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# SHIP PRICE PREDICTIONS OF PANAMAX SECOND-HAND BULK CARRIERS USING GREY MODELS\*

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Key words: ship prices, panamax carriers, bulk carriers, grey theory.

## ABSTRACT

### 1. Purpose

The purpose of this paper is to apply the traditional Grey Model, GM(1, 1), rolling GM(1, 1), and recursive residual GM(1, 1) models of Grey theory to forecast the ship prices of Panamax second-hand bulk carriers in different time periods with different sample sizes.

### 2. Design/Methodology/Approach

This paper calculates the ship prices of Panamax second-hand bulk carriers from June 2013 to October 2017 according to the traditional GM(1, 1) and rolling GM(1, 1) models. It also calculates the traditional GM(1, 1) and recursive residual GM(1, 1) models for the traded ship prices of Panamax second-hand bulk carriers equal to or less than five-years-old, and then uses mean absolute percentage error (MAPE) to compare the degree of accuracy of the forecasting.

### 3. Findings

This paper shows only a few differences in the accurate predictions among the traditional GM(1, 1), rolling GM(1, 1), and recursive residual GM(1, 1) models of Grey theory for the ship prices of Panamax second-hand bulk carriers.

### 4. Practical Implications

According to the ship size class, this paper uses 'decreasing', 'fair' and 'increasing' to forecast the drybulk shipping markets of the interval forecasting values for the ship prices of Panamax second-hand bulk carriers. Grey theory is found highly accurate.

### 5. Originality/Value

The traditional GM(1, 1), rolling GM(1, 1), and recursive residual GM(1, 1) models of the Grey theory all performed well enough to forecast the ship prices of Panamax second-hand bulk carriers in different time periods with different sample sizes. Armed with these findings, shipowners can better understand the assets of ships, improve the quality of sale and purchase (S & P), and strengthen chartering business strategies depending on their degree of optimism or pessimism towards sale and purchase (S & P) trading markets with the outlook for tramp shipping markets.

## I. INTRODUCTION

The development of global seaborne trades reflects the growth of the world economy. There is a positive relationship between global gross domestic product (GDP) and seaborne deadweight tonnages (DWTs). Naturally, the world economy's focus on commodity trades has drawn attention to the developing trend of global seaborne DWTs. The international seaborne trades and the percentages of main drybulk cargoes for selected years are shown in Fig. 1.

From Fig. 1, with the exception of 2009, the main drybulk cargoes in the past decade have gradually grown. Nowadays, there are 11,139 bulk carriers, totalling 771.1 million DWTs (Institute of Shipping Economics and Logistics, 2017) as shown in Table 1.

Table 1 shows for the existing and ordered bulk fleet, in terms of DWTs, modern Capesize ships are total 38.7% and 47.7%; Panamax ships are total 25.4% and 35.3% respectively. The fleets of modern Capesize and Panamax bulk carriers comprise the majority of seaborne DWTs of the worldwide bulk carriers, and the ordered fleets of these ships are also growing more than other bulk carriers. It shows that Panamax ships have the great impact on worldwide bulk shipping sectors.

Fig. 2 shows within the past decade, the highest ship price of Panamax second-hand bulk carriers was 92 million USD in October 2007 and the lowest ship price was 13 million USD in December 2015. The large gap between these ship prices signifies both the risks and opportunities for shipowners. This paper focuses on the ship prices of Panamax bulk carriers which are

