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Measuring the impact of an exogenous factor: An exponential smoothing model of the response of shipping to COVID-19

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ABSTRACT

Following the outbreak of the COVID-19 pandemic, various lockdown strategies restrained global economic growth bringing a significant decline in maritime transportation. However, the previous studies have not adequately recognized the specific impacts of COVID-19 on maritime transportation. In this study, a series of analyses of the Baltic Dry Index (BDI), the China Coastal Bulk Freight Index (CCBFI) and of container throughputs with and without the impact of COVID-19 were carried out to assess changing trends in dry bulk and container transportation. The results show that global dry bulk transportation was largely affected by lockdown policies in the second month during COVID-19, and BDI presented a year-on-year decrease of approximately 35.5% from 2019 to 2020. The CCBFI showed an upward trend in the second month during COVID-19, one month ahead of the BDI. The container throughputs at Shanghai Port, the Ports of Hong Kong, the Ports of Singapore and the Ports of Los Angeles from 2019 to 2020 presented the largest year-on-year drops of approximately 19.6%, 7.1%, 10.6% and 30.9%, respectively. In addition, the authors developed exponential smoothing models of BDI, CCBFI, and container transportation, and calculated the percentage prediction error between the observed and predicted values to examine the impact of exogenous effects on the shipping industry due to the outbreak of COVID-19. The results are consistent with the conclusions obtained from the comparison of BDI, CCBFI, and container transportation during the same period in 2020 and 2019. Finally, on the basis of the findings, smart shipping and special support policies are proposed to reduce the negative impacts of COVID-19.

1. Introduction

The World Health Organization (WHO) officially declared that the outbreak of novel coronavirus constituted a Public Health Emergency of International Concern on January 31, 2020 and characterized the outbreak of Coronavirus Disease (2019) (COVID-19) as one pandemic event on March 11, 2020 (World Health Organization (WHO), 2020). To control the spread of the epidemic, governments worldwide have adopted various levels of prevention and control measures, such as work stoppages and restrictions on travel and ship traffic activities (Depellegrin et al., 2020; Lau et al., 2020; McKechnie and Fernando, 2021). Generally, these measures can interrupt the transmission cycle to effectively block propagation of the highly infectious virus, thereby reducing the COVID-19 impact (Yen et al., 2020). However, such measures could hinder the world economy’s development, resulting in a cliff-like decrease in international trade and the transportation volume (Shi and Weng, 2021).

As an essential freight transportation mode, international maritime transportation accounts for 90% of the total freight volume (Lin et al., 2019; Zhang et al., 2019). As the main undertaker of international trade, the shipping industry bore the brunt of COVID-19. Faced with weak transportation demand, liner companies cancelled some routes to reduce costs (Menhat et al., 2021). The Maritime Safety Agency (EMSA) published a report on November 27, 2020, suggesting that cruise and cargo transportation declined especially between Europe and Asia (E.M.S.A, 2020). India, Australia and Turkey have implemented quarantine controls for ships entering the port for 14 days, which makes the sailing time of ships longer, disrupting the sailing plan, containers can no longer

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arrive at the port to unload on time, and even face potential shipping
stoppage (Rothengatter et al., 2021). Hülya and Eda (2021) investigated
the effects of COVID-19 on maritime freight transportation and observed
that the major change was in container shipping operations and that
the number of vessels calling at the seaports decreased radically (Hülya,
2021). There was a decline in total cargo traffic volume and a reduction
in vessel call performance during COVID-19 period compared to the
period before the COVID-19 (Narasimha et al., 2021). Malaysia has also
responded to the pandemic by imposing lockdown measures and
restricting movement, leading to the disruption of transportation net-
works encompassing the maritime sector specifically the port and
shipping sector (Menhat et al., 2021). Many major ports experienced a
container throughput plunge in the first half of 2020, but also experi-
enced a large rebound in activity in the second half of 2020 (Cullinane
and Haralambides, 2021). The global container freight demand faced an
uncertain future, owing to the country/regional disparity in COVID-19
control (Zhao et al., 2021). The strict index of government prevention had a
significant positive impact on export cargo throughput (Xu et al.,
2021a).

