Study on the upsizing of container ships based on VAR model

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Abstract. In this paper, the large-scale container, and the relationship between the world economic pattern and the analyses, the first analysis of container development history and the influence factors of the development of the economic situation of the world in recent years were reviewed, and then using VAR model for the world economy carries on the quantitative analysis and the container ship large-scale development. It has been concluded that the growth of the world economy has contributed to the large-scale production of container ships, and this effect will gradually turn negative and eventually fluctuate up and down to zero. The research results can be used as a guide for shipping enterprises to select and build ships and to study the large-scale container.

1. Introduction
The main purpose of this paper is to explore the internal relationship between the world economy and trade and the development trend of the upsizing of container ships, so as to provide certain data for shipping companies to invest in building new ships or operating old ships.

Since the birth of container transport, numerous scholars at home and abroad have launched research on it. In 2004, Wang Chuanrong [1] made a comprehensive summary and prediction of the technology used by large container ships and the development trend of their upsizing. In 2011, Ronen D [2] studied the effect of oil prices on container speed and fleet size. In 2015, Yin Hongxin [3] discussed the relationship between carbon emissions from the shipping industry and ship upsizing. In the same year, foreign scholars Nguyen Khoi Tran and Hans-Dietrich Haasis [4] established a multiple regression model to measure the influence of factors such as fleet capacity, ship size, shipping space utilization rate, market freight rate and oil price on shipping revenue and cost during 1997-2012. In 2019, Bao Guangde [5] summarized the forms of international trade in his article "Exploration of the Status Quo and New Trend of International Trade", combining with the domestic and foreign economic environment.

From the above literature review, we can see that the previous studies on the upsizing of container ships are very rich, including analysis from various angles and various predictions. Whether it is empirical research or theoretical discussion, there are a large number of detailed reference materials. However, with the passage of time, the research has some limitations and time limits, and this paper will conduct research and discussion under the current shipping trade environment.

2. The relationship between the world economy and the upsizing of container ships
The ups and downs of the world economy will have a significant impact on the development of the shipping industry and the upsizing of container ships. The relationship between the world economy and the upsizing of container ships is as follows:
Container ships are the link of international trade. Among various modes of transportation, the advantages of large volume of container ships, low rate of goods breakage and cost saving make container transportation the most popular mode of transportation in international trade. Thousands of commodities are circulated among all continents and countries through containers. It can be said that the container is one of the most important parts in the development of production and consumption globalization. The more developed countries and regions are, the more inseparable from the container. Container ships, as the three main types of shipping, have promoted the development of the world economy. The more economically developed the region is, the more obvious the trend of global economy will be, so the stronger the demand for international shipping and the greater the demand for container ships will be.

3. Discussion on the relationship between upsizing of container ships and world economy and trade based on VAR model

In this chapter, we will establish a VAR model to conduct an empirical analysis on the relationship between the world economy and trade and the upsizing of container ships.

3.1 Model description

Vector autoregressive model, or VAR model, is a commonly used econometric model, which was proposed by Christopher Sims in 1980. VAR model uses all current variables in the model to regress several lagging variables of all variables. The VAR model is used to estimate the dynamic relationship of the joint endogenous variables without any prior constraints. It is the extension of AR model, which has been widely used at present.

The general form of VAR model (p-order VAR model) is as follows:

\[ y_t = A_1 y_{t-1} + \cdots + A_p y_{t-p} + B_1 x_t + \cdots + B_r x_{t-r} + \epsilon_t \]

Among them, \( y_t \) is called the endogenous variable vector, \( x_t \) is called the exogenous variable vector, and the sum of the two is the parameter matrix to be estimated. Where, \( p \) and \( r \) respectively represent the lag order of endogenous variables and exogenous variables, \( \epsilon_t \) is the random disturbance term.

Next, this paper will test whether the variables can be explained to each other through the estimation of VAR model, and further conduct the impulse response function and variance decomposition of VAR model to explore and analyze the relationship between the upsizing of container ships and the world economy and trade.

