# The Roll of Capesize Vessels in Freight Markets

## - A Structural Linkage Model for Freight Rates -

○ Takashi Kanamura, J-POWER

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## Agenda

1. The objectives and results of this study
2. A Structural Linkage Model for Freight Rates
3. Empirical studies for Freight Markets
4. Conclusions

# 1. The objectives and results

# Background

- Seaborne trading has been activated due to the upsurge of commodity demand from developing countries.

- The traders become wise in an economical sense, while little by little, resulting in the change of the trading strategies between different freight markets.

- One of the famous trading strategies in freight markets is the economical switching of a capesize vessel to a panamax vessel when cape prices are hiking.

- In addition, it is well known in freight market practices that the cape markets can drive the other freight markets.

- The capesize vessel markets seem to be key to the freight markets.

# Literature survey

• The famous price models in financial markets are applied to freight markets. Kavussanos(1996a), Kavussanos(1996b), Kavussanos(1997) among others employ (G)ARCH type models to analyze time-varying volatility in freight rates.

• Bjerksund and Ekern (1995), Adland and Cullinane (2006), Koekebakker, Adland, and Sødal (2007) among others focus on the reduced type models for freight rates by employing the stochastic processes.

• The models may be useful to capture the characteristics of time varying volatility in freight rates and to obtain the freight derivative prices, referred to as forward freight agreements and freight options. However, the models do not tell any story about the information regarding freight markets, e.g., the supply and demand.

• Prokopczuk(2011) examined freight futures pricing and hedging where the spot prices are modeled using a reduced type model. He points out the role of the supply and demand relationship in the freight markets but unfortunately does not use the relationship for the freight pricing.

• Adland and Strandenes (2007) present a discrete-time partial equilibrium model using the supply and demand relationship of freight markets. The model is useful in that the supply and demand for freight markets are considered to characterize the freight rates in that backyard. But the supply curve of freight markets is not modeled using the parametric function rather using non parametric function stemming from the market data. The model does not offer the continuous-time price processes that will be beneficial for risk management and derivative pricing. More importantly, the model cannot take into account the interactive demand behavior between cape and panamax markets, which has recently been observed in the freight markets.

• Chen, Meersman, and Voorde (2010) examined the interrelationships in returns and volatilities between capesize and panamax markets. But they do employ the existing VECM (Vector Error Correlation Model) and ECM-GARCH model but do not use the structural model based on the supply and demand in the freight markets.

# The objectives

This paper theoretically and empirically investigates the roll of capesize vessels in freight markets by proposing a continuous-time freight rate model based on the functional supply and demand curves taking into account the interaction between cape and panamax vessel trading.

This paper assesses the roll of capesize vessels in freight markets in two ways:

1. A structural linkage model for freight rates

2. Empirical evidence for freight markets.

## The results regarding the model

(1) The model incorporates the market participant trading behavior in that high cape prices induce shipowners and charterers to switch from cape use to panamax use, resulting in the panamax demand rise, while high panamax prices tend to reduce panamax demand due to switching from panamax to much smaller ships like handysize vessels.

(2) The model can also represent the negative relationship between the price and volatility, referred to as “leverage effect,” which is often observed in stock markets.

## The results regarding empirical findings

(3) The model parameter estimation using the BCI and the BPI from the Baltic Exchange in the recent upward trend periods after the financial turmoil in 2008 demonstrates that the panamax demand increases in cape prices and decreases in panamax prices, which is consistent with the model we propose. It implies that capesize vessels have an important roll in panamax markets.

(4) It is also shown that the switching from cape to panamax in high cape prices is not observed after the end of 2010. The violation may correspond to the recent market trends such that the market disintegration proceeds since the upsurge of Chinese and Indian trades need much smaller vessels than capesize vessels.

(5) We show the leverage effects in freight markets often observed in security markets regardless of the sample periods.

## 2. A Structural Linkage Model for Freight Rates

## The model framework

Regarding freight markets, it is generally known that the supply curve is fixed and upward sloping because it takes a long period of time to build up new ships.

The demand curve is inelastic to the prices in the short period of time and the vertical demand curve is moving in parallel towards the horizontal direction.

The intersection between supply and demand curves determines the equilibrium price.

# The model setting

We define the second order differentiable, monotone, and increasing supply curve function $f(X)$, i.e., $f'(X) = \frac{\partial f}{\partial X} > 0$ for a freight market. We employ the two inverse Box-Cox transformations as the supply curves of panamax and capesize markets that can have the exponential function built in

$$P_t = f_1(X_t) = \left(1 + a_1 \frac{X_t}{c_1}\right)^{\frac{1}{a_1}}, \tag{1}$$

$$C_t = f_2(X_t) = \left(1 + a_2 \frac{X_t}{c_2}\right)^{\frac{1}{a_2}}, \tag{2}$$

where $a_i$ for $i = 1, 2$ is referred to as inverse Box-Cox transformation parameter, which determines the curvature of the supply curve where $c$ is referred to as positive scale parameter. If each $a_i$ in Eqs. (1) or (2) is zero, it collapses to the exponential function. Else if $a_i$ demonstrates greater than 0, it has smaller slope changes than the exponential.

