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The effect of COVID-19 pandemic on port performance: Evidence from China

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ABSTRACT

The COVID-19 outbreak has had a serious effect on the global economy, particularly the volume of port trade between imports and exports. We construct a panel regression model with month as time series where panel data from 14 major ports in China from January to October 2020 to analyze how the macro economy, the severity of the epidemic, and government control measures affect port operations. Based on the results, we have identified the key factors affecting port operations in the context of the pandemic and the managerial insights can help shipping company, port operator and government to change the strategy to copy with the effect of COVID-19 pandemic.

1. Introduction

The COVID-19 pandemic is spreading in many parts of the world to impact all aspects of human society (Corlett et al., 2020; Chen et al., 2020; Wan et al., 2020) where negative influences on port throughput mainly includes closure of shipping line, transportation market disruption and increased healthy risk of international goods (Campbell et al., 1920). Because of the increased mobility, enhanced connectivity and increasing efficiency of international trade have been become a double-edged sword. Therefore, shipping mobility has allowed more goods to transport to more and remote ports, there undoubtedly contributes to the risk of spreading pandemic. In China, the reports of influences on export and import trades in many sectors including transportation, have even far-reaching impacts on the agricultural, industry and living standard.

China imports from Japan, South Korea, for example, electrical, electrical, audio and video equipment and accessories, zero upgrades will affect China's imports of such products. Next, the outbreaks in Japan and South Korea affected midstream industries such as metal products, plastics and chemicals, leading to shortages of raw materials. In the end, the negative impact of the pandemic will be passed on to consumer electronics, automobiles and other downstream industries. At the same time, the government temporarily changed the original export and tariff policy, restricting the export of medical supplies, medicines, grain and other products (Simon 2020). For shipping industry, India, Australia and Turkey have implemented the quarantine control for ships entering the port for 14 days, which makes the sailing time of ships longer, the sailing plan disrupted, the containers cannot arrive at the port to unload on time, and even face the crisis of shipping stoppage.

Beyond that, these ports underpin the international trade, most lack the ability to cope with epidemic shocks (Corbet et al., 2020). The volume of international trade is one of the main factors affecting port throughput where mainly simulates the growth of container transportation. For China, impacted by the outbreak of COVID-19, the international trade has seriously hindered, and the container scale has greatly reduced. From the view of port throughput with designated size, port throughput increased from 2015 to 2019, reaching 261.07 million TEU in 2019 whereas decreased by 1.3% from January to September in 2020because the COVID-2019 leads to the hindered international trade. The year-on-year growth of the throughput of China's ports above designated size is shown in Fig. 1.

The international trade between export and import volumes during the pandemic are distributed unevenly in space and across different periods. Hence, two questions need to be further answered: (1) How much the decline in international trade can be explained by the outbreak of COVID-19? (2) How much do the factors of COVID-19, government and economics contribute to the decline of international trade? To solve the above-mentioned questions, we build a panel regression model with month as time series where panel data from 14 major ports in China from January to October 2020 including the port operation indicators,

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macroeconomic indicator, epidemic severity indicator and government control indicator were analyzed. On the one hand, the pandemic has a significant negative effect on import and export throughput, while government control measures have a certain degree of positive effect on exports, while import throughput is not affected. On the other hand, in the context of the pandemic, the time effect of import throughput is more obvious, and the traditional peak season for shipping from June to September is still maintained. However, due to the impact of the pandemic, export throughput no longer has a clear difference between low and peak seasons. Based on the results, the managerial insights can help shipping company, port operator and government to change the strategy to copy with the effect of COVID-19 pandemic.

2. Literature review

Beginning in early 2020, the COVID-19 pandemic broke out suddenly and quickly spread to various countries around the world. As of 24:00 on October 31, a total of about 56,4962,000 confirmed cases and 7,479,000 deaths have been reported globally. Many countries implementing unparalleled mobility restrictions to control the spread of the virus (March et al., 2020). For example, many governments have adopted restrictive measures to reduce citizens' social activities and suspended the operations of some companies to reduce contact between people (Lau et al., 2020). Besides, facts have proved that curbing population movement is one of the effective ways to respond to public health emergencies and stop the spread of the epidemic (Chen et al., 2020).