3.2 Data source and Settings

The empirical data variables selected in this paper are the total export volume of world commodity trade set as EXP, and the average shipping capacity of each container ship in the world set as S. Set the total number of container ships to X, and the total capacity of container ships to Y. The sample interval is 1998-2017, and the time series data of a total of 20 years are shown in Table 1. Among them, the total export value of the world merchandise trade, EXP, is an indicator to measure the changes in the world economy. The data comes from the official data published by WTO. The world average shipping capacity of each container ship is calculated according to the annual total number of container ships and total shipping capacity published by Clarkson. For data stability, natural logarithms of the two data areas are taken here. Eviews software is used to study the data in this paper.

| Time | EXP/US$ billion | X/ship | Y/TEU | S/TEU | Time | EXP/US$ billion | X/ship | Y/TEU | S/TEU |
|------|-----------------|--------|-------|-------|------|-----------------|--------|-------|-------|
| 1998 | 55031           | 2331   | 3807710 | 1633.51 | 2008 | 161653           | 4383   | 10918620 | 2491.13 |
| 1999 | 57193           | 2539   | 4260780 | 1678.13 | 2009 | 165606           | 4745   | 12333580 | 2599.28 |
| 2000 | 64561           | 2615   | 4477370 | 1712.19 | 2010 | 173110           | 4808   | 13052750 | 2714.80 |
| 2001 | 61933           | 2755   | 4925160 | 1787.71 | 2011 | 183379           | 4969   | 14283760 | 2874.57 |
| 2002 | 61979           | 2904   | 5513050 | 1898.43 | 2012 | 184959           | 5080   | 15414030 | 3034.26 |
For the overall trend analysis of the export value of the world's total commodity trade, EXP, and the world's average shipping capacity of each container ship, S, the broken line chart is shown in Fig. 1 and 2, and the abscissa is the year. The y-coordinate is the logarithmic value.

### Figure 1 Trend of the total amount of world economic exports over time

### Fig. 2 Trend of average container shipping capacity over time

As can be seen from the above figure, the total export value of world commodity trade and the world's average annual container ship transport capacity show roughly the same overall trend, and there may be correlation between the total export value of world commodity trade and the world's average annual container ship transport capacity. But that still requires a little bit more calculation and analysis to determine if there is a stable equilibrium relationship.

### 3.3 Empirical analysis on the world economy and trade and the upsizing of container ships

The main purpose of this step is to check whether our data is a stationary series, so as to avoid false regression and other problems. In this paper, the Augmented dickey-Fuller (ADF) test method was used to test the unit root of EXP and S variables, and the model was as follows:

\[
\Delta y_t = \alpha + \beta t + \delta y_{t-1} + \sum_{j=1}^{p} \lambda_j \Delta y_{t-1} + U_t
\]

Let the null hypothesis be \( H_0: \delta = 0 \), that is, the unit root exists; The test statistic is set to \( t_\delta = \frac{\hat{\delta}}{s(\hat{\delta})} \). The null hypothesis is tested with the critical value \( T \) obtained by the test. If \( T < t_\delta \), the null hypothesis is accepted and the time series is considered uneven; otherwise, the null hypothesis is accepted. Among them, \( \alpha \) is the constant term, \( \beta \) is the coefficient of time, \( \delta \) is the parameter of AR process, \( \Sigma_{j=1}^{p} \lambda_j \Delta y_{t-1} + U_t \) is the random trend term.

Using software, unit root test is carried out on the natural logarithm of the total export value of the world's total merchandise trade, EXP, and the world's average shipping capacity of each container ship, S. The results are shown in the table below:
Table 2 ADF unit root test results for Exp and S

| variable | Check the | Critical value | P-value | conclusion |
|----------|-----------|----------------|---------|------------|
| EXP      | -1.358    | -4.499         | 0.8821  | not smooth |
| D EXP    | -2.995    | -4.602         | 0.1502  | not smooth |
| D2 EXP   | -5.012    | -4.623         | 0.0049  | smooth     |
| S        | -0.669    | -4.517         | 0.9597  | not smooth |
| D S      | -4.339    | -4.567         | 0.0149  | not smooth |
| D2 S     | -6.181    | -4.598         | 0.0007  | smooth     |

Note: D denotes first-order difference and D2 denotes second-order difference

It can be concluded from the above table that the two variables obey the second-order unit root test, and the VAR model can be built for analysis.