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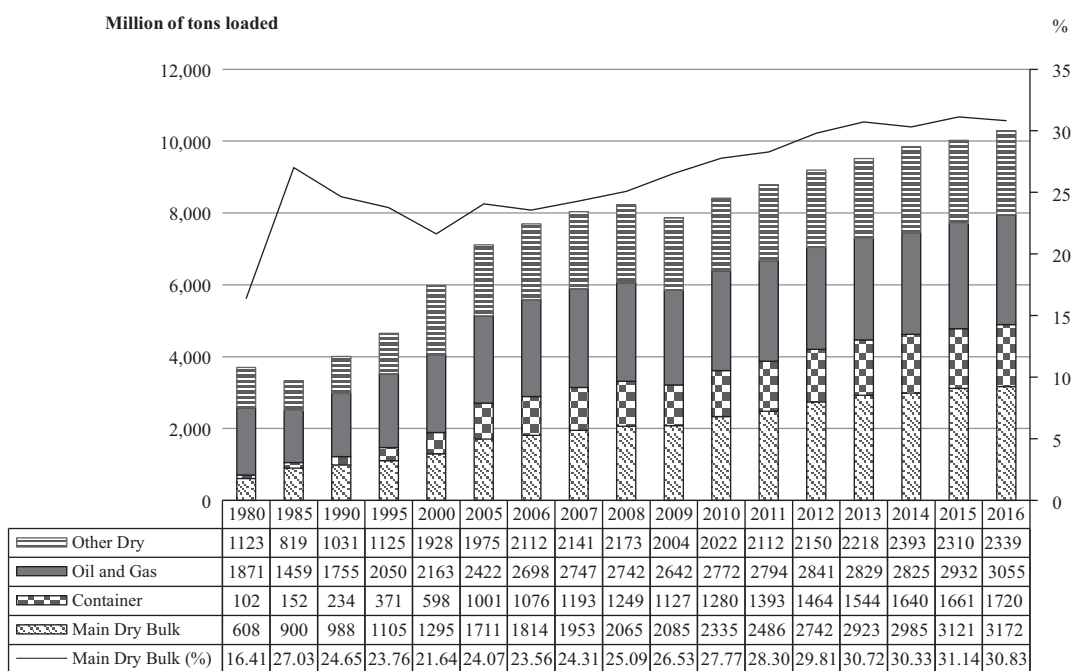
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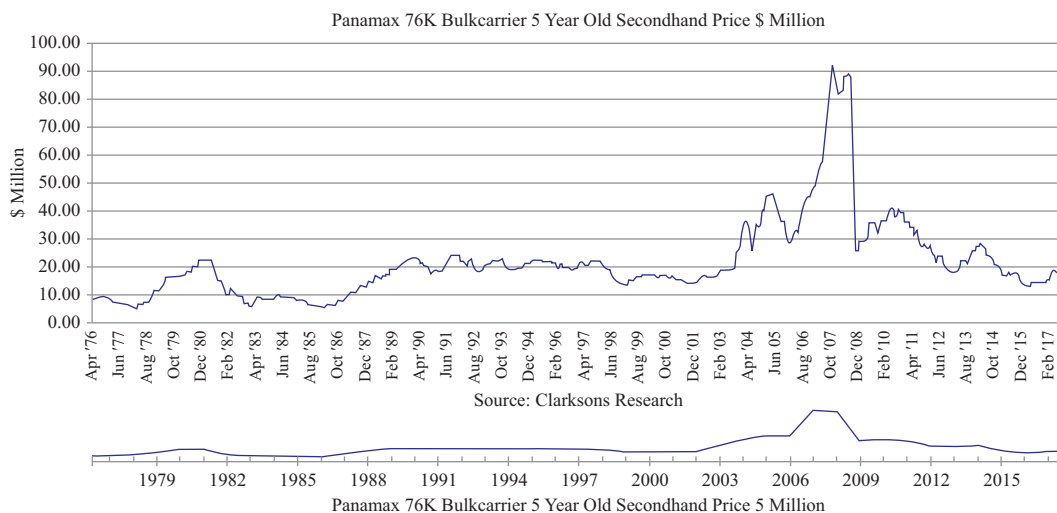
**Table 1. Bulk carrier fleet and order book by size class.**