With the implementation of quarantine measures such as work stoppages, production shutdowns, and even "city closures", commercial consumption, logistics and transportation have suffered heavy losses. Luo and Tsang, 2020 pointed out that the impact of the COVID-19 pandemic has caused global output in 2020 to drop by 1.0% year-on-year. At the same time, according to the analysis report on the impact of the COVID-19 pandemic on the global economy released by the United Nations Conference on Trade and Development (UNTCAD 2020) in March et al., 2020, the epidemic will become a major threat to the global economy and may cause the annual growth rate of the global economy to drop to 2.5% in 2020.

As the most efficient, reliable and effective means of transportation, shipping is especially important in keeping the world supply chain open during this challenging period (Cleopatra 2020). In particular, the behavior of human activities in the ocean have been radically altered by the COVID-19 pandemic, with port restrictions and changes in consumption patterns impacting multiple maritime sectors most notably fisheries, passenger ferries and cruise ships sectors which rely heavily on the movement of people and goods (Bennett et al., 2020; Depellegrin et al., 2020; Wan et al., 2019). For example, In the first quarter of 2020, the cargo throughput of China's ports was approximately 3.073 billion tons, a year-on-year decrease of 4.6%. The international cruise tourism market has entered the stagnation of the entire industry. Take Carnival Corporation as an example. After the COVID-19 outbreak, the company's stock price dropped $50 to a low of $7.80, wiping nearly $24 billion off its market value to just $6 billion (Rocklöv et al., 2020; Hanaoka et al., 2020).

In order to explore the impact of finance, transportation and various industries during the pandemic period, many scholars have conducted research on this. Scholars in the financial field have mainly studied the characteristics and reasons of stock volatility under the background of the pandemic. Al-Awadhi et al. (2020) used a panel data model to analyze the impact of daily newly confirmed cases on the average daily return of listed companies. The results show that the daily newly confirmed cases are negatively correlated with the stock returns of listed companies that day. Liu et al. (2020) analyzed the mechanism of the impact of the COVID-19 pandemic on the stock market in the short term, and found that investors' expectations and emotional fluctuations during the pandemic are the main reasons for stock price changes in the short term. Xiong et al. (2020) conducted a survey of people in eight countries including China and Spain and found that negative emotions such as anxiety and depression were relatively high during the COVID-19 pandemic. Michail and Melas (2020) used GARCH regression and impulse response of the value-at-risk model to capture how the shipping market responded to COVID-19. Experimental results proved that COVID-19 had a negative impact on dry bulk and crude oil vessels.

By summarizing the literature on the COVID-19 pandemic, it can be found that the current research objects are mainly concentrated in the economic or financial fields, and there are few analyses on the maritime industry. In addition, the research goal of most of the literature is to explore the correlation between indicators and the pandemic, without considering the impact of government control measures and the cycle of the economy itself. Therefore, this paper takes the import and export throughput of China's major ports as the explanatory variable, and selects 4 indicators representing consumption, industry, government control measures, and the severity of the epidemic as the explanatory variables. The panel data model composed of the above monthly data is used to study the key factors affecting port throughput in the context of the pandemic. In addition, by adding time dummy variables to the model, we also investigated whether the cycle of the shipping industry has changed. The model also reveals the advantages and disadvantages of government control measures in the shipping industry. Our research fills the gaps in the existing literature and helps shipping companies make strategic decisions.