The research methods related to the impact of COVID-19 on the
shipping industry are mainly as follows. Generalized autoregressive
conditional heteroskedastic model (GARCH) and impulse response of the
value-at-risk model were used to capture how the shipping market responded
to COVID-19 (Michail and Melas, 2020). A panel regression model was constructed to analyze the effect of COVID-19 on port per-
formance (Xu et al., 2021b). A comparative analysis method was used to
study the different impacts of COVID-19 within different transportation
sectors (Mack et al., 2021). The SARIMA (Seasonal Autoregressive In-
tegrated Moving Average) model was used to predict the impact of
COVID-19 on the variations in the container throughputs index (Koyuncu
et al., 2021). Before COVID-19, the univariate time series approach (seasonal autoregressive integrated moving average model)
also was applied to forecast the container throughputs (Rashed et al., 2017).
The support vector machine (SVM) model and the method of system
dynamics were used to forecast the fluctuations of the China Coastal
Bulk Freight Index (CCBFI) and Baltic Freight Index (BFI) (Jeon et al.,
2020; Yang et al., 2008).

By summarizing the literature on the COVID-19 pandemic, it can be
found that the data of the dry bulk and container transportation markets
during the outbreak of the COVID-19 pandemic are rarely used to
analyze the impact of COVID-19 on the shipping industry. Furthermore,
before and after the outbreak of COVID-19, scholars have used various
methods to study the impact of the epidemic on the shipping industry,
but the exponential smoothing model as a time series forecasting
method is rarely used in research. Therefore, this study focuses on
and container transportation markets and conducts compara-
tive analysis during the same period between 2019 and 2020 to explore
the influence of COVID-19 on maritime transportation. In addition, this
study applies the exponential smoothing model to the short-term fore-
casts of the BDI, CCBFI and container throughputs. The percentage
prediction error between the observed and predicted values is used to
provide a quantifiable assessment of the impact of COVID-19 on the
whole shipping market. Finally, the authors put forward some sugges-
tions and call for worldwide, interdisciplinary and cross-sectoral col-
laborations to minimize the adverse impacts of COVID-19 on the
development of the shipping market.

2. Data and methods

2.1. Data description

The aim of this study was to reveal the impact of the COVID-19
pandemic on the shipping market, and the development of dry bulk
cargos and containers during the outbreak of COVID-19 was selected as a
reflective an indicator. Generally, due to the variety of cargo cate-
gories, the status of dry bulk cargo markets is well represented by the
Baltic Dry Index (BDI) and domestic trades by the China Coastal Bulk
Freight Index (CCBFI/CBFI). The BDI value is a “barometer” of dry bulk
freight shipping and has been widely used as one major indicator in the
shipping industry, but also, in recent years, for international trade and
the worldwide global economy (Bildirci et al., 2015; Papapostolou
et al., 2016). As the “barometer” of China’s coastal shipping market, the
CCBFI released by the Shanghai Shipping Exchange promptly reflects
the freight rate fluctuations of five types of goods (e.g., coal, grain, metal
ore, refined oil and crude oil) in Chinese coastal transportation (Ex-
change, 2005). The BDI and CCBFI data were collected from Eastmoney
Securities (http://data.eastmoney.com/cjjs/hyzs_EMI0107664.html)
and China Port (http://www.chinaports.com/cfisPage/CBFI) respec-
tively. For BDI, the daily data samples have a total of 448 observations
from February 15 to December 24, 2019 and February 17 to December
24, 2020, excluding holidays. The shipping routes included in the BDI
involve five countries (the United States, Britain, Norway, Italy, and
Japan). The time period of the COVID-19 outbreak in Italy, Norway, the
United States, the United Kingdom, and Japan was March 10, March 12,
March 13, March 24 and April 7, 2021 respectively. In these countries,
the relief of urban restriction strategies occurred on May 4, May 11, May
10, May 10 and May 14, 2021, respectively. As the two time periods are
not fully identical among the five countries, the data were divided into
divide into four subphases during the outbreak of COVID-19 to better capture the
development of dry bulk transportation over time: Phase 1, prelock-
don (February 17 to March 16, 2020), Phase 2, 1st month (i.e., the
first month after the global lockdown, March 17 to April 16, 2020), Phase 3,
2nd month (i.e., the second month after the global lockdown, April 17 to
May 14, 2020), and Phase 4, lift of the lockdown (i.e., gradually
beginning the removal of restrictions around the world, after May 14,
2020). For the CCBFI, a total of 94 weekly data points were used in this
study, covering the period from December 28, 2018 to December 31,
2020, excluding holidays. The emergency response is generally divided
into four levels: Level I (particularly serious), Level II (serious), Level III
(heavier), and Level IV (general) (Li et al., 2020a). On January 24, 2020,
various cities in China activated the first-level public health emergency
response (Level I response) and actively carried out epidemic prevention
and control measures. To better understand the development of the
CCBFI during COVID-19, the dataset during the epidemic period
involved in this study was divided into four phases: Phase 1, prelock-
don (December 27, 2019 to January 23, 2020); Phase 2, Level I
response (January 24 to February 23, 2020); Phase 3, Level II & III
response (roughly February 24 to June 5, 2020); and Phase 4, complete
Level III response (from June 6, 2020 and beyond). The shipping routes
included in the CCBFI involved Qinhuangdao, Guangzhou, Shenzhen,
Shanghai, Tianjin, Ningbo, and Zhangjiagang. As the epidemic situation
in China improved, the emergency response level in some cities (e.g.,
Guangzhou, Nanjing, and Zhangjiagang) was downgraded from Level I to
Level II on February 24, 2020. A similar phenomenon in Shanghai and
Tianjin occurred on March 24 and April 30, 2020, respectively. The
emergency response in Ningbo and Zhoushan was downgraded from
Level II to Level III on March 23, 2020. Since June 6, 2020, Tianjin,
Qinhuangdao, and other cities have entered the Level III period. Since
different cities adjusted their emergency response levels against the
COVID-19 pandemic during various periods, the time period from
February 24 to June 5, 2020, was defined as the third phase (including
Level II and Level III responses). The time period after June 6, 2020 was
categorized as one complete Level III response.

