An econometric analysis for container shipping market**

MEIFENG LUO*, LIXIAN FAN and LIMING LIU

Department of Logistics and Maritime Studies, Faculty of Business, The Hong Kong Polytechnic University, Hung Hom, Kowloon, Hong Kong

This article presents an econometric analysis for the fluctuation of the container freight rate due to the interactions between the demand for container transportation services and the container fleet capacity. The demand is derived from international trade and is assumed to be exogenous, while the fleet capacity increases with new orders made two years before, proportional to the industrial profit. Assuming the market clears each year, the shipping freight rate will change with the relative magnitude of shifts in the demand and fleet capacity.

This model is estimated using the world container shipping market statistics from 1980 to 2008, applying the three-stage least square method. The estimated parameters of the model have high statistical significance, and the overall explanatory power of the model is above 90%. The short-term in-sample prediction of the model can largely replicate the container shipping market fluctuation in terms of the fleet size dynamics and the freight rate fluctuation in the past 20 years. The prediction of the future market trend reveals that the container freight rate should continue to decrease in the coming three years if the demand for container transportation services grows at less than 8%.

1. Introduction

Within the short history of containerization, transportation of containerized goods by sea has significantly increased trades between nations with different comparative economic advantages. Specialization and technological progress have boosted the efficiency in global shipping and port operation in the past two decades, making container transportation indispensable for global trading firms to thrive in the increasingly competitive economic environment. Recent statistics show that while the world seaborne trade doubled from 3631 million tons in 1985 to 7852 million tons in 2007, the containerized trade increased almost eight times within the same period from 160 million tons to 1257 million tons [1]. This demonstrates the increasing role of container transportation and its contribution to the global economy.

Regardless of the booming global seaborne trade and containerization, the fluctuating container freight rate, as shown by the container time charter rate in the past two decades (Figure 1), unhinged the profitability in the container shipping industry. When the freight rate is high, the high demand for container shipping services hastened shipping companies to order bigger and more efficient...

*To whom correspondence should be addressed. e-mail: lgtmluo@polyu.edu.hk

**A preliminary version of this article has been presented in International Forum on Shipping, Ports and Airports 2009 (Hong Kong), and the Annual Conference for International Association of Maritime Economists (IAME), 2009 (Copenhagen, Denmark).
container vessels in order to attract global customers with better services at lower cost and to gain larger shares of the global competitive shipping market. Companies with the most up-to-date container vessels can therefore outperform others because of faster and reliable services at a lower unit cost. While this reduction of sea transportation cost can induce additional demand, it also causes major problems for the companies with less efficient fleets. According to Drewry Shipping Consultants Ltd., compared with 2006, global carriers moved 14.7% more cargo, but earned 1.2% less revenue in 2008. On the main east-west trade routes, aggregated losses of the carriers amounted to $2.4 billion, an 8% net loss. Maersk Line, the world largest shipping line with more than 16% of the world’s liner fleet, suffered a $568 million loss in 2006.

The low freight rate in the shipping cycle not only has a significant negative impact on business operations and investment decisions, but has also brought extensive concerns at both national and international levels. Bankers, who finance the building or purchasing of ships, bear high financial risks due to the insolvency of the shipowners when the freight rate is low. According to Volk [2], most of the ship investment activities are concurrent with the high freight rate. Goulielmos and Psifia [3] point out that bankers finance 75–80% of the ship construction cost. Therefore, it is essential for the bankers to understand the shipping cycle and take it into consideration when making loan decisions.

Low freight rates and thin profits in the shipping industry can also create extensive concerns in maritime policy and administration. ‘Safer Shipping and Cleaner Oceans’, once the mission statement of the International Maritime Organization, resonates the wide concerns over substandard vessels and crews, two critical factors in maritime accidents that have caused loss of life and property at sea, as well as marine environmental pollution. These undesirable incidents most likely follow when shipowners have insufficient earnings to maintain their ships and train their crews. To stay in business when the freight rate is low, ship operators have to reduce operation cost in vessel maintenance and manning, even replacing qualified crews with inexperienced, low salary ones. This can multiply substandard
vessels, impair maritime safety, heighten maritime casualties, and undermine sustainability in maritime shipping. According to a report prepared by SSY Consultancy & Research Ltd. for Organization for Economic Cooperation and Development (OECD) Maritime Transportation Committee [4], low freight rate in the previous 30 years is the most important factor in substandard shipping, which has caused huge economic losses.

From the perspective of national and regional public policy, the major concern is perhaps the mass layoff from the shipping industry during low freight rate period. When the freight revenue cannot cover its operating cost, a shipping company has to layup a ship and layoff its employees. This is particularly harmful to those developing countries supplying a large maritime work force or providing various kinds of services to the shipping industry. The massive layoffs from the shipping industry facing low freight rate can significantly increase the unemployment rate in these countries. On 9 January 2008, having suffered huge losses in 2006 and very low profit in 2007, Maersk Line announced in the Los Angeles Times that it planned to layoff as many as 3000 people from 25 000 employees in its container division. On 6 November 2008, as part of the global layoff plan, Maersk A/S announced that it would cut 700 positions in the Chinese market by 2009, and shut down the global services centre in Guangdong. This province had already suffered massive layoffs recently from the shutting down of many manufacturers facing weak export demand. Further layoffs from the shipping company would further exacerbate the economic situation in this region.