# The switching from cape to panamax

If cape price is high, panamax demand increases by the users' switching from cape to panamax in an economics sense while in contrast the switch from panamax to cape is not an easy task because of physical restriction such as port water depth. The sensitivity of $V_C$ on $V_P$ is modeled using the parameter $\alpha$ which is positive and set to change with freight rates because freight rates determine the switching action. The volume models are represented by

$$dV_P = \alpha(C, P)dV_C + \sigma_{PV} du_t, \tag{3}$$

$$dV_C = \mu_{CV} dt + \sigma_{CV} dw_t, \tag{4}$$

where we assume that $E[du_t dw_t] = 0$ implying that $du_t$ represents the orthogonal panamax vessel trading volume fluctuation to cape size vessel trading volume fluctuation and that $\sigma_{PV}$, $\mu_{CV}$, and $\sigma_{CV}$ are constant. Here we assume that $\frac{\partial \alpha}{\partial C} \geq 0$ and $\frac{\partial \alpha}{\partial P} \leq 0$ because the cape boats are to be switched to panamax boats if cape price is high and the panamax demand is to be decreased due to the switching of the panamax to more smaller vessels if the panamax price is high.

# The linkage model

Supposing the inelasticity of demand to prices and taking equilibrium $V_t = X_t$, the freight rates are given as the inverse Box-Cox transformation of the demand. Employing Ito's Lemma to these equations, the correlation model between cape and panamax price returns is given by

$$\frac{dP_t}{P_t} = \mu_P dt + \sigma_P d\nu_t, \tag{5}$$

$$\sigma_P = \frac{P_t^{-a_1}}{c_1}\bar{\sigma}_P, \tag{6}$$

$$\mu_P = \frac{P_t^{-a_1}}{c_1}(\alpha\mu_{CV} + \frac{1-a_1}{2c_1}P_t^{-a_1}\bar{\sigma}_P^2), \tag{7}$$

$$d\nu_t = \frac{1}{\bar{\sigma}_P}(\alpha\sigma_{CV}dw_t + \sigma_{PV}du_t), \tag{8}$$

$$\bar{\sigma}_P = \sqrt{\alpha^2\sigma_{CV}^2 + \sigma_{PV}^2}, \tag{9}$$

$$\frac{dC_t}{C_t} = \mu_C dt + \sigma_C dw_t, \tag{10}$$

$$\sigma_C = \frac{\sigma_{CV}}{c_2} C_t^{-a_2}, \tag{11}$$

$$\mu_C = \frac{C_t^{-a_2}}{c_2} \Big( \mu_{CV} + \frac{1 - a_2}{2c_2} \sigma_{CV}^2 C_t^{-a_2} \Big), \tag{12}$$

$$\begin{aligned} \rho_{CP} &\equiv \frac{1}{dt} \mathsf{Corr}\left( \frac{dP_t}{P_t}, \frac{dC_t}{C_t} \right) \\ &= \frac{\alpha(C,P)\sigma_{CV}}{\sqrt{(\alpha(C,P)\sigma_{CV})^2 + \sigma_{PV}^2}}. \end{aligned} \tag{13}$$

## The characteristics

When we look at the correlation in Eq. (13), it demonstrates time varying due to the parameter $\alpha(C,P)$. Our interest nests in how the hike of cape prices affects the correlation between cape and panamax price returns. To examine the relationship, we calculate the derivative of $\rho_{CP}$ with respect to $C$:

$$\frac{\partial \rho_{CP}}{\partial C} = \frac{\partial \alpha}{\partial C} \frac{\sigma_{CV}\sigma_{CV}^2}{((\alpha(C,P)\sigma_{CV})^2 + \sigma_{PV}^2)^{\frac{3}{2}}}. \tag{14}$$

Since $\frac{\partial \alpha}{\partial C} \geq 0$ by definition, Eq. (14) is always positive. The model indicates that the correlation between cape and panamax prices increases when cape prices increase. Similarly, we have

$$\frac{\partial \rho_{CP}}{\partial P} = \frac{\partial \alpha}{\partial P} \frac{\sigma_{CV}\sigma_{CV}^2}{((\alpha(C,P)\sigma_{CV})^2 + \sigma_{PV}^2)^{\frac{3}{2}}}. \tag{15}$$

Since $\frac{\partial \alpha}{\partial P} \leq 0$ by definition, Eq. (15) is always negative. The model indicates that the correlation between cape and panamax prices increases when panamax prices decrease.