Container throughputs require that ports play an important role in
domestic goods exchange and foreign trade transportation, which are
important indicators of global trade (Loske, 2020). Therefore, port
container throughputs, as an important indicator of container develop-
ment, can intuitively reflect the development trends of ports and provide
an essential basis for studying the development of port container
transportation (Huang et al., 2015). Four major ports, namely Shanghai
Port, the Port of Hong Kong, the Port of Singapore and the Port of Los
Angeles, were chosen to demonstrate the development of ports in this study. There are two reasons why the authors chose these ports. First, these ports are all famous ports in the world. Shanghai Port and the Port of Singapore are the two largest ports in the world. The Port of Hong Kong is the famous entrepot port in the Asia-Pacific region while the Port of Los Angeles is the busiest port in the United States. Second, the COVID-19 pandemic first broke out in China and then spread to other Asian countries. Shipping transportation in these regions was easily affected by the COVID-19 pandemic. Hence, these four ports were selected to better reflect the development of the global economy in response to the COVID-19 pandemic. In this study, the monthly container throughput data of these four ports were extracted to describe the container transportation market. The monthly data of Shanghai Port were downloaded from the Ministry of Transport of the People’s Republic of China (http://www.mot.gov.cn/tongjishuju/gangkouhuowulvketl/). The data were obtained from the Marine Department of the Hong Kong Special Administrative Region (SAR) (https://www.mardep.gov.hk/sc/publication/portstat.html) for the Port of Hong Kong. The data of the Port of Singapore were available from the Maritime and Port Authority (MPA) of Singapore (https://www.mpa.gov.sg/web/portal/home/maritime-singapore/port-statistics). The data of the Port of Los Angeles were collected from the official website (https://www.portoflosangeles.org/business/statistics/container-statistics).

2.2. Exponential smoothing models

Classical econometric methods were used to predict the development of the shipping market in this study. Considering that the COVID-19 epidemic is still spreading across the world, the focus of this study is to use the percentage prediction error between the predicted value and the observed value to quantify the impact of COVID-19 on the shipping market. SPSS version 20.0 was used for time-series prediction and the statistical significance level was $\alpha = 0.05$. The Expert Modeler module in SPSS (including the exponential smoothing model and seasonal Autoregressive Integrated Moving Average model) can automatically filter the best-fitting model according to the user-defined conditions. Two variables were set in this study, namely time series and monthly BDI/CCBFI/container throughputs data. Time series of monthly BDI/CCBFI/container throughputs from January 2011 to December 2020 were input into the SPSS software. The autoregressive integrated moving average and exponential smoothing models were calculated by the expert modeler module in the traditional model of SPSS.

In terms of the evaluation metric, the R-squared ($R^2$), the root mean squared error (RMSE) and the mean absolute percent error (MAPE) are used to assess the goodness of fitting. For R-squared, the greater the value is, the better the goodness of fitting is. In contrast, as for RMSE and MAPE, the smaller the value is, the better the predictive performance is.