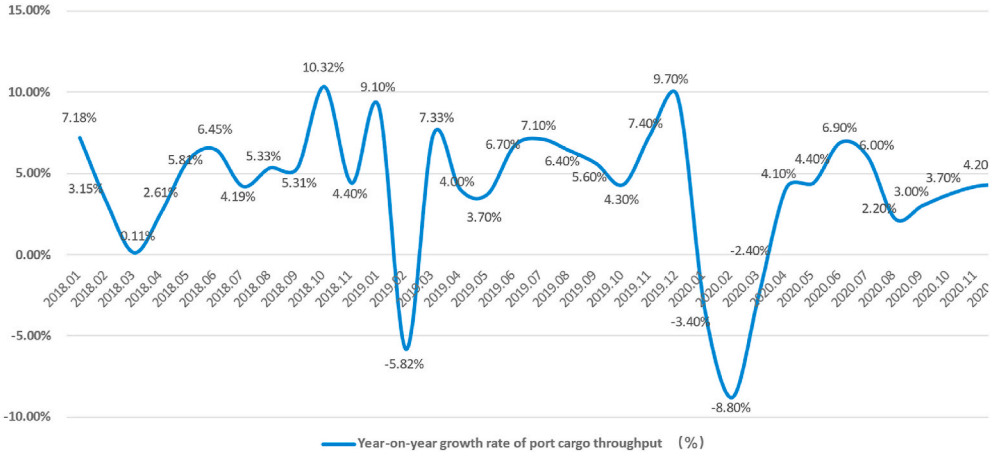

Fig. 1. *Year-on-year growth rate of cargo throughput at ports above designated size in China from January 2018 to December 2020.*

3. Data

We collect a set of panel data from 14 major ports in China over the period January to October 2020 consisting of port throughput, macroeconomic level, pandemic transmit and government control. The port throughput and the macroeconomic level are provided from the China Ports Yearbook. In addition, the pandemic transmit and government control are obtained from the open data in Ministry of Health where the ports locate. Constrained by the data acquisition, four independent variables, which can be classified into four categories as shown in Table 1, are carefully picked as follows:

(a) *Industrial added value*: IAV is the result of industrial production activities expressed in monetary form by industrial enterprises during the reporting period. This ratio helps us to gauge the health of China's big industrial companies.
(b) *Confirmed case characteristics*: We choose the cumulative number of confirmed cases to measure the severity of COVID-19 pandemic in the different port (Ashraf, 2020).
(c) *Stringency index characteristics*: Stringency index is published by Oxford COVID-19 Government Response Tracker (OxCGRT) database. It records information on social distancing, which is a lagging indicator on subsequent economic activity. Thus, we use the first-order lag of stringency index as independent variable (Michail et al., 2020).
(d) *CPI characteristics*: *CPI* is a macroeconomic indicator reflecting changes in the price level of good and service generally purchased by households, which has a high correlation with GDP and can reflect the region's macroeconomic development (Shan et al. 2018).

Although Chinese ports are with designated size, we select those ports have sufficient data to be representative of located region in the COVID-19 pandemic as shown in Fig. 2 where consists of the three ports (*Dalian*, *Tangshan* and *Tianjin*) belonging to Bohai Sea, three ports (*Lianyungang*, *Qingdao* and *Rizhao*) belonging to Yellow Sea, two ports (*Ningbo-Zhoushan* and *Shanghai*) belonging to Yangtze River Delta, three ports (*Fuzhou*, *Quanzhou* and *Xiamen*) belonging to Taiwan Strait, two ports (*Guangzhou* and *Shenzhen*) belonging to Pearl River Delta and one port (*Zhanjiang*) belonging to Beibu Gulf.

In order to study the key factors affecting port operations in the context of COVID-19, we established a panel regression model. The cargo throughput is widely accepted as an important indicator of port productivity (Cheung and Yip, 2011). Therefore, in this paper, the dependent variables are export cargo throughput (EcT) and import cargo throughput (IcT), respectively where is usually measured tonnage including containerized cargo, bulk cargo and oil. We summary that the correlation coefficient among the variables in Table 2, except for the linear correlation between import and export cargo throughput in the same month of 2019, there is no multicollinearity problem among other explanatory variables. However, because they do not appear in the same equation, the linear relationship between them can be ignored.

Fig. 2. The ports and regions analyzed in this study.

Table 2
Correlation coefficients of variables.

