country in the world to suspend flights to and from China

[3/13] outbreak of COVID-19

gradually resumed each state's businesses, 8 pm curfew still effective for the whole country

So far, the United States has become the country affected most by COVID-19 in the world.

China： timely and effective prevention and control measures, high degree of abidance by orders among Chinese citizens

Singapore： fine prevention and control (guarantee of supply for food and necessities, synergic cooperation among different industries)， yet not timely (the late proposal of 'Circuit Breaker', cluster cases among floating workers, affected by election)

The United States： unsatisfactory prevention and control It is mainly attributed to the following reasons:1)The enforcement of policy in many states was not supported by the federal government, and none of the policy was constrained by law;2) Citizens held psychological conflicts to quarantine and mask-wearing due to cultural

Background

In the meantime, aviation industry in these countries have all suffered great losses during the pandemic:

	Aviation Industry
China	The total loss reached hundreds of million Chinese Yuan.
Singapore	Air transportation capacity dropped (For instance, Singapore Airlines' capacity decreased by 96%. The loss reached 212 million Singapore Dollar, the first loss in the past 48 years.).
The United States	The decrease of air transportation capacity (For example, American Airlines 'capacity reduced by 20% and 30% in April and May respectively, and the company applied for government subsidy of 50 billion U.S. Dollar in March.)

Hence, research question is raised as follows：

Under different control policies, what has the pandemic brought to the aviation industry in China, Singapore and the United States? What's the future trend?

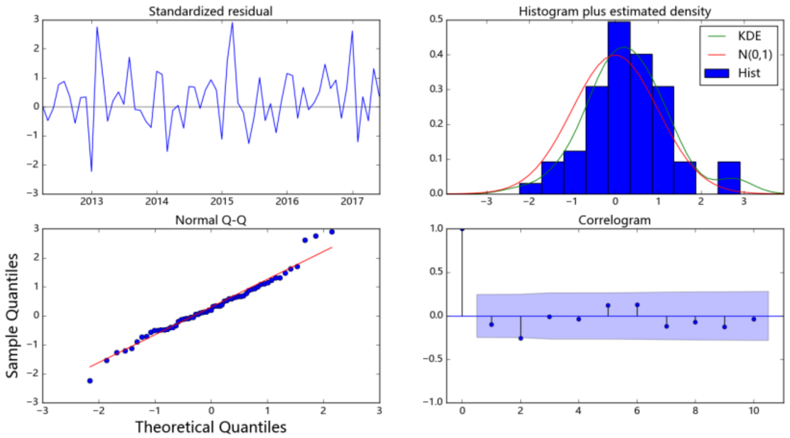
Steps: **Data cleaning, visualization processing, stationarity test, time series data stabilization, model identification, model diagnostic and forecasting**

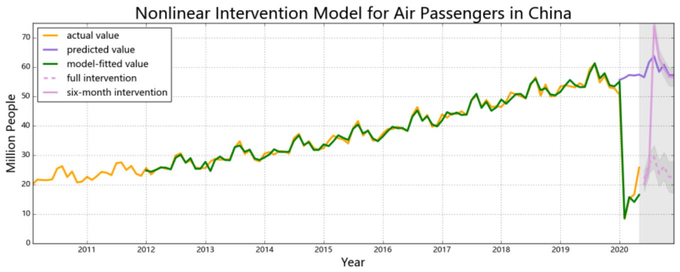
Data Mining

There are 12 time series including 3 countries and 4 industries, we take China Air Passengers for example

Data scraping：

- www.wind.com.cn
- www.ceicdata.com
- www.Investing.com
- 大智慧365
- ………………





2、Methodology and Model Selection

SARIMA fluctuation model

- The stationary process, meaning that the mean and covariance of the series are not change over time, is essential in time series modeling. There are three basic stationary time series models: auto-regressive (AR), moving average (MA), and auto-regressive moving average (ARMA) models.
- Seasonal fluctuation in time series has been found to effectively account for the time series non-stationarity, which is identified by Dickey-Fuller test and can be modeled by the seasonal ARIMA (SARIMA)

ARIMA model

$$\begin{aligned} F_t &= \phi_1 X_{t-1} + \phi_2 X_{t-2} + \cdots + \phi_p X_{t-p} + \epsilon_t \\ &\quad + \epsilon_t - \theta_1 \epsilon_{t-1} + \theta_2 \epsilon_{t-2} + \cdots + \theta_q \epsilon_{t-q} \end{aligned}$$

After the seasonal decomposition

SARIMA model

B: the back-shift operator

$$(1-B)^d (1-B^s)^D F_t = \frac{\theta(B)\Theta(B^s)}{\phi(B)\Phi(B^s)} \epsilon_t;$$

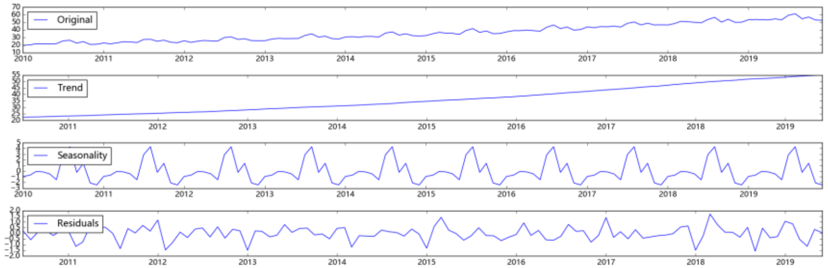
$$\begin{aligned} \phi(B) &= 1 - \phi_1 B - \phi_2 B^2 - \cdots - \phi_p B^p \\ \Phi(B^s) &= 1 - \Phi_1 B^s - \Phi_2 B^{s2} - \cdots - \Phi_P B^{sP} \\ \theta(B) &= 1 - \theta_1 B - \theta_2 B^2 - \cdots - \theta_q B^q \\ \Theta(B^s) &= 1 - \Theta_1 B^s - \Theta_2 B^{s2} - \cdots - \Theta_Q B^{sQ} \end{aligned}$$