3. Results and discussions

3.1. Influence of COVID-19 on the dry bulk transportation market

To gain insight into the impacts of global lockdown measures during the COVID-19 pandemic on the dry bulk market, the authors analyzed the trend of BDI values during the pandemic from February 17 to December 24, 2020 (Fig. 1). After many countries declared a lockdown from approximately March 17, 2020, the daily BDI values did not exhibit a substantial diminution, however, the changing trend of BDI during lockdown was similar to that during the prelockdown, both showing a slower increase (Fig. 1). In contrast, a pronounced reduction was found for BDI after the global lockdown strategies lasted for two months (between mid-April and mid-May). The daily BDI values presented the highest jump from mid-May to late-June. Subsequently, as the epidemic situation constantly varied, the BDI values reflected fluctuations in different months.

The authors also applied linear regression to the BDI data in the four phases (Fig. 1). While the daily BDI values fluctuated considerably, the slope of the regression equation clearly reflected the changing trend in the four phases. There was a linear increase with a slope of 7.4 points per day in the prelockdown stage. The daily BDI values rose with a slope of 2.5 points after the global lockdown lasting for one month. However, the daily BDI values plunged sharply in the second month after the global lockdown, with a slope of $-13.3$ points per day. The BDI points soared, with a slope of 40.5 points per day after the lift of the lockdown.

![Fig. 1. Development of the BDI values from February 17 to December 24, 2020.](image-url)
Hence, the results fully demonstrated that the fluctuation of BDI values was strongly associated with the development of global lockdown measures at different stages.

To further explore the predominant effect of lockdown strategies, the daily BDI values were compared during the same period (February 17 to December 24) between 2019 and 2020 (Fig. 2). Within one month before the global lockdown, the authors observed a similar trend between 2019 and 2020, and the BDI values in 2019 were slightly higher than those in 2020 (Fig. 2a). In the prelockdown period, the average BDI values were 653 points and 550 points in 2019 and 2020, respectively, indicating a drop in the BDI in 2020 compared with that in 2019. In the time period of the first month after the global lockdown, there was a slight decrease in 2020 compared with that same period in 2019. In contrast, as illustrated in Fig. 2a, compared with 2019 (from mid-April to mid-May), a dramatic decline in the BDI values was observed in the second month as a result of the outbreak of the COVID-19 pandemic and during which strict restrictions were imposed to prevent the further dissemination of COVID-19 in the world. With the improvement in the pandemic situation, most countries progressively lifted a strict quarantine in May (e.g., Britain, Italy, and Japan). BDI values in 2020 started to recover but they were still far below those during the same period in 2019. However, as the COVID-19 epidemic situation continued to change after July 2020, the BDI values fluctuated with uncertainty again.

Specifically, after the global lockdown lasted for one month, the COVID-19 epidemic situation improved, and the industrial production started to recover steadily in China; however, the epidemic situation abroad continued to deteriorate. Most of the cities and countries started to carry out urban partial and complete lockdown strategies, which slowed down the trade of international goods and raised people’s concerns about the development of the shipping market. Surprisingly, the global dry bulk transportation at this stage was not substantially affected. The average of the BDI values rose by 70 points (11.3%) for month-on-month (m-o-m) but dropped by 84 points (11.9%) for year-on-year (y-o-y) (Fig. 2b), indicating that the market situation during this period was slightly better than that during the previous period but worse than that during the same period in 2019. After two months of global lockdown, the Chinese import policies for coal were tightened and the epidemic prevention policies among various countries were variable. As a result, the international dry bulk market continued its downward spiral with the increase in market concerns. The average of the BDI values at this phase stood at 600 points and decreased by 35.5% for y-o-y. The BDI values started to rebound sharply after the lifting of lockdowns. Meanwhile, China’s economy recovered rapidly in the second quarter of 2020. With resuming work and production in China, enterprises began to replenish their stocks, and expenditures on infrastructure investment started to rise. Consequently, iron ore demands in China increased significantly, driving a steep rise in the daily rents for medium and large bulk carriers. In addition, as an increasing number of countries relieved lockdown strategies, some countries and regions in the world slowly returned to a ‘new normal’. The BDI broke through the limit of 1000 points and reached a new highest value in 2020, which was still lower than that during the same period of 2019. The average of the BDI values was 1348 points, which rose by 748 points (125%) for m-o-m and declined by 313 points (18.9%) for y-o-y.

For Chinese coastal dry bulk transportation, after New Year’s Day in 2020, some downstream factories were shut down one after another, and the coastal coal transportation market tended to be deserted. As downstream demands shrank, production overcapacity conflicts became prominent, and then the CCBFI declined significantly during the pre-lockdown (Fig. 3a). During the Level I response, the CCBFI values steadily fell from the extension of the Chinese New Year holidays and lockdown strategies among almost all cities were implemented to slow down the spread of COVID-19. During the third phase (Level II and Level III response), the resumption of production started to accelerate step by step as the epidemic situation improved in China. The recovery trend emerged at this phase. Although all regions entered the level III response after June 2020, the overall performance of the coastal bulk transportation market was sluggish, suggesting a downward trend again. Until August 2020, there was a trend of rebound for the development of the coastal bulk transportation market.