	Cum	Stri	IAV	CPI	LIcT	LEcT
Cum	1					
Stri	0.124	1				
IAV	0.332	0.00870	1			
CPI	−0.130	0.00720	−0.656	1		
LIcT	0.136	−0.0196	0.0847	−0.294	1	
LEcT	0.0871	−0.0194	0.0489	−0.284	0.859	1

4. Methodology

In this subsection, to investigate the key factors affecting the cargo throughput in the context of the COVID-19 pandemic, we employ a panel linear regression model. Further, the logarithm of cumulative confirmed case is considered to ensure the possibility of a non-linear relationship with explanatory variables because logarithmic transformation makes the estimated coefficient is robust for the unit of measurement of the variable (Shan et al., 2014). To further investigate the impact of COVID-19 pandemic on import and export cargo throughput, we first build a mixed effected model as a benchmark to analyze panel linear regression as follows

$$Y_{i,t} = \alpha_0 + \beta_1 \log\left(Cum_{i,t}\right) + \beta_2 Stri_{i,t-1} + \beta_3 CPI_{i,t} + \beta_4 IAV_{i,t} + \alpha_1 LcT_{i,t} + \varepsilon_{i,t} \quad (1)$$

Table 1
Descriptive statistics of variables.

Variable	Description	Unit	Mean	SD	Min	Max
IcT	Import cargo throughput	Million ton	2230.97	1349.37	450.67	6743.15
EcT	Export cargo throughput	Million ton	1590.25	1099.42	194.83	5124.41
Cum	Cumulative confirmed cases	Units	553.97	428.87	32.00	1396.00
Stri	Stringency index	%	71.01	8.51	58.33	79.80
IAV	Industrial added value	%	−1.88	7.28	−21.80	11.50
CPI	Consumer Price Index	%	102.92	1.37	99.70	106.70
LIcT	Import cargo throughput in 2019	Million ton	2130.32	1258.14	655.64	5833.20
LEcT	Export cargo throughput in 2019	Million ton	1588.01	1067.31	219.51	5101.98

where subscript i shows the port index, t is the temporal index, α and β are understood as the vector of independent variable. $Y_{i,t}$ is a dependent variable representing the import cargo throughput of port$i$ and $\varepsilon_{i,t}$ is the idiosyncratic error term. Because each port exists non-individual effect, to further investigate the individual effect on the import and export cargo throughput, we introduce an individual effect item in the benchmark model. Due to the existence of two forms of individual effects, it can be divided into random effects model (REM) and fixed effects model (FEM).

Random Effects Model is also called the Error component model or generalized least square technique. This model estimates panel data in which interference variables may be correlated over time and between individuals. In the random effect model, the differences between intercepts are accommodated by the error terms of each port (Zulfikar et al., 2018). The regression equation of panel data of random effects model is as follows

$$Y_{i,t} = \alpha_0 + \beta_1 \log\left(Cum_{i,t}\right) + \beta_2 Stri_{i,t-1} + \beta_3 CPI_{i,t} + \beta_4 IAV_{i,t} + \alpha_1 LcT_{i,t} + \delta_i + \varepsilon_{i,t} \quad (2)$$

where δ_i is the is the individual residual which is the random characteristic of port i. This model assumes that there is a difference of intercept for each individual and the intercept is a random variable. However, the difference between fixed effect model and random effect model is μ_i is not correlated with explanatory variable $X_{i,t}$; otherwise, in random effect model, the result is almost the opposite. Thus, we can describe the model as

$$Y_{i,t} = \alpha_0 + \beta_1 \log\left(Cum_{i,t}\right) + \beta_2 Stri_{i,t-1} + \beta_3 CPI_{i,t} + \beta_4 IAV_{i,t} + \alpha_1 LcT_{i,t} + \mu_i + \varepsilon_{i,t} \quad (3)$$

where μ_i is the unobserved fixed effect for port i. A city's time-invariant features affect its economy and seaport. For example, the Shanghai port serves as a transshipment hub between ocean transport and river transport, while the Qinhuangdao port mainly serves as an export gateway for raw materials. There is no good way to quantify those effects, but including specific fixed effect term μ_i for each port suffices for our purpose. Additionally, the effect of time factor on cargo throughput in the context of COVID-19 pandemic, we also employ the time fixed effect to build the two-tier fixed effect model as follows

$$Y_{i,t} = \alpha_0 + \beta_1 \log\left(Cum_{i,t}\right) + \beta_2 Stri_{i,t-1} + \beta_3 CPI_{i,t} + \beta_4 IAV_{i,t} + \alpha_1 LcT_{i,t} + v_t + \mu_i + \varepsilon_{i,t} \quad (4)$$

For the four approaches, the cluster-robust standard error to estimate p-value in the regressions is consider to prevent unstable regression caused by the heteroscedasticity and serial correlation (Petersen 2009).