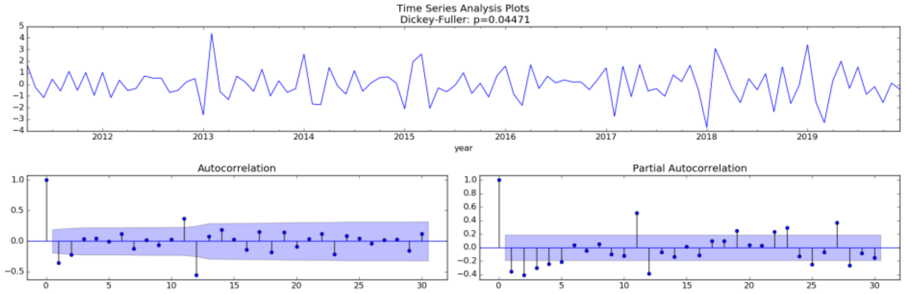
Step 1 → Model identification (D,d,p,P,q,Q)

- Test the stationarity of the time series: seasonal differencing is necessary to convert the time series to be seasonally stationary (D=1,d=1).

SARIMA fluctuation model

TS_Month	Passengers (百万人,国内	Freight (百万吨,国内外)	Retail (十亿元)
01/2010	19.408615	0.450726	1129.25
02/2010	20.247866	0.34269	1095.34
03/2010	21.72581	0.479627	1005.09
04/2010	21.566	0.4660138	1024.5
05/2010	21.528817	0.467271	1102.14
06/2010	21.849353	0.436321	1092.53
07/2010	25.472188	0.4454	1083.85
08/2010	26.296039	0.463206	1109.93
09/2010	22.600398	0.515708	1197.05
10/2010	24.476	0.49637	1260.41

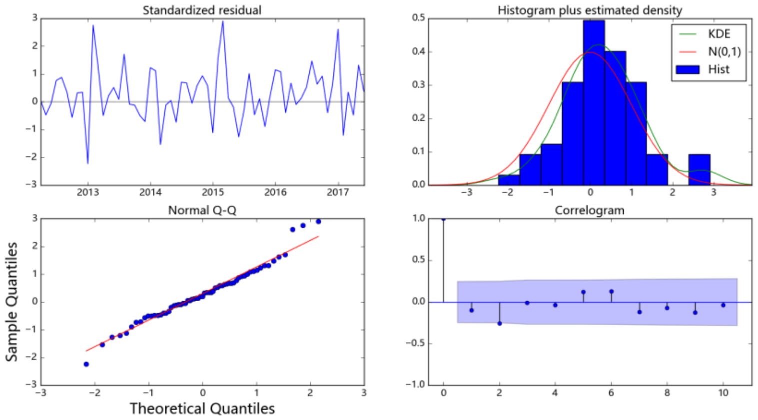




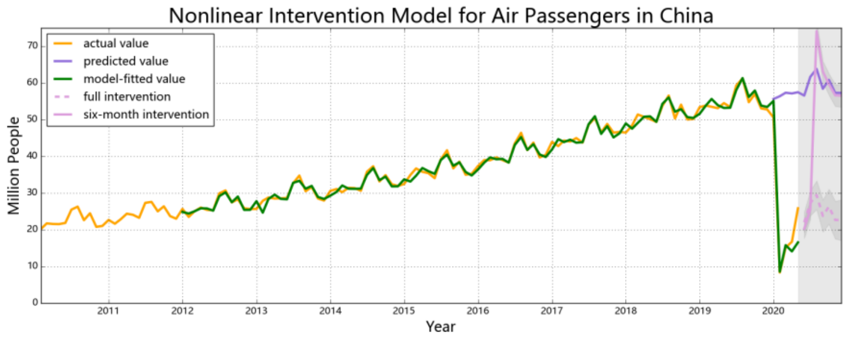
We have 12 time series

Data visualization: linear and seasonal trends

Stationary test



TS_month	真实值	SARIMA	干预6月（2参数）	全干预预	Covid
01/2010	1.3990				0
02/2010	1.2640				0
03/2010	1.4030				0
04/2010	1.2960				0
05/2010	1.3150				0
06/2010	1.4070				0
07/2010	1.4570				0
08/2010	1.3610				0
09/2010	1.3470				0
10/2010	1.4230				0
11/2010	1.4330				0
12/2010	1.5160				0
01/2011	1.4440				0
02/2011	1.2710				0
03/2011	1.3770	1.4100	1.41	1.41	0
04/2011	1.3780	1.2824	1.26709718	1.267097	0
05/2011	1.3670	1.3552	1.40953189	1.409532	0
06/2011	1.4020	1.4537	1.445833604	1.445834	0
07/2011	1.5070	1.4754	1.45700271	1.457003	0
08/2011	1.3910	1.3967	1.412564493	1.412564	0
09/2011	1.4110	1.2706	1.272620528	1.272621	0



Model estimation and diagnostic checking

D=1, d=1, p=P=0, q=Q=1

Model forecasting (SARIMA and Intervention)

Intervention terms

- Intervention analysis is an interactive process. There are three steps to model intervention: identification, estimation, and diagnosis. The intervention model is often used to study the impact of a major emergency.
- There are two general types of indicator variables used to represent the two kinds of basic interventions.