The authors further compared the variations in the CCBFI values...
During the same period between 2019 and 2020. As shown in Fig. 3a, the average CCBFI values generally showed a downward trend from December 27, 2019 to February 24, 2020 (during the prelockdown and Level I response). The average CCBFI value increased by 37 points (3.6%) to 1069 points before the lockdown in China (Fig. 3b). During the Level I response, under the combined effects of the Spring Festival holiday and the COVID-19 pandemic, and a slow resumption pace of work and production, the growth of shipping demands was not as expected and a steady drop in freight rates was observed. In this phase, the CCBFI values fell by 135 points (12.6%) for m-o-m to 934 points and declined by 6 points (0.6%) for y-o-y. The weekly CCBFI values from February 24 to mid-April 2020 exhibited a reverse trend (the downward trend in 2020) to those during the same period in 2019 and were maintained at a lower level.

After March 2020, the resumption of work and production gradually accelerated, bringing a slight increase in market demands. While against a backdrop of epidemic prevention and control measures that were not completely relieved, the demands continued to slump for coastal bulk cargo transportation and the freight rates remained subdued. As the outbreak of COVID-19 became a global pandemic, many countries gradually strengthened their epidemic prevention and control efforts. International trade was subject to the implementation of urban restriction strategies, which had a negative effect on Chinese coastal economic operations. As a result, the CCBFI values fluctuated slightly during the period. In May 2020, the spread of the epidemic was initially contained after several months of continuous efforts in China. Work resumption gradually occurred across China, and the industry operating rate was largely increased. Overall, the freight rates presented a fluctuating upward trend. The average of the CCBFI values was 955 points, rising by 21 points (2.2%) for m-o-m and decreasing by 84 points (8.1%) for y-o-y during the third phase (Fig. 3b). At the complete Level III phase, the CCBFI values demonstrated a similar trend to those during the same period in 2019 and were nearly close to the level of 2019. At this phase, the average of the CCBFI values increased by 69 points (11.41%) for m-o-m and decreased by 24 points (−0.8%) for y-o-y at 1064 points.

### 3.2. Influence of COVID-19 on the container transportation market

The container throughputs in most port cities all presented a decreasing trend, but the extent of the decrease varied with cities. In the first two months of 2020, the container throughputs plummeted by 4% and 19.6% for y-o-y in Shanghai Port, and 15.9% and 0.2% in the Port of Hong Kong respectively (Fig. 4a and 4b). It was inferred that the lockdown measures taken by the Chinese government had a negative impact on the economy and maritime trade, thus affecting the container transportation market (Yang, 2020). It was easily found that container throughputs showed a month-on-month downward trend from January to February 2020. In addition, the negative impact of COVID-19 on port throughputs was more obvious in February than in January 2020. In February, the container throughputs dropped by 1300 thousand twenty-foot equivalent units (TEUs) (−36.1%) for m-o-m to 2300 thousand TEUs in Shanghai Port. The container volumes in February also decreased by 265 thousand TEUs (−18.6%) compared with those in January for the Port of Hong Kong.

After March 2020, Chinese cities efficiently promoted the resumption of work and production, and transportation logistics gradually recovered. Chinese ports showed vitality and resilience, and the container throughputs began to rebound (Li et al., 2020b). For Shanghai Port and the Port of Hong Kong, the throughput volumes in March 2020 expanded by 1130 thousand TEUs (49.1%) and 391 thousand TEUs (33.7%) compared with those in February 2020 (Fig. 4a and b). As the COVID-19 pandemic occurred and spread globally, the world fell into a state of “massive lockdown and stagnant production”. The global trade and supply chains were disrupted (Yang, 2020), and the container throughputs of Chinese ports were also affected by the pandemic. In the next few months of 2020, although container throughputs showed a continuous increase, the year-on-year growth rate remained negative until July 2020 when overall positive values began to emerge.