## The characteristics

Assuming $a = 0$, the model collapses to a simple lognormal process.

Assuming that $a > 0$, the SDP model is partly categorized in the C.E.V. (Constant Elasticity of Variance) models because the volatility term is expressed by $\sigma_t = \sigma P_t^{-a}$. The remarkable point is that the C.E.V model parameter $a$ has an economic standpoint such that $a$ represents the curvature of supply curve. Eqs. (6) and (11) suggest that if $a$ is non zero the volatility becomes time-varying by the prices, otherwise it is constant. In particular, if $a = \frac{1}{2}$, then the volatility of the SDP model collapses to the well known CIR model.

It is found that the volatility increases when price falls if $a > 0$, implying that the model is possible to represent the negative relationship between the price and volatility, referred to as "leverage effect."

# 3. Empirical studies for freight markets

## Data

We use daily freight indices from the Baltic Exchange.

The freight data consist of Baltic exchange capesize and panamax indices (BCI and BPI, resp.) where the capesize and panamax ships haul dry cargos including three major cargos of coal, iron ore, and grain. Capesize vessels are mainly used to carry iron ore and coal although panamax vessels are used to carry coal and grain

The data covers from October 22, 2008 to October 18, 2011 considered as the recent upward trend periods.

# Model parameter estimation

We estimate the freight rate model for the BCI and BPI using the maximum likelihood estimation. We assume that $\alpha(C, P)$ is a linear function of cape and panamax prices for simplicity:

$$\alpha(C_t, P_t) = p + qC_t + rP_t, \tag{16}$$

where $p \geq 0$. In addition, we assume $\frac{c_2}{c_1} = \frac{1}{0.7}$ taking into account cape and panamax market scales ($c_2$ and $c_1$, resp.) for simplicity. We discretize the model:

$$\log C_{t+1} - \log C_t = (k\sigma_C - \frac{1}{2}a_2\sigma_C^2)\Delta t + \sigma_C \varepsilon_t, \tag{17}$$

$$\sigma_C = \bar{\sigma}_{CV} C_t^{-a_2}, \tag{18}$$

$$\log P_{t+1} - \log P_t = (-\frac{1}{2}a_1\sigma_P^2)\Delta t + \sigma_P \nu_t, \tag{19}$$

$$\sigma_P = P_t^{-a_1}\sqrt{(p + qC_t + rP_t)^2\bar{\sigma}_{CV}^2(\frac{c_2}{c_1})^2 + \bar{\sigma}_{PV}^2}, \tag{20}$$

$$\text{Corr}(\varepsilon_t, \nu_t) = \begin{pmatrix} \Delta t & \rho_{PC}\Delta t \\ \rho_{PC}\Delta t & \Delta t \end{pmatrix}, \tag{21}$$

$$\rho_{PC} = \frac{(p + qC_t + rP_t)\bar{\sigma}_{CV}(\frac{c_2}{c_1})}{\sqrt{((p + qC_t + rP_t)\bar{\sigma}_{CV}(\frac{c_2}{c_1}))^2 + \bar{\sigma}_{PV}^2}}. \tag{22}$$

Here we take $\Delta t = \frac{1}{252}$, $\bar{\sigma}_{CV} = \frac{\sigma_{CV}}{c_2}$, $\bar{\sigma}_{PV} = \frac{\sigma_{PV}}{c_1}$, and $k = \frac{\mu_{CV}}{\sigma_{CV}}$.

## The results

| | $a_1$ | $\bar{\sigma}_{CV}$ | $p$ | $q$ | $r$ | $k_2$ | $a_2$ | $\bar{\sigma}_{SV}$ |
|---|---|---|---|---|---|---|---|---|
| Est | 0.491 | 18.575 | 1.033 | 2.530E-4 | -4.052E-4 | 0.047 | 0.282 | 6.163 |
| SE | 0.003 | 0.432 | 0.018 | 1.208E-5 | 1.546E-5 | 0.250 | 0.002 | 0.000 |
| Llik | 2,990 | | | | | | | |
| AIC | -5,964 | | | | | | | |
| SIC | -5,980 | | | | | | | |

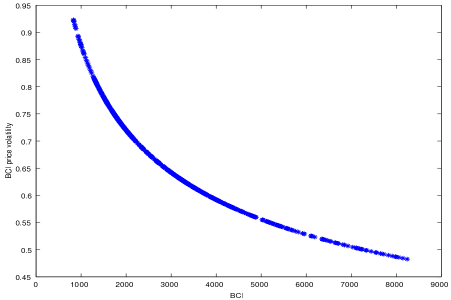
All estimates except cape demand drift $k$ are statistically significant.