exogenous indicator variables ζ

$$S_t^{\,T} = \begin{cases} 0 & t < T(\text{before the intervention}) \\ 1 & t \geq T(\text{at and after the intervention}) \end{cases}$$

step intervention: a temporary effect

Connection

$$P_t^{\,T} = (1 - B) S_t^{\,T}$$

$$P_t^{\,T} = \begin{cases} 0 & t \neq T(\text{not at intervention}) \\ 1 & t = T(\text{at intervention}) \end{cases}$$

pulse intervention: a lasting effect

- Based on the two scenarios with different time spans of the control policies, different intervention functions have been explored.

$$g_1(1, \xi, t) = \sum_{T=1}^{m} P_t^{\,T}, m = 3 \ or \ 6$$

$$g_2(1, \xi, t) = \sum_{T=1}^{m} \frac{\omega_1 B}{1 - \delta B} P_t^{\,T}, m = 3 \ or \ 6$$

Step 2

Determine the best intervention structure based on the characteristics of the data

SARIMA intervention analysis:

- The SARIMA intervention model can be treated as an extension of SARIMA model, which serves as a useful dynamic modeling tool to rigorously analyze the impact of intervention and can better predict the monthly socioeconomic data

- Model 1: Linear intervention (SARIMAX).

$$\begin{aligned} \mathrm{F}_t = \phi_1 X_{t-1} + \phi_2 X_{t-2} + \cdots + \phi_p X_{t-p} + \epsilon_t \\ + \epsilon_t - \theta_1 \epsilon_{t-1} + \theta_2 \epsilon_{t-2} + \cdots + \theta_q \epsilon_{t-q} \end{aligned} \quad + \quad g_1(1, \xi, t) = \sum_{T=1}^{m} P_t^{\ T}, m = 3 \ or \ 6$$

- Model 2: Non-linear intervention

$$f(\mathrm{F_t}) = g(k, \xi, t) + N_t$$

g(k, ξ, t) represents intervention functions (effects)， N_t represents SARIMA structure (stochastic variation), k is the num of exogenous variables

✓ Scenario 1: Short-term intervention

Three parameters

$$g_2(1, \xi, t) = \frac{\omega_0 - \omega_1 B}{1 - \delta B}(S_t^{\ T} - S_t^{\ T+m}), m = 3 \ or \ 6$$

Two parameters

$$g_2(1, \xi, t) = \sum_{T=1}^{m} \frac{\omega_1 B}{1 - \delta B} P_t^{\ T}, m = 3 \ or \ 6$$

✓ Scenario 2: Long-term intervention

$$g_2(1, \xi, t) = \frac{\omega_1 B}{1 - \delta B} S_t^{\ T}$$

Two parameters

SARIMA intervention analysis:

- During the COVID-19 outbreak, the time of negative impact of the control measures on the selected industrial indicators started to take effect varies in different countries. Thus, the proposed SARIMA intervention model was used to measure the effect of short-term and long-term interventions.

$$(1-B)(1-B^{12})\mathrm{F}_{\mathrm{t}} = (1-B)(1-B^{12})g_l(1,\xi,t) + \frac{\theta(B)\Theta(B^{12})}{\phi(B)\Phi(B^{12})}\epsilon_t, \quad l=1,2.$$

Comparisons of forecasting performances：

$$\mathrm{MAPE} = \frac{1}{T}\sum_{t=1}^{T}\left|\frac{F_t - X_t}{X_t}\right|,$$

$$\mathrm{MAE} = \frac{1}{T}\sum_{t=1}^{T}|F_t - X_t|,$$

$$\mathrm{RMSE} = \sqrt{\frac{1}{T}\sum\nolimits_{t=1}^{T}(F_t - X_t)^2}.$$

Step 3

Based on the optimal SARIMA model structures, the forecasting performances of linear and non-linear intervention models are compared

MAPE： Mean Absolute Percentage Error < 20% (平均绝对误差百分比);
MAE: Mean absolute errors (平均绝对误差);
RMSE: Root Mean Square Error

Model Performance Results

Table 1. Comparisons of Non-linear and Linear models

Indicators	Linear intervention			Non-linear intervention		
	MAPE (%)	MAE	RMSE	MAPE (%)	MAE	RMSE
China air passengers	5. 76	1. 56	3. 28	2. 82	0. 97	1. 45
U.S. air passengers	6. 91	1. 26	2. 53	1. 32	0. 77	1. 02
Singapore air passengers	43. 61	0. 060	0. 091	23. 36	0. 043	0. 067
China air freight	4. 46	0. 020	0. 031	4. 41	0. 021	0. 030
U.S. air freight	3. 37	14. 31	19. 87	3. 01	12. 81	16. 44
Singapore air freight	4. 37	0. 0037	0. 0054	3. 43	0. 0032	0. 0041

All models have the overall acceptable model performances; Nonlinear intervention models have higher predictive power

Table 2. Comparisons of Three-parameters and Two-parameters models

Indicators	Two-parameter				Three-parameter			
	AIC	MAPE (%)	MAE	RMSE	AIC	MAPE (%)	MAE	RMSE
China air passengers	400. 80	18. 95	3. 45	4. 77	385. 90	17. 12	2. 97	4. 31
U.S. air passengers	369. 60	0. 015	0. 017	0. 0032	323. 10	0. 00061	0. 00011	0. 00015
Singapore air passengers	−282. 50	19. 64	0. 25	0. 26	–	–	–	–
China air freight	−453. 90	5. 096	0. 023	0. 027	–	–	–	–
U.S. air freight	949. 90	15. 76	37. 09	38. 13	929. 70	2. 39	11. 12	14. 74
Singapore air freight	−796. 30	12. 33	0. 0071	0. 0073	−905. 30	3. 17	0. 0029	0. 0038

The results show that when both the two-parameter model and the three-parameter model are valid, the three-parameter model performs better than the two-parameter model.