Granger causality test is used to analyze the causal relationship between variables, that is, the impact between the world economy and trade and the upsizing of container ships is monomial or two-way. This step must be done after the single root test, that is, the tested variables must be stationary.

Granger causality test was conducted on the two variables EXP and S, and the results are shown in the table below:

Table 3 Granger causality test results for Exp and S

| The original assumption | The number of lag periods | F-S data | P-value | conclusion |
|-------------------------|---------------------------|----------|---------|------------|
| The Granger cause of EXP's non-S | 2             | 9.241566 | 0.0102  | refuse     |
| The Granger cause of S non-EXP    | 2             | 2.590144 | 0.2816  | accept     |

From the data in the table, we can draw a conclusion that in the relationship between the world economy and trade and the upsizing of container ships, the world economy and trade is the Granger cause of the upsizing of container ships, but the upsizing of container ships is not the Granger cause of the world economy and trade.

After the above single root test and Granger test, the following is the concrete construction of the VAR model. First, the VAR model was simulated and established, and then the Lag order of the model was determined by the Lag Specification function. At the same time, as the sample interval we used was not large enough, the smaller Lag order should be selected. The results are as follows:

Table 4 Selection of lag order of VAR

| Lag | LogL | LR       | FPE   | AIC   | SC   | HQ   |
|-----|------|----------|-------|-------|------|------|
| 0   | -96.10267 | NA      | 10942.58 | 12.20198 | 12.30875 | 12.19214 |
| 1   | -94.91324 | 0.474682 | 12363.63 | 12.77027 | 12.24562 | 12.11582 |
| 2   | -92.48325 | 4.10368 | 10413.04 | 12.04612 | 12.14626 | 12.06780 |

Note: the lagging order marked with "***" after the value is the best lagging order calculated by Eviews software.

It can be concluded from the above table that the VAR model we are going to establish is of lag order 2, namely VAR (2). Continue to run the model with Eviews software, and the results are shown in the table below: 
After the above steps, we will judge the stability of the VAR model.

As shown in the table, the corresponding modules of all roots are less than 1, indicating that the established VAR model is indeed stable and can be continued for the next impulse response analysis.

### 3.4 Impulse response function analysis

Impulse response function analysis is to use the above model in vivid images to show the relationship between the world economy and trade and the upsizing of container ships.

We calculate the influence of EXP on S, and get the following figure:

![Pulse image analysis of the relationship between world economy and trade and upsizing of container ships](image_url)

From Figure 3, we can see the impact of global economy and trade on ship upsizing. The total export volume of the world economy and trade starts from a large positive reaction at the beginning, then begins to decline, and turns to a negative effect. The degree of negative effect increases and then decreases, and finally fluctuates in the zero effect. The conclusion obtained by the impulse function is consistent with the model running result.
4. Result analysis

According to the above VAR model established on the basis of the 20 years' data of the total export value of world commodity trade and the world average shipping capacity of each container ship from 1998 to 2017, the following conclusions are drawn:

1. There is only a one-way causal relationship between the world economy and trade and the upsizing of container ships, that is, the export value of EXP world commodity trade is the Granger cause of the average shipping capacity of each container ship, but the reverse is not true. That is, the increase or decrease of international trade volume has some influence on the large-scale container ship, but the large-scale container ship has no significant effect on the international trade volume. This is consistent with the results of the Granger causal test.

2. The effect of the total value of trade exports on ship upsizing has a strong positive effect in the short term, and the positive effect from the first year to the second year tends to weaken; The long-term utility is not obvious in either positive or negative directions, and generally presents a decreasing trend, and eventually tends to zero. It shows that the total value of world commodity trade plays a promoting role in the upsizing development of container ships on the whole, and sea transport takes up more than 80% of the international trade volume. Therefore, the growth of international trade volume will lead to the growth of international sea transport volume, and then play a promoting role in the upsizing development of container ships.

The trend of container upsizing is still very obvious nowadays, with the shock of the reorganization of the shipping industry and the new opportunities and challenges brought by the economic and trade globalization.

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