The importance of the shipping cycle for both private business operation and public sectors has, unsurprisingly, motivated numerous efforts to understand, describe, model and predict the fluctuation of the shipping freight rate. Martin Stopford [5], for example, described the shipping cycle in the past 266 years, discussed its characteristics, frequency and prediction difficulties. Freight market analysis is the first area for applied econometrics. Tinbergen and Koopmans, two well-known pioneers in econometrics, actually started econometric analysis in shipping [6]. Tinbergen investigated the sensitivity of freight rates to changes in demand and supply. Koopmans proposed the first theory to forecast tanker freight rates, assuming market equilibrium between demand and supply. He explained the dynamic behaviour of the tanker market by investigating the interrelationship between the market size, freight rate and shipyard’s activity. Since then, many different models have been developed for tanker and bulk market analysis. Beenstock and Vergotti [6, 7] developed a market equilibrium model assuming explicitly profit optimization on the supply side, and perfect competition on the demand. They tested the model for the tanker and dry bulk shipping markets using annual data. This work is recognized as a milestone in econometric analysis of shipping market that ‘heavily influenced’ the modern analysis of the bulk shipping market [8]. The most recent work that follows BV’s model is Tvedt [9], who combined structural and econometric stochastic methods, and built a continuous stochastic partial equilibrium model for the freight and new building markets. He found that the equilibrium freight rate process is close to that of a standard geometric mean reversion process.

Despite the significant contribution of container shipping in world seaborne trade, the literature on economic modelling and statistical analysis of the container shipping market is scarce. This article is an attempt to fill the gap by building a dynamic-economic model for the container shipping market and testing it using
annual data from the past 28 years. Furthermore, this article reveals the significance of collective market adjustment principles using the observed data, without involving complexities in individual behaviour analysis, such as market competition strategies, speculation, and hedging.

This article first describes the theoretic model on the container shipping freight rate and container fleet dynamics. Then, it explains the econometric process for estimating the structural model, the data, the regression results, as well as the stability test of the model. After that, the article presents an in-sample model prediction to compare with the actual freight data in the study period, and a validity test by calculating the forecast errors for 2007 and 2008 using different estimated models. As an application, it presents the model predictions for the future container shipping market between 2009–2013, under different assumptions about the increasing rate of future container shipping demand, and possible cancellation of new orders. The purpose of this prediction is to alert the decision makers to the possible risks and short-term market trends in the container shipping sector.

2. Theoretical model

It is well recognized that the container shipping market is characterized by a high level of concentration, which can be exemplified by the statistics that show that some 48% of the market share is carried by three largest global alliances (Grand Alliance, the CKHY Alliances and the New World Alliance) and Maersk Line (Containerization International, 2008). This certainly is distinctive compared with the bulk and tanker market which is far more dispersed. However, whether this level of concentration is sufficient to change the container shipping market into a monopoly is still debatable. Sys [10] suggests that the container shipping industry is operating in an oligopoly market; while Haralambides [11] argues that it is the accessibility of the market to new or potential competitors that determines its contestability. A discussion about the structure of liner shipping market can be found in Shashikuma [12]. Instead of judging the nature of the liner shipping market, we build our model based on our hypothesis about the market structure, and test it using the observed data.

As in the dry bulk and tanker markets, the container shipping market also includes a second-hand market, new-building market and scrapping market. Several assumptions are made to simplify the model and focus on the freight market, and these assumptions are directly related to the formulation of the model.

First, as the container shipping industry is relatively new and the life time of the early container vessel is usually about 30 years, the scrapping activity has only started recently, and the size of the scrapping is just a small fraction of the total world fleet size. The average proportion of demolition to the world container fleet capacity was only 0.593% from 1994 to 2007. Thus we can ignore the impact of scrapping on the container fleet capacity.

Second, we assume that the second hand market will not affect the container freight market. As trade in the second hand market does not change the usage of a container vessel, it does not affect the world container fleet capacity.

To further simplify the model, we assume that the new building market will not affect the container freight market. When a shipping company considers placing a new order, the main decision variable is the freight rate, not the new building price. Statistics show that there is a high positive correlation between new building orders
and freight rate, as depicted in Figure 2. There are more new orders when the freight rate is high, which is often the time when the price of the new building is high.

The above assumptions enable us to focus on the freight market, i.e., model the fluctuation of the freight rate from the interaction between demand for container shipping services, and its supply measured by the total world fleet capacity (in TEU slots). We first model the change in world container fleet capacity with the industrial profit. As a high freight rate is a good indicator of high industrial profit, we first postulate that the total size of new orders $N_t$ at year $t$ is proportional to the overall industrial profit of that year, i.e.,

$$N_t = \eta \cdot \text{Profit}_t,$$

where $\eta$ is the average proportion of profits spent on purchasing new ships, and the $\text{Profit}_t$ follows the common definition:

$$\text{Profit}_t = P_t Y_t - c_1 X_t - c_2 OIL_t,$$

where $Y_t$ is the total number of containers carried, $P_t$ the market freight rate per TEU, $X_t$ the world container fleet capacity (in TEU slots), $OIL_t$ the bunker price, $c_1 > 0$ the constant marginal/average cost per fleet capacity (in TEU slots), and $c_2 > 0$ the profit adjustment factor for the bunker price.