Model Selection Results

Table 3. Intervention model choices for 3-month short-term intervention.

Indicators	Linear intervention	Non-linear intervention	
		Three-parameter	Two-parameter
China air passengers	×	×	√
U.S. air passengers	×	√	×
Singapore air passengers	×	√	×
China air freight	×	×	√
U.S. air freight	×	√	×
Singapore air freight	×	×	√

√ denotes the selected model form.

Table 4. Intervention model choices for 6-month short-term intervention.

Indicators	Linear intervention	Non-linear intervention	
		Three-parameter	Two-parameter
China air passengers	×	√	×
U.S. air passengers	×	√	×
Singapore air passengers	×	×	√
China air freight	×	×	√
U.S. air freight	×	√	×
Singapore air freight	×	√	×

√ denotes the selected model form.

Model Results

Table 5.1. SARIMA intervention results for 3-month short-term intervention.

Indicators	Estimated coefficients						Model performance		
	AR(1)	MA(1)	SMA(12)	ω_0	ω_1	δ	Adj-R^2	AIC	MAPE (%)
China air passengers	-	0.9077	0.2428	-	-19.475	0.829	0.95	503.8	3.84
U.S. air passengers	-	0.7241	-0.5158	-38.531	-22.980	0.752	0.99	323.1	1.32
Singapore air passengers	0.3750	0.7883	-	-0.462	0.474	0.769	0.98	-395.7	3.11
China air freight	-0.3797	0.7748	-	-	-0.0683	0.801	0.89	-457.6	4.27
U.S. air freight	-0.3481	-	0.6298	-203.699	239.825	-0.647	0.96	929.7	2.41
Singapore air freight	-	0.2155	0.6179	-	0.0117	-0.456	0.61	-793.8	4.27

D and *d* are both equal to 1, and all estimated coefficients are significant at the 0.05 significance level.

Intervention structures

$$g_2(1, \xi, t) = \frac{\omega_0 - \omega_1 B}{1 - \delta B}(S_t^{\,T} - S_t^{\,T+m}),\ m = 3\ or\ 6$$

Table 5.2. SARIMA intervention results for 6-month short-term intervention.

Indicators	Estimated coefficients						Model performance		
	AR(1)	MA(1)	SMA(12)	ω_0	ω_1	δ	Adj-R^2	AIC	MAPE (%)
China air passengers	-	0.7775	0.4601	-5.567	42.877	-0.211	0.98	385.9	2.74
U.S. air passengers	-	0.7241	-0.5158	-38.531	-22.980	0.752	0.99	323.1	1.32
Singapore air passengers	-0.8034	-0.8807	-	-	-0.649	0.812	0.94	-282.5	4.56
China air freight	-0.3797	0.7748	-	-	-0.0683	0.801	0.88	-457.6	4.41
U.S. air freight	-0.3481	-	0.6298	-203.699	239.825	-0.647	0.96	929.7	2.41
Singapore air freight	-	0.6657	0.5828	0.0125	0.0476	0.487	0.88	-905.3	3.25

D and *d* are both equal to 1, and all estimated coefficients are significant at the 0.05 significance level.

Model Results

Table 5.3. SARIMA intervention results for long-term intervention.

	Estimated coefficients					Model performance		
Indicators	AR(1)	MA(1)	SMA(12)	ω_1	δ	Adj-R^2	AIC	MAPE (%)
China air passengers	-	0.3018	0.5804	-44.143	-0.147	0.98	400.8	2.82
U.S. air passengers	-	0.9629	-0.4056	-43.409	0.453	0.98	369.6	3.23
Singapore air passengers	-0.8034	-0.8806	-	-0.649	0.8119	0.94	-282.5	4.56
China air freight	-0.3688	0.7810	-	-0.0912	0.356	0.88	-453.9	4.42
U.S. air freight	-0.5474	-	0.5627	-235.771	0.196	0.95	949.9	2.11
Singapore air freight	-	0.0706	0.6313	0.0213	-0.417	0.87	-796.3	3.43

D and *d* are both equal to 1, and all estimated coefficients are significant at the 0.05 significance level.