5. Empirical analysis

The regression models of panel data include fixed effects model (FEM), random effects model (REM) and mixed effects model (MEM). Each of the three models has applicable conditions. Therefore, in order to estimate the coefficients α and β more accurately, based on the panel data of 14 ports in China from January to October 2020, we construct a mixed effect model, a random effect model, an individual fixed effect, and a two-way fixed effect on the import and export throughput

Table 3
Regression results of Import and Export.

Variables	Import				Export			
	Model 1	Model 2	Model 3	Model 4	Model 1	Model 2	Model 3	Model 4
Cum	31.330	21.963	−323.504**	−531.128***	67.828	59.809	−279.425*	−459.439***
	(0.278)	(0.424)	(0.016)	(0.004)	(0.258)	(0.251)	(0.091)	(0.005)
Stri [-1]	1.516	1.166	2.558	24.123	3.127*	3.194*	4.192***	102.988*
	(0.303)	(0.440)	(0.243)	(0.115)	(0.050)	(0.063)	(0.000)	(0.061)
IAV	10.607**	13.643**	19.380***	9.398**	0.874	1.520	1.566	−3.517
	(0.028)	(0.050)	(0.001)	(0.037)	(0.849)	(0.786)	(0.689)	(0.123)
CPI	11.244	10.962	−4.510	20.036	−50.254	−72.117	−89.244***	−48.376
	(0.563)	(0.628)	(0.665)	(0.218)	(0.196)	(0.142)	(0.000)	(0.187)
LEcT	1.055***	1.041***	0.686***	0.723***	1.002***	0.983***	0.889***	0.892***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
month2				308.344				1769.343
				(0.316)				(0.134)
month3				−145.606***				5.341
				(0.004)				(0.964)
month4				−111.438***				−273.866***
				(0.004)				(0.000)
month5				426.097				1734.237*
				(0.116)				(0.077)
month6				254.228***				287.579
				(0.001)				(0.118)
month7				123.641***				−24.395***
				(0.000)				(0.004)
month8				81.439***				1.249
				(0.000)				(0.909)
month9				316.256*				1564.352
				(0.087)				(0.102)
month10				447.191*				1864.273*
				(0.091)				(0.055)
Constant	−1468.248	−1322.971	3038.703**	0.000	4552.089	6872.897	10,783.707***	0.000
	(-0.76)	(0.564)	(0.039)	(.)	(0.225)	(0.152)	(0.001)	(.)
Observations	126	126	126	126	126	126	126	126
R-squared	0.977	0.617	0.656	0.732	0.960	0.673	0.681	0.689

Note: Standard errors in parentheses, where ***p < 0.01, **p < 0.05, *p < 0.1. Figures in brackets (·) indicate lagged values, where (−n) is the nth month before the day examined.

respectively. The models are compared and tested to select the optimal model to analyze the key factors affecting port operations under the background of the COVID-19 pandemic.

The regression results of imports are shown in Table 3. After comparison, it is found that for import throughput, the regression coefficients of the individual fixed effects and two-way fixed effects models are more significant. The R^2 of the MEM is the closest to 1, which shows that the MEM has the best fit. Furthermore, we use the F statistic of Chowtest to judge the pros and cons of the MEM and the FEM. The null hypothesis H_0 is all $u_i - u = 0$, that is, there is no individual effect. According to the F test statistics, the p value can be obtained. The calculation result is to reject the null hypothesis, indicating that the establishment of a fixed-effect model is more reasonable than a mixed-effect model. In addition, we can see that the R^2 of the two-way fixed effects model is greater than the individual fixed effects, and the regression coefficients of the time dummy variables in the two-way fixed effects model is significant. Therefore, the two-way fixed effects model is the optimal model.