For simplicity, we use the average lag ($\theta$) to represent the time from a new order to delivery. Then the change of the world container fleet capacity can be expressed as:

$$\Delta X_t = N_{t-\theta},$$

where $\Delta X_t = X_t - X_{t-1}$. By putting Equations (1)–(3) together, the world shipping fleet dynamic equation can be specified as:

$$\Delta X_t = \eta(P_{t-\theta} Y_{t-\theta} - c_1 X_{t-\theta} - c_2 OIL_{t-\theta}).$$

Next we describe how the freight rate changes with the demand for container shipping, and the world fleet capacity. The change of market price due to the change
in demand and supply, a fundamental economic problem, has been well studied in the literature. When there is no short-term flexibility in demand and supply, the delayed response to the excessive demand or supply can also result in price oscillation. Kaldor [13] used the well-known Cobweb model (Figure 3) to describe the price change with alternative excessive demand and excessive supply.

When the market price is high at time 1, the quantity demanded ($Q_1$) at $P_1$ is lower than the quantity supplied ($Q_2$). The excessive supply ($Q_2 - Q_1$) will reduce the price to $P_2$ in the next period. At this price level, the quantity demanded ($Q_2$) is higher than the quantity supplied ($Q_3$). This excessive demand ($Q_2 - Q_3$) will increase the price. The stability of the market price in the long run will depend on the relative price sensitivity of demand and supply. According to this theory, the change of market price can be written as:

$$\Delta P_t = \delta(Y_t - \phi X_t),$$

where $\Delta P_t = P_t - P_{t-1}$, the price change in year $t$, and $\phi$ the reuse rate of a TEU slot. This equation states that price will increase when there is excessive demand, and drop with excessive supply.

Considering the nature of maritime transportation for containerized goods, first, shipping freight rate is flexible and negotiable between the shipper and carrier. Second, it is well-known that the marginal cost for an additional container, especially in liner services, is very low. Container carriers can always accept one more box as long as it covers the marginal cost. Third, there are many ways to provide short-term shipping services when facing a sudden demand increase, including increase loading factors or increase cruise speed. Thus, demand and supply are both flexible enough in the container shipping industry, especially on an annual level. This conforms to BV's model assumption in market equilibrium in his econometric analysis for the dry bulk and tanker markets [6].

Assuming market clears each year, the freight rate changes with exogenous demand shift caused by the exogenous change in international trade, and the supply shift as more container vessels are added to the world container fleet capacity. From the demand side, with the increase in international trade, the demand for container
shipping will increase even when the market freight rate is constant. On the supply side, when more capacity is added to the industry, more container ships are available in the market to provide more services even at the same market price. An illustration of how market price changes with relative shifts in demand and supply are given in Figure 4.

Assuming at time $t$, the market clearing price and quantity are ($P_t, Q_t$), the intersection of demand $D_t$ and supply $S_t$. If there are equal amount of supply and demand shifts ($D_t \rightarrow D_{t+1}$, $S_t \rightarrow S_{t+1}$), the new market clearing price will remain unchanged, while the quantity will be $Q_{t+1}$. This confirms to the description by Tvedt [9]. If the supply only moves to $S'_{t+1}$, less than the demand shift, the market clearing price will increase to $P'_{t+1}$. On the other hand, if the supply moves to $S''_{t+1}$, more than the demand shift, the market clearing price will drop to $P''_{t+1}$. Applying this to the container market freight rate with respect to the supply and demand change, we postulate:

$$
\Delta P_t = \delta(\Delta Y_t - \varphi \Delta X_t),
$$

where $\Delta Y_t$ is the change in the total number of containers handled, $\varphi > 0$ is a constant representing the average annual container slot reuse rate, and $\delta > 0$ is the price adjustment factor due to the demand and supply shifts.

Equations (4) and (6) are the two dynamic equations that describe the two major forces in the container shipping market. The interaction of these two forces can be illustrated in Figure 5. We assume that the market demand for container shipping increases exogenously. When the price is high (at A in Figure 5), the high industry profit will bring up the number of new orders (denoted by larger upper triangles). If the delivery of new container ships results in a larger increase in capacity than that in demand, the market price will fall. When this happens (at B), there will be very few new orders (denoted by smaller upper triangles) by the speculators, but the ships ordered in the previous two or three years when the freight rate increases will keep adding to the existing fleet, which will accelerate the decreasing rate of the freight rate. This downward trend in the market freight rate will end when the capacity increases slower than the demand increase (at point C where the delivery
is very small). Because of the few new orders during the previous two or three years, the low supply in shipping capacity will push up the market price. When the market price increases, there will be a stronger incentive to order more new container vessels again, which will lead to a new shipping cycle.

To test the model, using the annual data for container market freight rate, the total number of containers handled, the world fleet capacity in TEU slots, and the bunker price from 1980 to 2008, we estimated the parameters in the statistical model using the above data, which will be explained in the next section.