Intervention structure

$$g_2(1, \xi, t) = \frac{\omega_1 B}{1 - \delta B} S_t^{\ T}$$

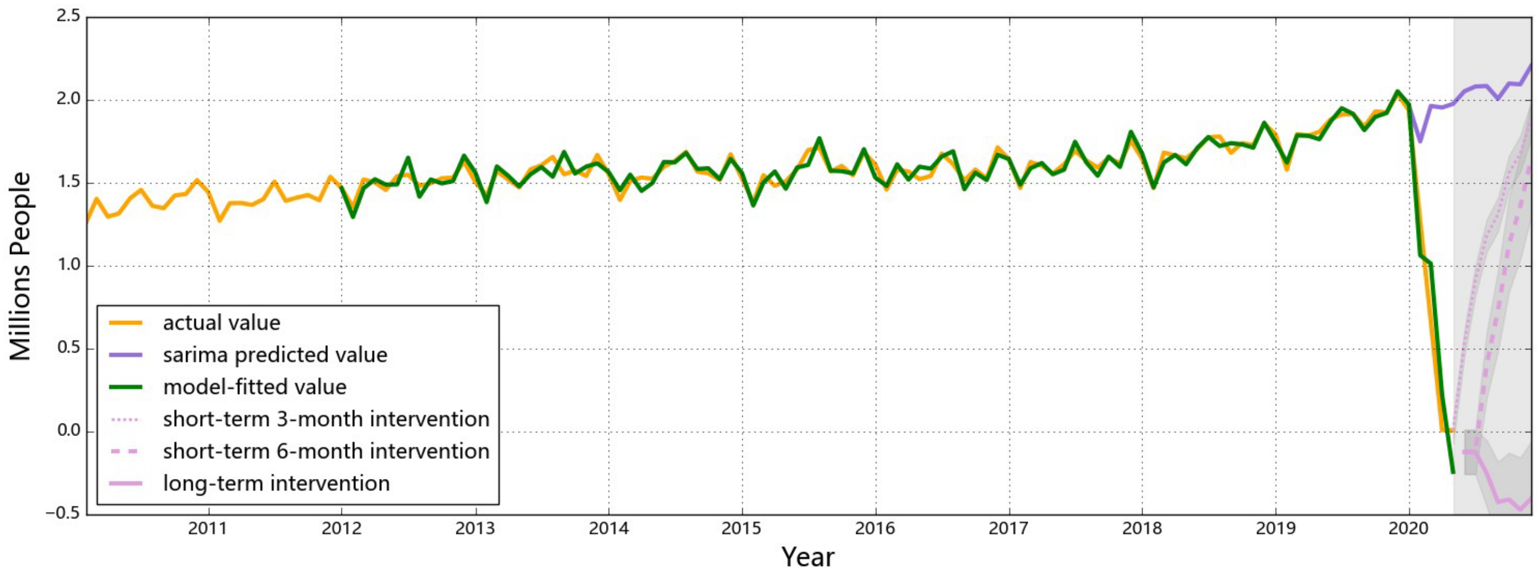
3、Results Discussion and Suggestions

China Air Passengers

Control measures：
Jan 23rd: human-to-human transmission was confirmed, and Wuhan city was locked down. Airports and train stations were closed temporarily. (Air passengers decline)
Mar 12th: Civil Aviation Administration of China (CAAC) controlled the total number of international arriving passenger Flights.
Mar 26th: CAAC announced “Five Ones” policy. (Air passengers began to increase)

Fig 1. Predictions for air passengers in China. The observed data dropped from 50.6 million in Jan , 2020 to 8.3 million in Feb of the same year. For the short-term intervention scenario (as shown by the solid pink line), air passenger will rebound to 74.1 million in Aug and then gradually drop back to the level as the SARIMA predictions (i.e. the purple line).

Singapore Air Passengers



Control measures：

Feb 18th: Singapore Airline and Silkair announced plans for massive international flight cancellations over the network.

Mar 3rd: travel advisories were issued by the Ministry of Foreign Affairs targeting at banning visitors from South Korea, Iran, Northern Italy, etc.

Apr 3rd: circuit breaker (CB) was initially enforced with control measures including closing nonessential workplaces, schools transitioned to home-based learning.

Fig 2. Predictions for air passengers in Singapore. The drop of the observed number of air passengers in Singapore is almost linear at the beginning of 2020, and the value has reached 0.009 million in Apr. The hybrid model predicts that the decreasing trend of air passenger traffic will last till the end of 2020, but the actual numbers will be at thousand level. The air passenger is predicted to be unable to recover to the normal level (the purple line) within this year for both short-term and long-term interventions.

U.S. Air Passengers

Control measures：

March 11th: President Trump issued an order restricting travel to the US from certain European countries with high risk levels. Universities and colleges suspended in-person classes.

March 23rd: stay-at-home orders were issued in 20 states either statewide or in part of the state.

Fig 3. Predictions for air passengers in the U.S. An obvious decline in the number of American air passenger is observed from Feb to Apr, 2020 (from 59.8 to 2.6 million), and then the number flautas to 7.6 million in May. The number will keep dropping to 0 level if the intervention is valid till the end of 2020 (shown as the pink dashes), yet a rebound will occur in Sep at the end if the intervention ends after six-month (shown as the solid pink line).

Air Passengers Discussions

- Impacts from long-term control measures

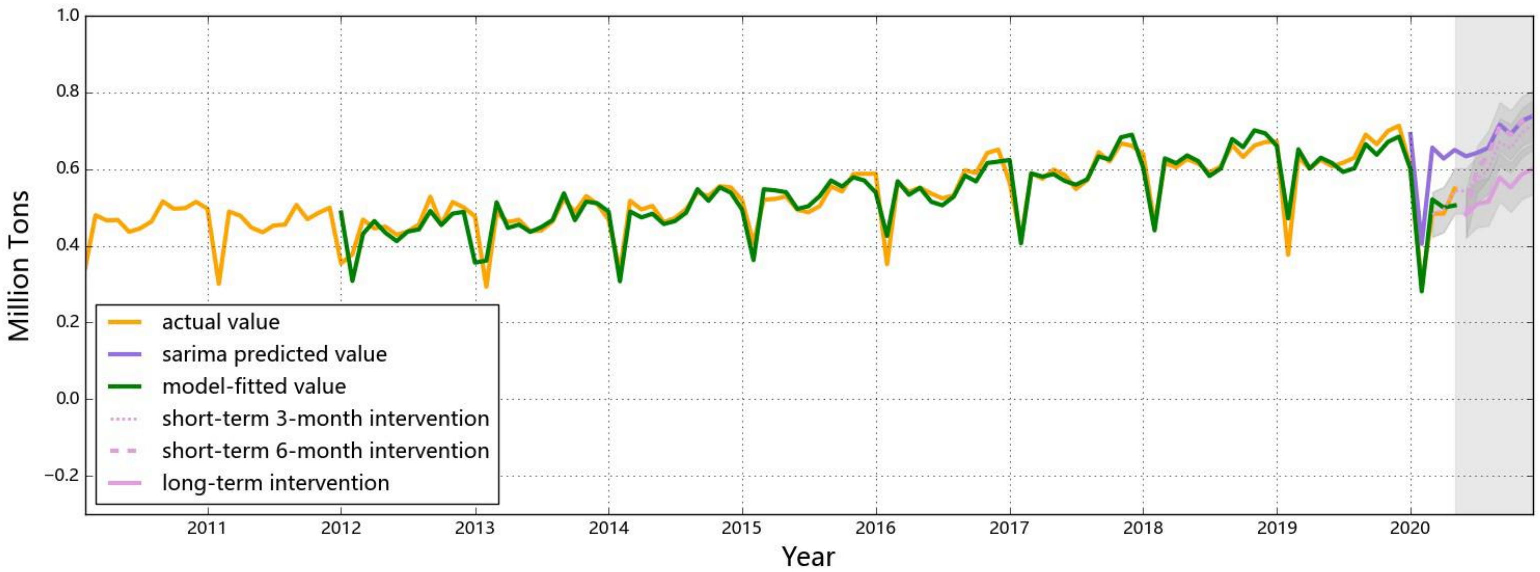
For air passengers, different patterns between China, Singapore and the U.S. are found if the intervention last till the end of 2020 (see Figs 1 to 3).