The Port of Singapore did not show an extremely sharp “shock” caused by COVID-19 in the first quarter of 2020. In January and February 2021 urban lockdown strategies exerted a widely severe impact on the Chinese container shipping sector. At the same time, the Port of Singapore continued to operate and undertook some of the goods
transferred from Chinese ports. The throughput volumes increased in the first quarter compared with the same period last year, but the growth rate became increasingly slower. The container throughputs in the first three months of 2020 were 3183, 2899, and 3198 thousand TEUs, with a year-on-year rise of 6.8%, 5.8%, and 1.1%, respectively in the Port of Singapore (Fig. 4c). There was a stable balance among trade, port cargo throughput, and container throughputs (Wu, 2020). The container throughputs of U.S. ports heavily relied on imports from China, and as a result, they were most affected by fallout from COVID-19 (Morley, 2020). In the Port of Los Angeles, in February and March 2020, the container throughputs showed decreases of 22.9% and 30.9% for year-on-year (y-o-y), respectively (Fig. 4d). Approximately 40 sailings from Asia (mainly China) to the Port of Los Angeles were canceled between February 11 and April 1, 2020, with a fall of approximately 25% from the typical volume after the Lunar New Year (Link-Wills, 2020). On March 4, 2020, the California governor announced a statewide emergency as a result of the threat caused by the COVID-19 pandemic. Overall, U.S. seaborne container imports fell by 10.1% in March, including a decline of 34% in shipments from China (Paris, 2020).

In the second quarter, in the context of the global pandemic, the container freight market obviously contracted. In May 2020, as the prevention and control measures for COVID-19 had a clear impact, container volumes declined by 10.6% and 29.8% for y-o-y in the Port of Singapore and Los Angeles respectively. The Circuit Breaker measures were implemented from April 7 to June 1, 2020, to curb the spread of COVID-19 in Singapore, including the closure of most workplace premises and suspension of nonessential services (Singapore Department of StatisticsNational Accounts, 2020). Based on the statistical data from MPA, the number of vessel calls in the Port of Singapore dropped to 3059 ships in May 2020, which was the lowest level since January 1993 (Singapore and M.a.P.A.M.o, 2020). The global pandemic led to a surge in canceled sailings, which in turn significantly contributed to a decline in throughput for the Port of Los Angeles (2020). An eventual ‘bounce back’ in the volumes of container throughputs may be associated with the relief of restriction strategies (Research, 2020). In the Ports of Singapore and Los Angeles, container throughputs in June 2020 appeared to increase compared to those in May 2020 but still declined by 3% and 9.7% for y-o-y, respectively. The year-on-year growth rate also began to show a positive value in the Ports of Singapore and Los Angeles after August.

### 3.3 Results of time series prediction

Through the expert model, the simple seasonal exponential smoothing model and Holt-Winters additive model (exponential smoothing with the additive trend and additive seasonality) were selected as the best-fitting models for the forecasts of dry bulk and container transportation in this study, respectively. The simple seasonal exponential smoothing model included two parameters, comprising, the horizontal parameter (Alpha) and the seasonal parameter (Delta). The Holt-Winters additive model had three parameters, comprising, horizontal parameter, seasonal parameter and trend parameter (gamma). In this study, a total of 120 consecutive monthly data (from January 2011 to December 2020) were collected, the first 108 data samples were used as the training dataset, and the last 12 data samples were used as the testing dataset.

Taking the BDI as an example, the exponential smoothing predicted and observed values from January 2011 to December 2020 are shown in Fig. 5. It can be seen initially that the predicted BDI values from exponential smoothing models correlated with the observed data. To further evaluate the predicted models, the R-squared, RMSE and MAPE were selected to reflect the prediction errors. The model fit statistics and the related parameters in the testing dataset are shown in Table 1. Table 1 shows that the R-squared ranged from 0.56 to 0.94, suggesting a good fitting of the model outputs with the true values. The RMSE of the model was less than 93.91 (except for BDI), and the MAPE of the model was approximately 10%, which indicated a good forecast of the seasonal exponential smoothing model. Therefore, the exponential smoothing model can be better applied for the forecasts of dry bulk and container transportation. The three parameters (horizontal, seasonal, and trend)
all exhibited a statistical significance of \( p < 0.05 \); however, the gamma and delta values were smaller than the alpha value.