3. Quantitative analysis of the dynamic model

We construct the statistical model by transferring Equations (4) and (6) into linear forms as follows:

\[
\begin{align*}
\Delta X_t &= \eta P_{t-\theta} Y_{t-\theta} - \eta c_{1} X_{t-\theta} - \eta c_{2} OIL_{t-\theta} + \varepsilon_{1t} \\
&= \alpha_{1} P_{t-\theta} Y_{t-\theta} - \alpha_{2} X_{t-\theta} - \alpha_{3} OIL_{t-\theta} + \varepsilon_{1t}, \tag{7}
\end{align*}
\]

\[
\begin{align*}
\Delta P_t &= \delta \Delta Y_t - \delta \varphi \Delta X_t + \varepsilon_{2t} = \alpha_{4} \Delta Y_t - \alpha_{5} \Delta X_t + \varepsilon_{2t}. \tag{8}
\end{align*}
\]

The last term \(\varepsilon_{it}\) in each equation is the error term. Although \(Y_{t-\theta}\) appears in Equation (7) and \(Y_t\) appears in Equation (8), they are not contemporaneously correlated, so Equation (7) can be estimated by itself. As \(\Delta X_t\) appears on the left-hand side of Equation (7) and the right-hand side of Equation (8), the error terms are not independent (\(\text{cov}(\Delta X_t, \varepsilon_{2t}) = \sigma_{12}\)). Thus we apply the Simultaneous Equation (SE) method to estimate the coefficients in the system. The first step in the SE is to rewrite Equations (7) and (8) as reduced forms by expanding the \(\Delta X_t\) in Equation (8):

\[
\begin{align*}
\Delta X_t &= \pi_{1} P_{t-\theta} Y_{t-\theta} - \pi_{2} X_{t-\theta} - \pi_{3} OIL_{t-\theta} + \varepsilon_{1t} \\
\Delta P_t &= \alpha_{4} \Delta Y_t - \alpha_{5} P_{t-\theta} Y_{t-\theta} + \alpha_{5} \alpha_{2} X_{t-\theta} + \alpha_{5} \alpha_{3} OIL_{t-\theta} + \alpha_{5} \varepsilon_{1t} + \varepsilon_{2t} \\
&= \pi_{4} \Delta Y_t - \pi_{5} P_{t-\theta} Y_{t-\theta} + \pi_{6} X_{t-\theta} + \pi_{7} OIL_{t-\theta} + \pi_{8} \varepsilon_{1t} + \varepsilon_{2t}
\end{align*}
\]

As can be seen from the reduced form, the two equations are not independent. Thus, the Two Stage Least Square (2SLS) is not sufficient to make full use of the
correlation between error terms. Therefore, the Three Stage Least Square (3SLS) method was applied in the estimation process for the coefficients in the reduced form. The estimated parameters are transferred back to the structural equation. The instrument variables used in the 3SLS include all the exogenous variables and predetermined variables. The estimation process follows the standard treatment as specified in [14], so it will not be included in this article.

3.1. Data
Demand for container transportation services is derived demand from global trade, which is determined by the comparative advantage of individual countries. We take demand as given to avoid modelling the global trade. Besides this, as unsatisfied demands are not observable, the assumption on market clearance each year enables us to use the container throughput as quantity demanded. The data used in this study and their sources are included in Table 1.

The world container throughput, from the Drewry Annual Container Market Review and Forecast, is the total port throughput, including the empty and transhipment containers. We use container throughput, not the world trade volume, as the demand for container shipping services, for the following two reasons. First, the world trade volume includes many commodities that are not carried by ships. Furthermore, not all the seaborne trade is containerized and the containerization rate is changing. As a result, to convert world trade volume of different commodities to a number of TEUs is not currently feasible. Secondly, container throughputs are a more appropriate data to use. Although there are empty containers, transhipments and possible double counting, they are actually part of the demand for container transportation services. Thus, we used container throughput, rather than the world trade volume, as the demand for container transportation services.

The same report from Drewry also provides the container freight rate, which is the weighted average of Transpacific, Europe-Far East and Transatlantic trades, inclusive of THCs (Terminal Handing Charge) and intermodal rates. This variable is a synthetic index, representing the average level of container freight rates. This can be an index for shipowners’ unit revenue. As Drewry only reported freight rates from 1994–2008, we have to calculate the missing period (1980–1993) from the General Freight Index in the Shipping Statistics Yearbook 2007, using a simple statistical equation between container freight rate and the general freight index from 1994 to 2008. The container fleet capacity data are also from the Drewry Annual Container Market Review and Forecast.

On the supply side, we use the data from Clarkson Research Services Limited 2008, which include the new order, delivery and scrapping data in TEU slots and bunker prices. Although some of these data are not used to estimate the main model, they are used to determine whether to include the scrapping market and the shipbuilding lag. Therefore, they are also included in the table.