- A drop in Chinese air passengers were observed in Jan followed by a drastic plunge (a decrease by 83.5%) in Feb. Owing to the strict lock-down measures (influencing the movements of over 40 million people) and the domestic and international travel bans, the situation of the epidemic in China was controlled to a safe level by the end of Feb.
- The largest percentage decrease in air passengers for the U.S. appeared in Apr (i.e. a 92% decrease relative to Mar), indicating that the impact from domestic and international restrictions in traveling still remained severe in Apr.
- Similar patterns to the U.S. air passengers are found for Singapore: a stark drop from Feb to Apr is observed and the values almost hit zero in Apr and May.

- Impacts from short-term control measures

If the control measures could effectively contain the situation of COVID-19 within 6 months, releasing these measures and reactivating certain markets would be expected. Air passenger numbers in the three selected countries would all be bounding up, but the shapes of the ‘V”s are different.

China Air Freight



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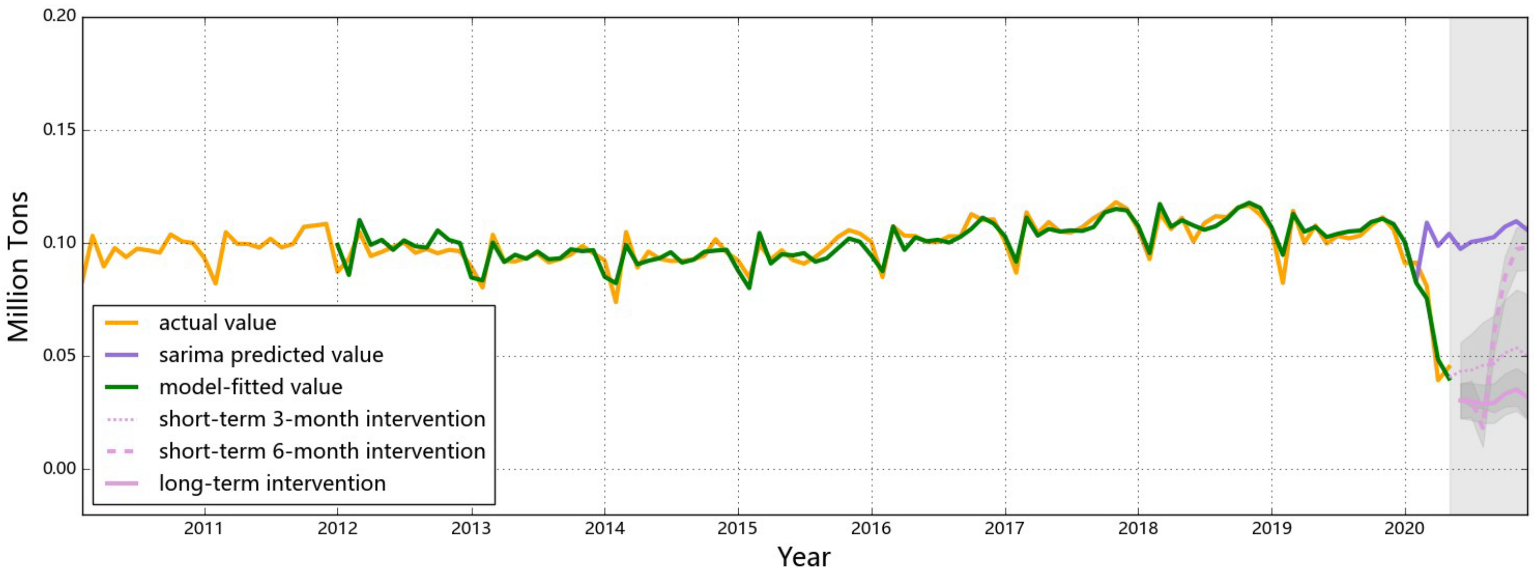
Mar 12th: Civil Aviation Administration of China (CAAC) controlled the total number of international arriving passenger Flights.

Mar 26th: CAAC announced "Five Ones" policy. (Air passengers began to increase)

Fig 4. Predictions for air freight in China. China air freight was mostly impacted in Feb, Mar and Apr, 2020, but the distances between the predicted values without intervention (the purple line) and the actual values (the yellow line) are almost the same for these three months (i.e. 0.12, 0.14 and 0.13 for the three months, respectively). The numbers are predicted to rebound to normal level once the intervention ends in Jun (as shown by the solid pink line).