The regression results of exports are also shown in Table 3. We can see that the regression results of the individual fixed-effects model are the most significant, while the R^2 of the MEM is the closest to 1, indicating that the explanatory variables in the mixed-effects model have the strongest correlation with the explained variables. As before, we again use the F test of Chow's statistics to determine whether to choose a mixed-effects model or a fixed-effects model, and the calculation results also reject the null hypothesis. Therefore, when export cargo throughput is the explained variable, the individual fixed effects model is more suitable.

Industrial added value and the government's strict index of prevention and control have the same impact on the throughput of imported goods and export goods. As shown in column 4 and row 5 of Table 3, import cargo throughput is positively correlated with Industrial added value above designated size and the regression coefficient of IAV is 9.398, which means that for every 9.398% increase in industrial added value, the port's import cargo throughput will increase by 1%. And the p value of the IAV regression parameter is less than 5%, indicating that it is statistically significant at the 95% confidence level. With the recovery and development of the primary industry, the demand for raw materials by enterprises has gradually increased. The import of a large amount of raw materials such as iron ore and rubber has promoted the increase in the port's import throughput. According to Table 3, column 7 and row 5, for export cargo throughput, although the industrial added value has a positive impact on it, the regression results are not statistically significant.

In addition, combining the analysis of row 3, we find the government's strict prevention and control index is positively correlated with both import and export throughput, but the regression result for import cargo throughput is not significant, while the regression result for exports is very significant. The results of FEM model show that the stricter the government's prevention and control measure, the more goods exported. Thus, we have every reason to believe that the prevention and control measures have effectively controlled the domestic pandemic and help the gradual return of the shipping industry to normal. The CPI index has opposite effects on the throughput of imported cargo and the throughput of exported cargo. As shown in row 7, CPI is negatively correlated with port export cargo throughput, the regression coefficient is -89.244, and $p < 0.01$. The rise in CPI leads to inflation, currency devaluation, and a decline in the competitiveness of exported goods, which has led to a decline in exported goods. The CPI is positively correlated with import throughput, with a regression coefficient of 20.036, but the regression results are not significant.

Compared with other factors, the cumulative number of confirmed cases has the greatest impact on the throughput of imported and exported cargo. As shown in the fourth column of Table 3, the import cargo throughput is negatively correlated with the cumulative number of confirmed cases. The estimated coefficient is -531.128 and is statistically significant at $p < 0.001$ level. This means that the severity of the pandemic has largely affected the throughput of imported goods at various ports, which may be directly caused by the company's shutdown. Similarly, Table 3 shows that the export cargo throughput is negatively correlated with the cumulative number of confirmed cases, with a regression coefficient of -279.425, but the p-value of 0.091 is only statistically significant at the 90% confidence level, indicating that the pandemic has limited impact on export cargo throughput. The export of medical and health equipment (including masks, protective clothing, etc.) may alleviate the losses caused by the decrease in the export volume of other products. In addition, under the influence of the pandemic, new demand for home office and home entertainment has recovered strongly, which has also driven the export of furniture and home entertainment facilities.

Moreover, we also find that the coefficients of the dummy variables in March and April are negatively correlated with import throughput, but they are positively correlated after May. We know that the pandemic in China was severe before May and had a greater impact on the shipping industry. After May, thanks to government control and the efforts of medical personnel, the pandemic gradually eased and the shipping industry began to resume normal operations. What is interesting is that time does not have a greater impact on exported goods. This may be related to China's large export of anti-pandemic materials, but the specific reasons are worthy of our further study.

Another point worth noting is that the control variable, the port's import and export cargo throughput in the same month in 2019, has a very significant positive impact on the dependent variable in both models. Therefore, it can be considered that the port's initial scale has a certain impact on the throughput of imported goods, but this is not the focus of our study.

In general, the cumulative number of confirmed cases has had a significant negative impact on the throughput of imported and exported goods, but the throughput of imported goods has been more severely affected by the pandemic. The government's strict prevention and control index only has a significant positive effect on exports. In terms of macroeconomics, the value-added of industries above designated size is significantly positively correlated with the throughput of imported goods, while CPI is significantly negatively correlated with the export cargo throughput. The time effect of import throughput is more significant, but the change of export throughput over time is not obvious. The shipping industry gradually resumed normal operations after May. The results of the model basically agree with the actual situation.