3.2. Specification of $\theta$
As a key factor in shipping market analysis, the shipbuilding lag is ubiquitous in almost all the econometric analysis in this field. Binkley and Bessler [15] found that the shipbuilding construction lag, ranging from 8 months to around 2 years, is one of the most important market features in the bulk shipping market analysis. In our study, we assume constant construction lag during the study period.
<table>
<thead>
<tr>
<th>Year</th>
<th>Container throughput ($Y$; K TEU)*</th>
<th>Freight rate ($P_t$; $$/TEU$)*</th>
<th>Fleet capacity ($X_t$; K TEU)*</th>
<th>Bunker price ($OIL_t$; $$/ton$)*</th>
<th>Delivery ($N_t$; K TEU)†</th>
<th>Scrap ($S_t$; K TEU)†</th>
<th>New order ($O_t$; K TEU)†</th>
</tr>
</thead>
<tbody>
<tr>
<td>1980</td>
<td>38 821</td>
<td>1762</td>
<td>665.0</td>
<td>307.0</td>
<td>115.8</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1981</td>
<td>41 900</td>
<td>16 441</td>
<td>702.0</td>
<td>288.3</td>
<td>38.3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1982</td>
<td>43 800</td>
<td>14 499</td>
<td>745.0</td>
<td>284.8</td>
<td>72.6</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1983</td>
<td>47 600</td>
<td>14 441</td>
<td>799.0</td>
<td>243.7</td>
<td>100.6</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1984</td>
<td>54 600</td>
<td>14 511</td>
<td>883.0</td>
<td>229.6</td>
<td>130.3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1985</td>
<td>56 170</td>
<td>14 201</td>
<td>1012.0</td>
<td>222.8</td>
<td>131.1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1986</td>
<td>62 200</td>
<td>13 555</td>
<td>1189.0</td>
<td>142.1</td>
<td>140.1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1987</td>
<td>68 300</td>
<td>14 555</td>
<td>1276.3</td>
<td>144.1</td>
<td>92.7</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1988</td>
<td>75 500</td>
<td>16 320</td>
<td>1384.7</td>
<td>124.7</td>
<td>116.4</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1989</td>
<td>82 100</td>
<td>16 322</td>
<td>1487.9</td>
<td>144.1</td>
<td>102.3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1990</td>
<td>88 049</td>
<td>15 444</td>
<td>1613.2</td>
<td>191.2</td>
<td>133.6</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1991</td>
<td>95 910</td>
<td>15 444</td>
<td>1756.0</td>
<td>170.8</td>
<td>152.1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1992</td>
<td>105 060</td>
<td>14 711</td>
<td>1916.3</td>
<td>161.9</td>
<td>167.6</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1993</td>
<td>114 920</td>
<td>14 801</td>
<td>2101.3</td>
<td>150.5</td>
<td>200.1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1994</td>
<td>129 380</td>
<td>14 666</td>
<td>2370.7</td>
<td>133.2</td>
<td>268.8</td>
<td>2.8</td>
<td>472.5</td>
</tr>
<tr>
<td>1995</td>
<td>144 045</td>
<td>15 191</td>
<td>2684.0</td>
<td>140.6</td>
<td>330.1</td>
<td>10.9</td>
<td>597.4</td>
</tr>
<tr>
<td>1996</td>
<td>156 168</td>
<td>14 344</td>
<td>3048.1</td>
<td>175.1</td>
<td>408.1</td>
<td>21.5</td>
<td>501.5</td>
</tr>
<tr>
<td>1997</td>
<td>175 763</td>
<td>12 822</td>
<td>3553.0</td>
<td>157.2</td>
<td>523.1</td>
<td>25.0</td>
<td>203.6</td>
</tr>
<tr>
<td>1998</td>
<td>190 258</td>
<td>12 672</td>
<td>4031.5</td>
<td>112.2</td>
<td>529.6</td>
<td>87.3</td>
<td>414.5</td>
</tr>
<tr>
<td>1999</td>
<td>210 072</td>
<td>13 852</td>
<td>4335.2</td>
<td>133.0</td>
<td>257.1</td>
<td>51.7</td>
<td>555.2</td>
</tr>
<tr>
<td>2000</td>
<td>236 173</td>
<td>14 211</td>
<td>4799.1</td>
<td>231.6</td>
<td>449.1</td>
<td>15.5</td>
<td>956.9</td>
</tr>
<tr>
<td>2001</td>
<td>248 143</td>
<td>12 691</td>
<td>5311.0</td>
<td>192.4</td>
<td>623.2</td>
<td>36.1</td>
<td>519.1</td>
</tr>
<tr>
<td>2002</td>
<td>277 262</td>
<td>11 555</td>
<td>5968.2</td>
<td>188.2</td>
<td>642.8</td>
<td>66.5</td>
<td>414.2</td>
</tr>
<tr>
<td>2003</td>
<td>316 814</td>
<td>13 511</td>
<td>6528.6</td>
<td>230.4</td>
<td>560.7</td>
<td>25.7</td>
<td>2057.0</td>
</tr>
<tr>
<td>2004</td>
<td>362 161</td>
<td>14 531</td>
<td>7162.8</td>
<td>313.4</td>
<td>643.0</td>
<td>4.0</td>
<td>1652.9</td>
</tr>
<tr>
<td>2005</td>
<td>397 895</td>
<td>14 911</td>
<td>8117.0</td>
<td>458.4</td>
<td>941.5</td>
<td>0.3</td>
<td>1644.3</td>
</tr>
<tr>
<td>2006</td>
<td>441 231</td>
<td>13 911</td>
<td>9472.0</td>
<td>524.1</td>
<td>1366.6</td>
<td>20.4</td>
<td>1784.6</td>
</tr>
<tr>
<td>2007</td>
<td>496 625</td>
<td>14 351</td>
<td>10805.0</td>
<td>571.3</td>
<td>1321.1</td>
<td>23.8</td>
<td>3060.1</td>
</tr>
<tr>
<td>2008</td>
<td>540 611</td>
<td>13 751</td>
<td>12126.0</td>
<td>850.7</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

†Clarkson Research Services Limited 2008.
Note: Freight rates (in italic) computed from general freight index (from Shipping Statistics Yearbook, 2007, Bremen; Institute of Shipping Economics and Logistics [16].
Furthermore, as we are using annual data, we require the lag to be rounded to an integer. Therefore, we constructed six statistical equations between the delivery and the new order data, and selected the most significant one to use in our model.