Singapore Air Freight



Control measures:

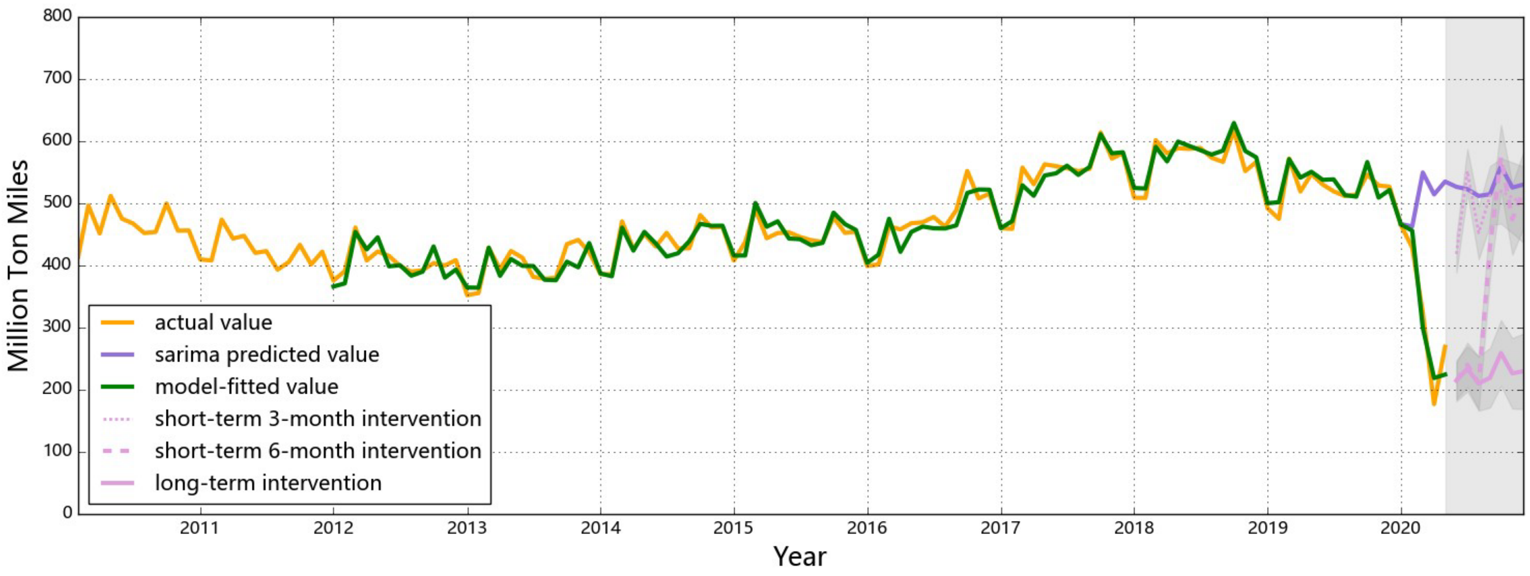
Feb 18th: Singapore Airline and Silkair announced plans for massive international flight cancellations over the network.

Mar 3rd: travel advisories were issued by the Ministry of Foreign Affairs targeting at banning visitors from South Korea, Iran, Northern Italy, etc.

Apr 3rd: circuit breaker (CB) was initially enforced with control measures including closing nonessential workplaces, schools transitioned to home-based learning.

Fig 5. Predictions for air freight in Singapore. The actual air freight traffic in Singapore has been dropping from Feb (0.081 million tons) till Apr, 2020 (0.039 million tons). Since it stops decreasing from May, the number will keep fluctuating if the same policies last till the end of the year. Nonetheless, air freight will not recover to the normal level (represented by the purple line) for both scenarios.

U.S. Air Passengers



Control measures：

March 11th: President Trump issued an order restricting travel to the US from certain European countries with high risk levels. Universities and colleges suspended in-person classes.

March 23rd: stay-at-home orders were issued in 20 states either statewide or in part of the state.

Fig 6. Predictions for air freight in the U.S. The lowest point of air freight turnover in the U.S. was in Apr, 2020 at 177.0 million ton-miles. For the short-term intervention, the number will quickly rebound to 524 million ton-miles in Sep (shown as the solid pink line). If the same control policies last the whole year, the numbers will fluctuate around 230 million ton-miles till yearend.

Air Freight Discussions

➢ Impacts from long-term control measures

For air cargo transportation, China once again had a distinct pattern in terms of the observed impact from the intervention and the predicted trends if the intervention pertains for the rest of the year, compared to the other selected countries (see Figs 4 to 6).

- In the first and second month since the outbreak of the pandemic, third-party logistics in China has been impacted severely since local travel controls have been widely applied. The rebound in Mar indicates that air freight in China has been under recovery.
- For the U.S. air cargo industry, the start of the year has always been the lowest point annually, but the continuous plunges in Mar and Apr have to be explained by the impacts from the control measures.
- Flight cancellations and the circuit breaker (CB) were issued in Mar and Apr in Singapore, respectively, and pertaining the same measures would keep its air freight at a low level

➢ Impacts from short-term control measures

China, with comprehensively the strictest control measures has undergone a rather temporary impact on the air cargo level and is expected to retrieve its normal air cargo level within two months once the control policies are canceled. Comparatively, air transportation of goods in the U.S. and Singapore would be influenced for relatively longer time, although the number would finally rebound if the control policies are called off.

Relative changes (%) compared to 2019 (Long-term intervention)

Table 6. Relative changes (%) compared to 2019 for 3-month intervention.