Fig. 5 and Table 1 show that the predicted values were consistent with the observed data. Therefore, the simple seasonal exponential smoothing model and the exponential smoothing winters additive model were applied to separately predict the monthly data for dry bulk and container transportation from January to April 2021 in this study. The results are shown in Fig. 6. To assess the prediction accuracy, previous studies suggested that the percentage prediction error (PPE) can be adopted as a good indicator to describe the prediction performances, with the following calculation equation (Park and Stefanski, 1998; Yapuncich, 2018):

\[
\text{Percentage prediction error (PPE)} = \frac{(\text{predicted value} - \text{measured value})}{\text{measured value}} \times 100 \tag{1}
\]

In this study, it should be noted that the percentage prediction error was used to provide a quantitative evaluation of the impact of COVID-19 by calculating the difference between the predicted and observed values. Furthermore, according to the previous findings, the exponential smoothing prediction model used in this study exhibited better prediction performances on each index (e.g., BDI and CCBFI). When the PPE value is positive, the predicted value is larger than the observed value. When the error percentage value is larger, the COVID-19 pandemic exerts more severe impacts on maritime transportation. Meanwhile, when the PPE value is close to zero, this indicates that the dry bulk and container transportation market may be affected by the mitigation of the epidemic and that the market begins to recover.

For BDI, it was found in Section 3.1 that compared with the same period in 2019, the year-on-year decline rate was the largest (\(-35.5\%\)) in the first month after the global lockdown in 2020 (April 17 to May 14, 2020). Fig. 6 shows that the PPE of the BDI was the largest in April and May 2020. Similarly, in Section 3.1, it was observed that the CCBFI had the largest year-on-year decrease (\(-8.1\%\)) in the Level II & Level III response (from 24 February to June 5, 2020). It was also found that the predicted and observed CCBFI values varied greatly during the time period, as shown in Fig. 6. For container transportation, it was observed in Section 3.2 that compared with the same period in 2019, the

| Simple Seasonal | Holt-Winters Additive |
|-----------------|-----------------------|
| BDI             | CCBFI                 |
| Shanghai Port   | Hong Kong Port        |
| Port of Singapore| Port of Los Angeles   |
| Alpha           | 0.70                  | 0.16                  |
| Gamma           | 1.00                  | 0.40                  |
| Delta           | 0.16                  | 0.61                  |
| R-squared       | 4.62E-04              | 1.55E-05              |
| RMSE            | 238.20                | 93.91                 |
| MAPE            | 17.71                 | 2.41                  |

Fig. 5. The predicted value of the exponential smoothing model and the observed values from January 2011 to December 2020.

Fig. 6 shows that the PPE of the BDI was the largest in April and May 2020. Similarly, in Section 3.1, it was observed that the CCBFI had the largest year-on-year decrease (−8.1%) in the Level II & Level III response (from 24 February to June 5, 2020). It was also found that the predicted and observed CCBFI values varied greatly during the time period, as shown in Fig. 6. For container transportation, it was observed in Section 3.2 that compared with the same period in 2019, the
container throughputs in Shanghai Port showed the largest drop in February (−19.6%), and a similar result can also be found in Fig. 6. For the container throughputs of the Port of Hong Kong, the Port of Singapore port and the Port of Los Angeles, the results were in good agreement with those in Section 3.2. The data before and after the outbreak of COVID-19 were used to predict the changes during COVID-19 and to compare the forecasts with the observed data. The prediction results from the exponential smoothing model in this study were consistent with the conclusions from the data comparison during the same period between 2019 and 2020 in Section 3.1 and Section 3.2. Therefore, this also further explained the negative impact of the lockdown measures on the dry bulk and container transport market in response to the COVID-19 pandemic.

From Fig. 6, it was also found that the exponential smoothing model provided a low percentage prediction error (approximately 10%) for the validation samples from January to April 2021 except for the BDI values. Specifically, the verification results of the data samples showed that the absolute value of the percentage prediction error for Shanghai Port was 0.75%–6.27%, and the absolute value of the percentage prediction error for Singapore Port ranged from 0.53% to 2.04% (Fig. 6). Although some percentage errors were large for other ports, the overall trend tended to be consistent when compared with the actual throughputs of each port. Therefore, the results were indeed validated considering the development of the first four months of 2021.

The predictions of the BDI and CCBFI are different from the port container outputs. There are two reasons for that. First, the definitions of the BDI and CCBFI make the predictions different. The BDI is compiled by 20 large intermediaries from five countries (the United States, Britain, Norway, Italy, and Japan), while the CCBFI involves five cities, Qinhuangdao, Guangzhou, Shenzhen, Shanghai and Ningbo, in China. One is to reflect the regional shipping market, and the other is to reflect the Chinese shipping market. Port container outputs reflect the development of each port. Second, the outbreak time and impact of COVID-19 in different countries and cities varied. The forecast of container throughput is more affected by the development of the epidemic in the city where each port is located. It also caused the prediction to be different. The predicted values may not be completely accurate compared with the observed values. This was due to the influence of other factors (e.g., global economic development, oil price fluctuations, national policies and regulations) in the market and the error of the model itself.