The regress results of the 6 equations are listed in Table 2. The 2-year lag and 3-year lag are all significant in models 1–6, but $R^2$ in model 5 is much bigger than that in model 6, so we choose $\theta = 2$. This means on average it takes 2 years to build a container vessel, although bigger ships may take longer and smaller ones may only need several months.

3.3. 3SLS results of the system parameters

The regression result from the 3SLS process for the structure equation, including the estimates of the structural parameters and their corresponding $t$-values, $R^2$ and adjusted $R^2$ are listed below:

$$\Delta X_t = 0.000034P_{t-2}Y_{t-2} - 0.06411X_{t-2} - 0.438215OIL_{t-2}$$

$$R^2 = 0.95, \text{ Adjusted } R^2 = 0.947$$

$$\Delta P_t = 0.00894\Delta Y_t - 0.378085\Delta X_t$$

$$R^2 = 0.353, \text{ Adjusted } R^2 = 0.328$$

All the estimated coefficients ($a_1$ through $a_5$ in Equations (7) and (8)) are significant at at least 90% confidence level, and the coefficient estimates on revenue ($a_1$), bunker ($a_3$), demand ($a_4$) and supply ($a_5$) are all significant at 99% confidence level.

To evaluate the overall explanatory power of the whole system, we use the Error Sum of Squares (SSE) and Total variance (SST) in the respective regression equation to construct the overall coefficient of determination for the system. From the first equation, we have $SSE_1 = 200,197$, $SST_1 = 4,125,572$. From the second equation, we get $SSE_2 = 158,424$, and $SST_2 = 245,222$. So the overall $R^2$ could be written as:

$$R^2 = 1 - \frac{SSE_1 + SSE_2}{SST_1 + SST_2} = 0.9179,$$

which indicates the overall explanatory power of the system is about 92%.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Model 1</th>
<th>Model 2</th>
<th>Model 3</th>
<th>Model 4</th>
<th>Model 5</th>
<th>Model 6</th>
</tr>
</thead>
<tbody>
<tr>
<td>$b_0$</td>
<td>255.5099</td>
<td>257.6291</td>
<td>175.4902</td>
<td>218.035</td>
<td>297.841</td>
<td>356.7358</td>
</tr>
<tr>
<td></td>
<td>(0.0436)</td>
<td>(0.0174)</td>
<td>(0.0061)</td>
<td>(0.0035)</td>
<td>(0.0022)</td>
<td>(0.004)</td>
</tr>
<tr>
<td>$order_t$</td>
<td>$-0.00475$</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.9475)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$order_{t-1}$</td>
<td>0.167043</td>
<td>0.166467</td>
<td>0.112564</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.0596)</td>
<td>(0.0327)</td>
<td>(0.0444)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$order_{t-2}$</td>
<td>0.211811</td>
<td>0.210334</td>
<td>0.251027</td>
<td>0.313896</td>
<td>0.434595</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.0361)</td>
<td>(0.0152)</td>
<td>(0.0021)</td>
<td>(0.0007)</td>
<td>(0.0003)</td>
<td></td>
</tr>
<tr>
<td>$order_{t-3}$</td>
<td>0.271466</td>
<td>0.269166</td>
<td>0.267692</td>
<td>0.279653</td>
<td></td>
<td>0.441905</td>
</tr>
<tr>
<td></td>
<td>(0.0156)</td>
<td>(0.0037)</td>
<td>(0.0013)</td>
<td>(0.0028)</td>
<td></td>
<td>(0.0043)</td>
</tr>
<tr>
<td>$order_{t-4}$</td>
<td>$-0.20405$</td>
<td>$-0.212$</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.3479)</td>
<td>(0.1867)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$R^2$</td>
<td>0.966885</td>
<td>0.966844</td>
<td>0.954026</td>
<td>0.914724</td>
<td>0.745311</td>
<td>0.615101</td>
</tr>
</tbody>
</table>
3.4. Explanation of the regression result

To understand the regression results, we first transform them back to the dynamic Equations (4) and (6):

\[
\Delta X_t = 0.0000034P_{t-2}Y_{t-2} - 0.06411X_{t-2} - 0.438215OIL_{t-2}
\]

\[
= 0.0000034(P_{t-1}Y_{t-2} - 19080X_{t-2} - 130421OIL_{t-2}) \quad (9)
\]

\[
\Delta P_t = 0.00894\Delta Y_t - 0.378085\Delta X_t = 0.00894(\Delta Y_t - 42.27\Delta X_t) \quad (10)
\]

Thus the coefficients in Equations (4) and (6) can be obtained from Equations (9) and (10), which are listed in Table 3.