Bulk carriers by size class	Existing bulk fleet			Ordered bulk fleet		
	Fleet	Millions DWTs (%)		Fleet	Millions DWTs (%)	
Modern Capesize ships	1,504	298.5	(38.7)	161	40.1	(47.7)
Capesize ships	580	57.6	(7.5)	21	2.0	(2.4)
Panamax ships	2,634	195.5	(25.4)	422	29.7	(35.3)
Supramax ships	1,936	107.9	(14.0)	42	2.4	(2.8)
Handymax ships	658	30.3	(3.9)	22	1.0	(1.2)
Handysize ships	2,803	78.3	(10.2)	247	8.8	(10.4)
DWTs below 10,000 Tons	1024	3.1	(0.4)	10	0.1	(0.1)
Total	11,139	771.1	(100)	925	84	(100)

Source: ISL (2017).



**Fig. 1. International seaborne trades and the percentages of main drybulk cargoes. (Source: UNCTAD (2017)).**



**Fig. 2. The traded ship price trends of Panamax second-hand bulk carriers. (Source: Clarkson Research (2017)).**

five-years-old or less.

The forecast will be important for shipping companies to optimize budget planning and risk management strategies (Adland and Cullinane, 2006; Alexandridis et al., 2017). The policy of sale and purchase (S & P) determines the success of operations for shipping companies; however, it is difficult to recognize the opportunities when they arise. Therefore, how shipowners manage the variation of ship prices in dynamic shipping markets becomes an important issue. Shipowners understand the price of second-hand ships will not only become assets to the company in time, but also be crucial with respect to the timing for selling and purchasing ships. The purpose of this paper is to predict the ship prices of Panamax second-hand bulk carriers for tramp shipping companies to help them operate more efficiently.

## II. LITERATURE REVIEW

Research on the international drybulk markets has focused on Capesize and Panamax ships of major seaborne deadweight tonages. Xu et al. (2011) studied the relationship between freight volatility and fleet size growth in drybulk shipping markets. Chang and Lai (2011) developed a nonlinear predictive model for Panamax second-hand bulk carriers.

The impact of second-hand ships on price changes is an important issue in the drybulk sector of the shipping industry. Kavussanos and Alizadeh (2002) examined the efficient market hypothesis with information on newly built and second-hand ship prices in the drybulk sector of the shipping industry using a series of statistical tests. Syriopoulos and Roumpis (2006) sought to gain insight into S & P market dynamics and the sensitivity of ship prices movements.

Grey System Theory became a popular approach to enhance the quality of forecasting and decision-making since Deng (2000) proposed it in 1982. The GM(1, 1) model of Grey theory was used to compare the growth trend of ship tonnage structures among China, Hong Kong, Singapore, and Taiwan by Chung et al. (2009). Liu (2016) showed Grey information can deal with uncertain information well. The recursive residual GM(1, 1) model computed by Chang (2008) is an improved method that raises the performance of GM(1, 1) by adjusting the residual.

The trade of second-hand ships in terms of price is influenced by the flux of supply and demand of global trades, with this being highly uncertain. The paper applies the traditional GM(1, 1), rolling GM(1, 1), and recursive residual GM(1, 1) models to calculate the one-month period for the ship prices of Panamax second-hand bulk carriers equal to or less than five-years-old.

## III. FORECAST MODELS

The Grey model was adopted to predict the ship prices of Panamax second-hand bulk carriers. The first order differential equation of GM(1, 1) model is adopted in this study.