6. Conclusion

In this paper, we collected the relevant panel data of 14 ports in China from January 2020 to October 2020, mainly including epidemic indicators and city-level economic data, to evaluate the impact of various indicators on the operation of Chinese ports under the background of COVID-19 pandemic. Specifically, we employ the port cargo throughput to represent the port operations, import and export goods and put in the same period in 2019 the port cargo throughput as control variables, respectively, using the mixed effects model, random effects model and individual fixed effects model to analyze the import and export throughput. Through relevant theories and empirical analysis, the main conclusions are as follows:

First of all, the severity of the epidemic has a significant negative effect on both import and export cargo throughputs, further the impact of the pandemic on import is greater than export. This may be related to large-scale shutdown of factories during the pandemic and the inclusion of a certain amount of anti-pandemic materials in the export goods. In order to prevent the pandemic from causing a more serious impact on the ship's transportation process, port and shipping companies should conduct pandemic investigation and registration for boarding personnel, and set up fixed cabins as isolation cabins. In addition, the government

should do a good job of supervision to prevent ship transportation from becoming a carrier of spreading the virus.

Secondly, the strict index of government prevention has a significant positive impact on the export cargo throughput, indicating that government prevention plays a certain role in promoting the recovery of shipping industry. However, for import, the government's strict control index does not seem to have much impact, and the reason behind this is worth further study. In addition to the prevention and control of the pandemic, differentiating the severity of the impact of the pandemic on various sectors of the shipping industry, the government can provide targeted policy support. For the waterway passenger transport industry that has been hit hardest, the government can provide financial subsidies to prevent the industry from regressing. For the freight industry, financial concessions such as tax cuts and interest-free loans can enable relevant companies to reduce costs and maintain normal operations.

Finally, at the macroeconomic level, the industrial added value above the designated size has a significant positive correlation with import throughput, but has no significant impact on the export throughput. CPI index has obvious negative correlation with export, on the contrary, it has no significant impact on import. Different economic indicators have different effects on import and export, which may be related to the types of goods, such as imported raw materials needed for industrial production. Affected by the government's monetary easing policy and the replenishment demand of European and American companies, as well as the traditional peak season of the shipping industry, the shipping volume after the pandemic is bound to increase substantially. Therefore, it is necessary to scientifically coordinate all berths, anchorages, waterways and other resources in the port, improve the efficiency of berth loading and unloading, reduce the working time of ships in the port, and avoid large-scale ship congestion waiting to enter the port and channel congestion.

The regression of import and export panel data shows that during the pandemic period, whether the severity of the epidemic, the strict index of government prevention and control or the macroeconomic indicators, all have a great impact on the import and export cargo throughput of the port, that is to say, the operation of the port has been seriously affected. In addition, from the time section, we can see that January to April is a serious pandemic period, and the pandemic tends to ease after May, and the shipping industry can gradually return to normal operation.

In the future, this paper can be expanded in several ways. First, due to the availability of data, our analysis focuses on port cargo activity, which is measured by throughput. But other indicators, such as port investment and handling efficiency, are also worth studying. Secondly, it is also of great significance to investigate the trade exchange between different countries and China, so as to more comprehensively analyze the effects of pandemic on the worldwide ports, especially China. Furthermore, the indicators affecting port operation are not limited to city where the port is located. Future research can analyze how adjacent ports and their hinterland interact. Finally, our study only discussed the impact of various indicators on the overall cargo throughput of the port in the context of the pandemic, and then we could focus on the impact on the throughput of different cargo types.

Declaration of competing interest

The authors declare that there is no conflict of interests regarding the publication of this paper.

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References

Al-Awadhi, A.M., Alsaifi, K., Al-Awadhi, A., Alhammadi, S., 2020. Death and contagious infectious diseases: impact of the COVID-19 virus on stock market returns. Journal of behavioral and experimental finance 27, 100326.