The economic meanings of the estimated parameters are explained here. Parameter \( \eta \) is the propensity to order new ships or the increase rate of container capacity per dollar increase in industrial profit. The estimation indicates that 34 TEU slots will be added to the capacity per US$10 million profit in the industry. Considering that the cost for a 3500TEU container vessel was about US$63 million in 2007 (Clarkson, Shipping Review Database, 2009), our result shows that to order a container ship of that size, the total industrial profit has to be US$1029 million. This implies around 6.1% of the earnings are used for building new ships.

\( c_1 \) is the annual average cost to own and operate one TEU slot. It is the total cost paid by a shipping company in the transportation process, as long as that process is covered by the freight rate. \( c_2 \) is the gross cost adjustment factor per dollar increase in bunker price for the whole industry, in thousands of US dollars. It indicates that for a US$1 increase in bunker price, the operation cost for the whole industry will increase by about US$130 million. \( \delta \) represents the price sensitivity for the relative annual increment in demand and supply. The result shows that if demand shifts by 100,000 or more in TEU slots than the shift in fleet capacity, there will be an 89 cent increase in freight rate. The higher the \( \delta \), the more sensitive the freight rate is to the relative magnitude in demand and capacity change. \( \varphi \) is the capacity utilization factor, representing the annual reusing rate per TEU slot.

To test the stability of the regressed model, we conducted another two regression analyses using the same model applied to data from different time periods. The regression periods are from 1980 to 2006 and 1980 to 2007, respectively. The comparisons of the two additional regression results together with the regression on all observations (1980 to 2008) are shown in Table 4.

Table 4 indicates that the parameter estimates are stable, and the \( t \)-values for all the parameters are all significant. Hence, first, it is predictable that the estimated parameters in the model will not change much when there are more data observations in the future. Secondly, the stability in the parameter estimation and
the $t$-value indicate the stability of the whole model and is free from the autocorrelation and heteroskedasticity. Therefore, as we will show next, the prediction reliability using the estimated model can also be assured.

4. Prediction of the estimated model
When market demand is exogenous, the container shipping fleet capacity and the market freight rate are the two most important variables in the container shipping market analysis. The specification of the model enables us to predict the fleet capacity increases in 2 years based on the current container throughput, freight rate and bunker price. The relative capacity increase, determined endogenously from the first dynamic equation, can then be used to predict the adjustment in freight rate, for given container transportation demand.

4.1. In-sample prediction
To demonstrate the explanatory power of our model, we first compare the model prediction with the actual data. An in-sample prediction for the market fleet capacity and the freight rate, together with the actual freight rate and fleet capacity from 1980 to 2008 (called 80-08 model), are provided in Figure 6.

Figure 6 exhibits that the fleet capacity increased faster in recent years than the earlier years, as the horizontal distances between each pair of dots are wider in recent years. The freight rate generally decreases over time, and oscillates around the US$1400 in the later years. Our prediction can largely replicate the trend of the actual freight rate change. The predicted fleet capacity each year is very close to the real fleet capacity (They are basically in the same vertical line). The predicted fleet capacity and the freight rate for 2008 (12 030 000 TEU slots, US$1329 per TEU) are very close to the real capacity and freight rate (12 126 000 TEU slots, US$1375 per TEU).

To check the prediction stability of the model, we estimated it again using the observations from 1980 to 2006, and used it to predicate the freight rate and fleet capacity for 2007 and 2008. The actual value of the fleet capacity and freight rate and the predicted ones with the 80-06 model and 80-08 model are shown in Table 5.

Comparing the predicted results from the two different models, it is obvious that both models can predict the fleet capacity with a relatively smaller error than the prediction of the freight rate. The freight rate prediction errors range from 2.52% to 4.14%, while those for fleet capacity are less than 2.10%. In both models, the

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>$n$</td>
<td>0.00000312</td>
<td>0.00000362</td>
<td>0.0000036</td>
</tr>
<tr>
<td>$c_1$</td>
<td>−17003</td>
<td>−22683</td>
<td>−19080</td>
</tr>
<tr>
<td>$c_2$</td>
<td>−141064</td>
<td>−134830</td>
<td>−130421</td>
</tr>
<tr>
<td>$\delta$</td>
<td>0.009386</td>
<td>0.009093</td>
<td>0.008944</td>
</tr>
<tr>
<td>$\varphi$</td>
<td>−45</td>
<td>−43</td>
<td>−42</td>
</tr>
</tbody>
</table>
prediction errors are within 5%, which indicates a good fit, even for the out-sample prediction. Therefore, in the prediction for the container market, the 80-08 model prediction result will be presented.

4.2. Prediction for container shipping market

The purpose of this dynamic-economic model is to predict the future market situation, so that decision makers can anticipate and respond to possible market changes. The first necessary step is to assume that the future container demand growth rate is based on the past information. Our data shows that the average increase rate of the container throughput in the past 27 years from 1981 to 2007 is about 9.94%, with the highest 14.31% in 2004, and the lowest 2.88% in 1985. Considering the possible range of container transportation demand in the coming years, we assume three different growth rates (5%, 8% and 10%) from 2009 to 2013.

During the current global financial crisis, the shipping sector has not only refrained from ordering new ships, but has also been motivated to cancel existing orders.

Figure 6. A comparison between the actual and predicted fleet capacities and freight rates (1980–2008).

Table 5. Comparison of predicted values using different model results.