They can be written as Eq. (1), let  $n \geq 4$  and  $x^{(0)}(k)$  mean the data of  $k$  variable,

$$x^{(0)} = (x^{(0)}(1), x^{(0)}(2), \dots, x^{(0)}(n)) \quad (1)$$

When constructing a model, the Grey system must apply one order accumulated generating operation (AGO) to the primitive sequence to provide the middle message of building a model to weaken the variation tendency. Herein,  $x^{(0)}$  is defined to be  $x^{(0)}$ 's one order AGO sequence. That is,

$$x^{(1)} = (x^{(1)}(1), x^{(1)}(2), \dots, x^{(1)}(n)) \\ = \left( \sum_{k=1}^1 x^{(0)}(k), \sum_{k=1}^2 x^{(0)}(k), \dots, \sum_{k=1}^n x^{(0)}(k) \right) \quad (2)$$

The mean generating operation can be written as Eq. (3):

$$z^{(1)}(k) = \frac{1}{2} [x^{(1)}(k-1) + x^{(1)}(k)], k \geq 2 \quad (3)$$

The first order differential equation of GM(1, 1) model is shown as Eq. (4). They can be written as Eq. (5):

$$\frac{dx^{(1)}}{dt} + ax^{(1)} = b \quad (4)$$

$$k^{(0)}(k) + az^{(1)}(k) = b \quad (5)$$

where  $t$  is an independent variable,  $a$  is the developed coefficient;  $b$  is the Grey controlled variable.

After applying the ordinary least square (OLS) method in Eq. (5), the coefficient vector  $\hat{a}$  becomes

$$\hat{a} = \begin{bmatrix} a \\ b \end{bmatrix} = (B^T B)^{-1} B^T y_n$$

The constant vector  $y_n$  is:

$$y_n = [x^{(0)}(2), x^{(0)}(3), \dots, x^{(0)}(n)]^T$$

The accumulated matrix is:

$$B = \begin{bmatrix} -z^{(1)}(2) & 1 \\ -z^{(1)}(3) & 1 \\ \vdots & \vdots \\ -z^{(1)}(n) & 1 \end{bmatrix} = \begin{bmatrix} -0.5(x^{(1)}(2) + x^{(1)}(1)) & 1 \\ -0.5(x^{(1)}(3) + x^{(1)}(2)) & 1 \\ \vdots & \vdots \\ -0.5(x^{(1)}(n) + x^{(1)}(n-1)) & 1 \end{bmatrix}$$

After solving Eq. (5), Eq. (6) is obtained

$$\hat{a}^{(1)}(k+1) = \left[ x^{(0)}(1) - \frac{b}{a} \right] e^{-ak} + \frac{b}{a} \quad (6)$$

**Table 2. Forecasting ability of the models.**

The value of MAPE	Forecast ability
$MAPE < 10\%$	High accuracy
$10\% \leq MAPE < 20\%$	Good
$20\% \leq MAPE < 50\%$	Logicalness
$MAPE \geq 50\%$	Incorrect

**Table 3. Accuracy for Panamax second-hand bulk carriers. (Units: %)**

Time periods	Sample size	4	5	6	7	8	9	10	average
	Model								
One month	GM(1, 1)	94.38	95.10	97.49	95.14	91.64	89.83	89.15	94.25
	Rolling GM(1, 1)	97.40	98.01	98.47	98.76	97.33	94.61	93.04	96.80
Two months	GM(1, 1)	95.20	97.32	97.00	91.66	88.70	87.30	87.53	92.10
	Rolling GM(1, 1)	98.53	98.55	98.47	97.47	95.39	93.38	92.32	96.30
Three months	GM(1, 1)	95.04	90.46	86.65	86.17	86.87	88.75	90.93	89.27
	Rolling GM(1, 1)	98.22	97.47	95.48	93.67	92.59	92.53	93.10	94.72

The average accuracy calculated for one-month forecasting is 96.80% according to the rolling GM(1, 1) model, which is better than the GM(1, 1) model, and both models have high forecasting accuracy.