3.4. Countermeasures

Analyzing the impact of the COVID-19 pandemic on dry bulk and container transportation can help government departments and industries take accurate and timely measures in response to similar situations as a global epidemic. Based on the authors’ findings, the authors put forward the following countermeasures and suggestions to address the impact of the epidemic.

(1) The government should promote the development of smart ports and intelligent shipping, and build information-sharing systems across departments and industries. The outbreak of public health emergency events has highlighted the necessity and importance of developing informatization, paperlessness, and platformization. Informatization has superior advantages that traditional operating modes cannot compare to in terms of efficiency, health and safety, and information sharing. The government should focus on the transformation and upgrade of ports and shipping companies and promote the construction of intelligent ports, intelligent shipping, and digital ports. Meanwhile, an integrated information-sharing platform that integrates ports, shipping companies, agents, traders, ports and financial systems should also be built to promote the development of paperless documents and online business.

(2) The government should give appropriate tax relief or subsidies to key departments. The government takes the lead in building a multiparty communication platform to encourage container companies, shipowners, and landlords to reduce the delivery of container costs, ship rents, office space rents, and property fees during the epidemic. At the same time, the government should propose appropriate policies for shipping companies to reduce or exempt port charges and port construction fees.
CCBFI was 1.25% consistent with the conclusions obtained from the above analysis. For the pandemic by the World Health Organization on March 11, 2020, the ports showed a year-on-year decline of approximately 19.6% and 22.9% in February, respectively. After the declaration of the COVID-19 pandemic, a great initial ‘shock’ due to the global lockdown. Shanghai Port and the Port exhibited a notable year-on-year decrease of approximately 35.5% in the first month after the globally massive lockdown and then increased in the first month after the epidemic. In addition, port operators should also scientifically guide ships to enter and leave the port to avoid heavy ship congestion.

4. Conclusions

Based on the above analysis, the main three conclusions can be summarized as follows:

First, the dry bulk transportation market was found to be greatly affected by the lockdown strategies. The BDI values showed a slight increase in the first month after the globally massive lockdown and then exhibited a notable year-on-year decrease of approximately 35.5% in the second month. The BDI values increased but still fell 18.3% after the gradual lifting of the lockdown for two months across the world. The CCBFI values showed a gradually decreasing trend of approximately 0.6% in the first month after the lockdown (Level I response) in China, and an increasing trend began to appear earlier from the second month than that in the global market. Therefore, urban lockdown policies led to a great initial ‘shock’ in global dry bulk transportation.

Second, the container transportation market also presented a decreasing trend due to the global lockdown. Shanghai Port and the Port of Los Angeles were heavily exposed to material disruption after the initial outbreak of COVID-19, and the container throughputs of the two ports showed a year-on-year decline of approximately 19.6% and 22.9% in February, respectively. After the declaration of the COVID-19 pandemic by the World Health Organization on March 11, 2020, the spread of COVID-19 had more negative effects on port container outputs (except for Shanghai Port). The container throughputs of the Port of Los Angeles, Singapore, and Hong Kong fell by 30.9% in March, 10.6% in May, and 7.1% in April 2020, respectively.

Finally, the results from the exponential smoothing models were consistent with the conclusions obtained from the above analysis. For the dry bulk transportation market, the verification results of the data samples showed that the absolute value of the percentage error for the CCBFI was 1.25%–12%, except for the BDI. For the container transportation market, except for the Port of Los Angeles, the absolute value of the percentage errors of the other three ports ranged from 0.53% to 11.74%. Considering the presence of the global epidemic and the continuous dynamic changes of the maritime transportation market, there is still great uncertainty in relation to the market prospects for dry bulk and container transportation.

In summary, the authors’ findings suggest that COVID-19 exerted a negative influence on dry bulk and container transportation. The authors suggested that similar measures, such as strengthening port linking tracking, decentralizing asset allocation, promoting the development of smart ports and smart shipping, should be put forward and further steps taken to reduce the negative impacts of the COVID-19 pandemic on maritime transportation.

Author contributions

The authors confirm contributions to the paper as follows: study conception and design: Hong-Mei Zhao and Hong-Di He; data collection: Hong-Mei Zhao; analysis and interpretation of results: Hong-Mei Zhao, Hong-Di He, Kai-Fa Lu, Xiao-Long, Han, Yi Ding, and Zhong-Ren Peng; draft manuscript preparation: Hong-Mei Zhao. All authors reviewed the results and approved the final version of the manuscript.

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