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Fleet capacity (error)</td>
<td>Freight rate (error)</td>
<td>Fleet capacity (error)</td>
<td>Freight rate (error)</td>
</tr>
<tr>
<td>2007</td>
<td>10.691</td>
<td>$1399</td>
<td>10.744</td>
<td>$1382</td>
</tr>
<tr>
<td></td>
<td>1.06%</td>
<td>2.52%</td>
<td>0.56%</td>
<td>3.66%</td>
</tr>
<tr>
<td>2008</td>
<td>11.873</td>
<td>$1318</td>
<td>12.030</td>
<td>$1329</td>
</tr>
<tr>
<td></td>
<td>2.09%</td>
<td>4.14%</td>
<td>0.79%</td>
<td>3.36%</td>
</tr>
</tbody>
</table>

Note: Fleet capacity in thousand TEUs.
According to recent statistics from Lloyd’s Register, total new orders in October 2008 dropped by 90% compared with the same period in 2007. According to Clarkson, there were 94 new order cancellations at the same period. Cancellations can reduce the number of new deliveries to the market and slow down the freight rate decrease. As recent new orders are easier to cancel, we assume a 10% cancellation rate for the new orders made in 2007, and a 20% cancellation rate for the new orders made in the following years. The continued cancellation after 2008 reflects the change in industry behaviour for making new orders, a more prudent measure facing the financial crisis. The prediction of the market freight rate and the fleet capacity from 2009 to 2013 are shown in Figure 7. The actual data for 2007 and 2008 are included in the figure.

Figure 7 also includes the market prediction based on Drewry’s forecast of the possible growth rate of the future container transportation demand. According to this, our model shows that the freight rate will continue to decrease until 2010, then increase slowly until 2013. This reveals the excessive capacity in the world container fleet. Our prediction base on the 10% growth rate is more optimistic than the Drewry figure, reflecting the best situation for a quick recovery. However, the high freight rate can encourage larger new orders, causing an earlier decreasing market in 2011. Our prediction using 8% growth rate in future container throughput represents a more conservative prediction than Drewry’s. The freight rate will be below US$1200 from 2010 to 2013, with a turning point after 2011. In this case, the new order activity will decrease, as the net profit decreases in the industry. Considering the current financial crisis and the low demand in container shipping, if the future demand increase rate is only 5%, then the freight rate will be below US$1100 in 2009, close to US$800 in 2010, and below US$800 in 2011.

Cancellations of new orders could slow down the decrease of the freight rate. For 8% future growth rate, if 10% of the new orders made in 2007 and 20% of new orders made afterwards are cancelled, the freight rate will stop decreasing in 2010.
when it was slightly lower than US$1200, and it could be better than the predicted rate based on Drewry's prediction later. For a 5% growth rate, under the same cancellation scheme, the predicted freight rates are higher than those in the no cancellation case, and will never be below US$800. This shows that cancellations are beneficial to prevent a further drop in the freight rate, if the current financial crisis has a serious negative impact on the world economy and international trade. Because of the comparatively higher freight rate, when there is a cancellation, the new order will be higher than the case when there is no cancellation; therefore, the capacity with cancellation is larger than the capacity without cancellation.

5. Summary and conclusion
We presented a dynamic-economic model for the container shipping market characterized by the container shipping freight rate and the global container fleet capacity. The model postulates the changing of equilibrium freight rate under demand and supply shifts in the container shipping market. The world container fleet capacity is augmented by the size of new orders which is proportional to the industrial profit earned 2 years before. The quantity demanded of container transportation services, as a derived demand from international trade, is assumed to be exogenously determined in the model.

The model parameters were estimated using the global container shipping market data from 1980 to 2008, based on the available data from Drewry and Clarkson. Considering the interdependency of the two dynamic equations, a 3SLS method was adopted in the regression analysis. The estimated results are quite stable, provided a high goodness of fit, and the parameter estimates are significant at above 90% confidence level. The overall model can explain more than 90% of the variations in fleet capacity and freight rate, and the in-sample prediction of the model can largely replicate the actual data within the research period. The errors of in-sample prediction and out-sample prediction for the previous two years, using model estimated with a different number of observations, reveals that the stability of prediction is within 5% margin of error.

As an application of the research, we predicted the future container market from 2009 to 2013, based on different assumptions of the future growth rate of container transportation demand. The result shows that if the world financial crisis continues to decrease the international trade, the container freight rate could drop to below US$800 in 2011. With a decreasing rate of new orders and the cancellation of existing orders, the market freight rate could be saved from reaching such a low level, although the companies who cancel new orders will suffer some immediate losses.

In conclusion, the model can provide information for decision makers of both public policy and in private business. The maritime agencies or organizations at regional, national and international level can use this information to stabilize the market freight rate, so as to mitigate the negative impact of the recent financial crisis on the maritime industry, marine environment, maritime safety, and national, regional and local economies. In addition, bankers can use this information in ship financing decisions, to minimize the possible risks caused by the low freight rate. Finally, shipowners and ship operators can also use this method to setup their strategies to prevent or reduce possible losses in the coming years.
Acknowledgements
This work has been supported by Hong Kong Research Grants Council through grant PolyU5238/07E and by Hong Kong Polytechnic University’s Niche Area Grant J-BB7A. The authors appreciate the two anonymous referees for their constructive comments and suggestions which helped us to improve the manuscripts significantly.

References