Ashraf, B.N., 2020. Economic impact of government interventions during the COVID-19 pandemic: international evidence from financial markets. Journal of behavioral and experimental finance 27, 100371.

Bennett, N.J., Finkbeiner, E.M., Ban, N.C., Belhabib, D., Jupiter, S.D., Kittinger, J.N., et al., 2020. The COVID-19 pandemic, small-scale fisheries and coastal fishing communities. Coast. Manag. 48 (4), 336–347.

Campbell, S.J., Jakub, R., Valdivia, A., Setiawan, H., Setiawan, A., Cox, C., Box, S., 1920. Immediate impact of COVID-19 across tropical small-scale fishing communities. Ocean Coast Manag. 200, 105485.

Chen, Y., Wang, Y., Wang, H., Hu, Z., Hua, L., 2020. Controlling urban traffic-one of the useful methods to ensure safety in Wuhan based on COVID-19 outbreak. Saf. Sci. 131, 104938.

Cheung, S.M.S., Yip, T.L., 2011. Port city factors and port production: analysis of Chinese ports. Transport. J. 50 (2), 162–175.

Corbet, S., Hou, Y.G., Hu, Y., Larkin, C., Oxley, L., 2020. Any port in a storm: cryptocurrency safe-havens during the COVID-19 pandemic. Econ. Lett. 194, 109377.

Corlett, R.T., Primack, R.B., Devictor, V., Maas, B., Goswami, V.R., Bates, A.E., et al., 2020. Impacts of the coronavirus pandemic on biodiversity conservation. Biol. Conserv. 246, 108571.

Depellegrin, D., Bastianini, M., Fadini, A., Menegon, S., 2020. The effects of COVID-19 induced lockdown measures on maritime settings of a coastal region. Sci. Total Environ. 740, 140123.

Lau, H., Khosrawipour, V., Kocbach, P., Mikolajczyk, A., Schubert, J., Bania, J., Khosrawipour, T., 2020. The positive impact of lockdown in Wuhan on containing the COVID-19 outbreak in China. J. Trav. Med. 27 (3), taaa037.

Liu, Y., Gayle, A.A., Wilder-Smith, A., Rocklöv, J., 2020. The reproductive number of COVID-19 is higher compared to SARS coronavirus. J. Trav. Med.

Luo, S., Tsang, K.P., 2020. China and World output impact of the Hubei lockdown during the coronavirus outbreak. Contemp. Econ. Pol. 38 (4), 583–592.

March, D., Metcalfe, K., Tintoré, J., Godley, B., 2020. Tracking the Global Reduction of Marine Traffic during the COVID-19 Pandemic.

Michail, N.A., Melas, K.D., 2020. Shipping markets in turmoil: an analysis of the Covid-19 outbreak and its implications. Transportation Research Interdisciplinary Perspectives 7, 100178.

Petersen, M.A., 2009. Estimating standard errors in finance panel data sets: comparing approaches. Rev. Financ. Stud. 22 (1), 435–480.

Rocklöv, J., Sjödin, H., Wilder-Smith, A., 2020. COVID-19 outbreak on the Diamond Princess cruise ship: estimating the epidemic potential and effectiveness of public health countermeasures. J. Trav. Med. 27 (3) taaa030.

Shan, J., Yu, M., Lee, C.Y., 2014. An empirical investigation of the seaport's economic impact: evidence from major ports in China. Transport. Res. E Logist. Transport. Rev. 69, 41–53.

Wan, C., Yan, X., Zhang, D., Qu, Z., Yang, Z., 2019. An advanced fuzzy Bayesian-based FMEA approach for assessing maritime supply chain risks. Transport. Res. E Logist. Transport. Rev. 125, 222–240.

Wan, C., Tao, J., Wu, J., Zhang, D., 2020. An analysis of influences of the COVID-19 on the spatial structure of the China' s global shipping network. *Journal of Transport Information and Safety* 38 (2), 129–135 (in Chinses).

Xiong, J., Lipsitz, O., Nasri, F., Lui, L.M., Gill, H., Phan, L., McIntyre, R.S., 2020. Impact of COVID-19 pandemic on mental health in the general population: a systematic review. J. Affect. Disord.