Indicators	Jan.	Feb.	Mar.	Apr.	May.	Jun.	Jul.	Aug.	Sept.	Oct.	Nov.	Dec.	total
China air passenger	-9	-85	-74	-69	-56	-47	-34	-27	-26	-20	-18	-15	-40
U.S. air passenger	-	-	-53	-96	-90	35	4	3	2	2	1	1	-26
Singapore air passenger	-	-27	-66	-100	-100	-74	-56	-43	-34	-25	-20	-14	-50
China air cargo	-12	-27	-26	-21	-16	-14	-11	-9	-6	-5	-4	-3	-12
U.S. air cargo	-	-	-39	-64	-47	-17	11	-7	5	-3	2	-1	-16
Singapore air cargo	-	-9	-2	-64	-59	-59	-56	-55	-54	-50	-50	-55	-48

Table 7. Relative changes (%) compared to 2019 for 6-month intervention.

Indicators	Jan.	Feb.	Mar.	Apr.	May.	Jun.	Jul.	Aug.	Sept.	Oct.	Nov.	Dec.	total
China air passenger	-9	-85	-74	-71	-55	-64	-59	16	-8	-2	-1	-1	-32
U.S. air passenger	-	-	-53	-96	-90	-86	-83	-85	-38	6	4	3	-53
Singapore air passenger	-	-27	-66	-100	-100	-99	-106	-81	-63	-46	-35	-25	-68
China air cargo	-12	-27	-26	-23	-16	-24	-7	-3	0	0	0	0	-11
U.S. air cargo	-	-	-39	-64	-47	-41	-37	-36	7	27	15	8	-20
Singapore air cargo	-	-9	-2	-64	-55	-71	-70	-72	-38	-17	-9	-9	-38

Table 8. Relative changes (%) compared to 2019 for long-term intervention.

Indicators	Jan.	Feb.	Mar.	Apr.	May.	Jun.	Jul.	Aug.	Sept.	Oct.	Nov.	Dec.	total
China air passenger	-9	-85	-74	-71	-55	-61	-56	-54	-59	-57	-60	-60	-58
U.S. air passenger	-	-	-53	-96	-90	-97	-96	-100	-114	-105	-112	-107	-97
Singapore air passenger	-	-27	-66	-100	-100	-99	-106	-112	-121	-120	-123	-118	-101
China air cargo	-12	-27	-26	-23	-16	-24	-21	-21	-19	-20	-19	-19	-20
U.S. air cargo	-	-	-39	-64	-47	-57	-53	-57	-55	-51	-55	-54	-53
Singapore air cargo	-	-9	-2	-64	-55	-71	-70	-72	-71	-68	-67	-71	-58

Compared to 2019, the decrease in monthly numbers of air passengers in China would fluctuate between 54% to 61% in the second half of 2020. A total loss of 409.1 million passengers will be reached in 2020 (incurring a 58.4% annual decrease compared to the predictions from the SARIMA model), leading to an approximately 605.7 billion CNY (87.0 billion USD) revenue loss in the industry. The percentage change in the monthly air cargo tonnages in the second half of 2020 ranges from 19% to 21%.

Summary

- **Objective：** This study investigated the impact of different control measures for COVID-19 on the air transportation industry in China, Singapore and the United States based on SARIMA intervention model, with the aim to draw implications for countries to efficiently contain the epidemic while maintaining economy growth in case of potential pandemic in the future.

- **Method：** This study applies a hybrid SARIMA-based intervention model to measure the differences in the impacts of different control measures implemented in China, the U.S. and Singapore on air passenger and air freight traffic. To explore the effect of time span for the measures to be in force, two scenarios are invented, namely a long-term intervention and a short-term intervention, and predictions are made till the end of 2020 for all three countries under both scenarios.

- **Results：** As a result, predictive patterns of the selected metrics for the three countries are rather different. China is predicted to have the mildest economic impact on the air transportation industry in this year in terms of air passenger revenue and air cargo traffic, provided that the control measures were prompt and effective. The U.S. would suffer from a far-reaching impact on the industry if the same control measures are maintained. More uncertainties are found for Singapore, as it is strongly associated with international travel demands.

Conclusions

- ✓ The three selected countries have implemented different strategies to control the spread of COVID-19. The different patterns found in the results indicate that stricter and more effective measurements would possibly render larger impacts on the air transportation industry shortly.
- ✓ Choices of the epidemic control policies and their impacts on the industry, and very possibly on the total economy, are found to be dependent with the certain features of the local market, and hence the best way to find a balance varies from country to country, from market to market.
- ✓ For China, when the unfamiliar epidemic first raided its Wuhan City and disseminated fast to the whole country, it has quickly implemented relatively more strict control measures, having caused temporary drastic plunges in its air transportation industry. Since the measures were effective in controlling the epidemic, China gradually loosened the control measures and the passenger and cargo transport started to recover within two months. The next step for China is surely to gradually restore human mobility and freight transportation, under the condition that the importation and domestic transmission of COVID-19 is well controlled.
- ✓ The U.S. has a strong demand for related markets in both air passenger and freight transportation, and, at the same time, has a strong capability to serve the demand. Hence, the most urgent task for the U.S. is to implement more strict measures to confine the virus from spreading domestically, possibly sacrificing the more industrial and economical revenues for a short period of time.
- ✓ To balance the industrial losses and the development of COVID-19 situation, the Singaporean government is suggested to keep the pace to relax the CB and to introduce policies that may stimulate domestic consuming demands. On the supply side, airlines from low-risk countries could be conditionally open, yet the screening of the COVID-19 suspects should always be as strict as possible.

Thanks for Listening !