The inversed accumulated generating operation (IAGO) is obtained after solving Eq. (6); we can write the following:

$$\hat{x}^{(0)}(k+1) = \hat{x}^{(1)}(k+1) - \hat{x}^{(1)}(k)$$

$$\hat{x}^{(0)}(k+1) = \left[ \hat{x}^{(0)}(1) - \frac{b}{a} \right] e^{-ak} (1 - e^a)$$

The reduction sequence is obtained as follows:

$$\hat{x}^{(0)} = (\hat{x}^{(0)}(1), \hat{x}^{(0)}(2), \dots, \hat{x}^{(0)}(n))$$

The recursive residual GM(1, 1) model is a developed method from traditional GM(1, 1). We can write a new series as Eq. (7).

$$e^{(0)}(k) = x^{(0)}(k) - \hat{x}^{(0)}(k) \tag{7}$$

Eq. (8) can be derived from Eq. (7) and is calculated to be the new forecast value of the original forecast value.

$$\hat{x}^{(0)}(k)' = \hat{x}^{(0)}(k) + \hat{e}^{(0)}(k) \tag{8}$$

We write the second series as Eq. (10).

$$e^{(0)}(k)' = x^{(0)}(k) - \hat{x}^{(0)}(k)' \tag{9}$$

The new forecast value of the residual can be written as Eq. (10).

$$\hat{e}_{adj}^{(0)}(k)' = \hat{e}^{(0)}(k)' + \min(e^{(0)}(k)') \tag{10}$$

The final forecast value can be written as Eq. (11).

$$\hat{x}^{(0)}(k)'' = \hat{x}^{(0)}(k)' + \hat{e}_{adj}^{(0)}(k)' \tag{11}$$

Mean absolute percentage error (MAPE) will be used for comparing the degree of accuracy of the forecast. It can be written in the following way:

$$MAPE = \frac{1}{n} \sum_{k=1}^n \left| \frac{x_k - \hat{x}_k}{x_k} \right| \times 100\%$$

According to Chung et al. (2009), Table 2 indicates the four different levels the forecast ability of the models can reach.

#### IV. THE RESULTS OF THE GM(1, 1) MODEL FOR THE VARIATION IN SHIP PRICES OF PANAMAX BULK CARRIERS

This paper is based on data from Clarkson Research (2017), one of the reliable sources of research on ship prices. We calculated the ship prices of Panamax second-hand bulk carriers from June 2013 to October 2017 according to the traditional GM(1, 1) and rolling GM(1, 1) models. We first observed three data points and took the following data 4-10 as the input GM(1, 1) and rolling GM(1, 1) models.

The accuracy of ship prices for Panamax second-hand bulk carriers equal to or less than five-years-old is shown in Table 3.

The rolling GM(1, 1) model is applied to calculate the one-

**Table 4. Results of rolling GM(1,1) model. (Units: Million USD)**

Ship prices of Panamax second-hand bulk carriers							
$K$	1	2	3	4	5	6	7
Actual value	18.50	18.50	18.00	18.00	18.50	18.50	18.40
Forecast value		18.48	18.17	17.92	17.67	-	-
			17.92	18.17	18.42	18.67	-
				18.09	18.33	18.58	18.84
Average accuracy	97.40			Residual error (%)	4.49	0.94	2.37

**Table 5. MAPE to compare the degree of accuracy.**

Time periods	Model	Sample size							
		4	5	6	7	8	9	10	
One month	GM(1, 1)	0.1204	0.8203	0.6802	1.0436	1.0626	1.0960	3.0870	
	RRGM(1, 1)	0.1204	0.8202	0.6792	1.0434	1.0627	1.0960	3.1072	
Two months	GM(1, 1)	0.3624	0.4124	0.5708	0.8071	0.6920	1.8489	3.2000	
	RRGM(1, 1)	0.3625	0.4123	0.5704	0.8074	0.6921	1.8528	3.2220	
Three months	GM(1, 1)	0.0256	0.1903	0.4634	0.4742	1.1063	2.1098	3.4884	
	RRGM(1, 1)	0.0257	0.1902	0.4634	0.4740	1.1092	2.1328	3.5066	

**Table 6. Interval forecast values for the ship prices of Panamax second-hand bulk carriers. (Units: Million USD)**

Forecast Market	Decreasing			Fair		Increasing	
	The Most Pessimism	More Pessimism	Pessimism	Forecast Value	Optimism	More Optimism	The most Optimism
5	-15%	-10%	-5%	100%	5%	10%	15%
6	-20%	-15%	-10%	100%	10%	15%	20%
7	-25%	-20%	-15%	100%	15%	20%	25%
Ship prices of Panamax second-hand bulk carriers							
5	15.02	15.90	16.79	17.67	18.55	19.44	20.32
6	14.94	15.87	16.80	18.67	20.54	21.47	22.40
7	14.13	15.07	16.01	18.84	21.67	22.61	23.55

month period ship prices of Panamax second-hand bulk carriers, and these prices are shown in Table 4. The average accuracy is 97.40%, indicating the ship price trends are reasonable.

After calculating the GM(1, 1) and recursive residual GM(1, 1) models for one period of ship prices for Panamax second-hand bulk carriers, this research used MAPE to compare the degree of accuracy of forecasting, as shown below in Table 5.

As seen in Table 5, the traditional GM(1,1) and recursive residual GM(1,1) models show only a few differences in accurate predictions for the ship prices of Panamax second-hand bulk carriers.

To understand the ship price trends of Panamax second-hand bulk carriers, this research used an interval value instead of a single value. Besides the time series considered, the level of optimism of growing ship markets and the level of pessimism of decreasing ship markets are also considered. In accordance with the types classified by Chung et al. (2009), this paper tries to use 'decreasing', 'fair' and 'increasing' for forecasting the dry-bulk shipping market. The interval forecast values for the ship

prices of Panamax second-hand bulk carriers are shown in Table 6.

In Table 6, when  $K = 5$ , the single value of the rolling GM(1, 1) model is 17.67 million USD, and the interval forecast values are between [16.79, 18.55], [15.90, 19.44], [15.02, 20.32] million USD if the changes are -/5%, -/10% and -/15% in the forecast dry bulk shipping markets.

There are different predictive ship prices for  $K = 5, 6$ , and 7 that could assist shipowners in understanding the ship prices of existing bulk carriers according to the influence factors. Shipowners would be able to know the assets of a shipping company in time, as well as make decisions for S & P and chartering business strategies.

## V. CONCLUDING REMARKS

Global seaborne trades reflect the growth of the world economy and global GDP. Global seaborne trades will therefore be affected by the main drybulk cargoes. This research focuses on the bulk fleet of Panamax ships equal to or less than five-

years-old and predicts the ship prices of second-hand bulk carriers for tramp shipping companies for making strategic decisions.

1. In 2017, the global DWTs by size class, modern Capesize and Panamax bulk carriers were 38.7% and 25.4%, respectively. Modern Capesize and Panamax bulk carriers have the major seaborne DWTs in the worldwide bulk carriers, and their ordered fleet is also growing faster than other bulk carriers. This research applies the rolling GM(1, 1) model to calculate the one-month period for the ship prices of Panamax second-hand bulk carriers equal to or less than five-years-old; the average accuracy is 97.40%, thus indicating we can understand the ship price trends to a reasonable extent.
2. The paper shows adopting the traditional GM(1, 1), rolling GM(1, 1), and recursive residual GM(1, 1) models of the Grey theory with four samples led to only a few differences in terms of accurate predictions, and also shows the limitation for the price of ships is neither steady nor varies widely. Grey theory makes highly accurate predictions that can assist shipowners in understanding the ship prices of Panamax second-hand bulk carriers.
3. We suggest future research verify the models for bulk carriers with other size classes and different ages. Additionally, the interval values that are substituted for a single value on the points of optimism and pessimism were used to control the interval forecast values. However, as for the level of optimism or pessimism of the S & P markets, this research offers an ordinary change rate for discussion, and suggests further discussions on the interval forecast values are needed.

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