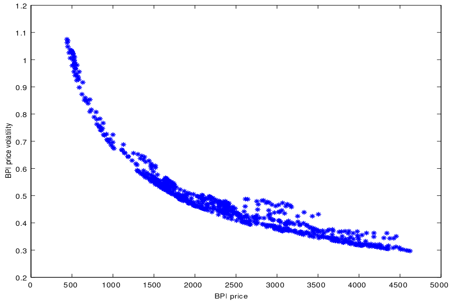
$q$ and $r$ are estimated as positive and negative value, respectively, implying that if the cape price is up, the panamax demand increases and if the panamax price is up, panamax demand is reduced.

The results are intuitive because if the cape is high price, the panamax is used for the alternative to the capesize ship and if panamax is high price, the panamax demand is reduced due to switching from panamax to much smaller vessels.

## The leverage effects

The estimated Box-Cox parameters $a$ are statistically significant and positive, resulting in leverage effect often observed in stock markets.




The results are consistent with Chen and Wang (2004) but we additionally illustrate that the leverage effects come from the flat shape of supply curve which is shown in the figure 1 of Adland and Strandenes (2007). More interestingly Adland and Cullinane (2006) suggest that C.E.V. model at high freight rates is not rejected to their data while the reason is not explained. Using our model, it is shown that the C.E.V. model comes from the supply curve flatness at high freight rates.

## Granger causality test

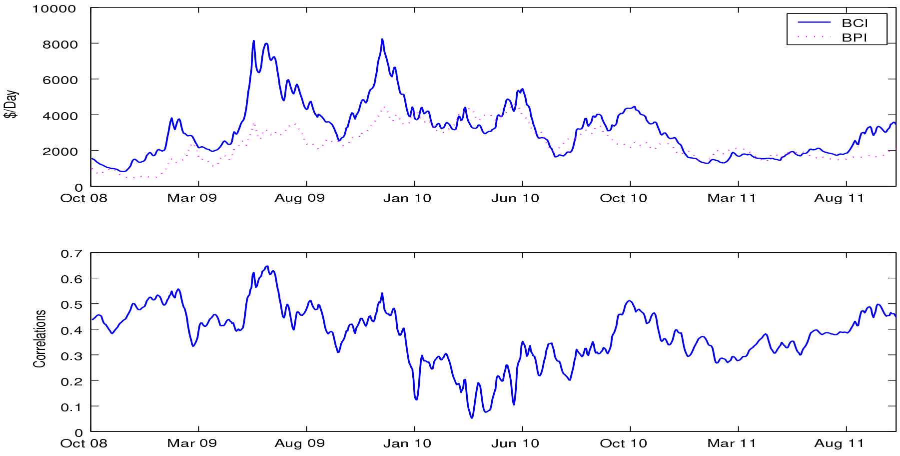
To verify the results in a different approach, we conduct Granger causality test for lag 1.

| Null Hypothesis: | F-Statistic | Probability |
|---|---|---|
| BPI does not Granger Cause BCI | 0.93244 | 0.33454 |
| BCI does not Granger Cause BPI | 5.60807 | 0.01813 |

It suggests that BCI does Granger cause BPI in the 5 % significance level while the opposite is not observed. The capesize market may drive the panamax market only judging from the Granger causality test results. The results may secure the former relation, i.e., the panamax demand gains in the BCI, often noted in freight markets.

# Correlations and freight rates

The correlation between BCI and BPI is relatively high, which reflects the freight markets. The correlations tend to increase in BCI, implying that the comovement of BCI and BPI is highlighted during high BCI periods. The capesize vessel rate is more influential to the correlation than the panamax vessel rate.



## The Recent Upsurge of China and India Trades in Freight Markets

The empirical studies using the data from 2008 to 2011 demonstrated that the panamax demand increases in cape prices and decreases in panamax prices.

But we have yet to answer whether it persists during the whole period.

Recently, the freight market participants say that the freight markets have drastically changed due to the upsurge of China and India trades in the Asia-Pacific area.

To focus on the recent trend of the freight markets and to examine the persistence of the previous results in the subsamples, here we split the date at December 4, 2010 after which is considered as the recent period in this study.

The former and latter periods are referred to as period I and period II, respectively.

# Comparison between period I and period II

Period I

| | $a_1$ | $\bar{\sigma}_{CV}$ | $p$ | $q$ | $r$ | $k_2$ | $a_2$ | $\bar{\sigma}_{SV}$ |
|---|---|---|---|---|---|---|---|---|
| Est | 0.245 | 3.068 | 0.655 | 1.783E-4 | -2.790E-4 | -0.168 | 0.110 | 1.689 |
| SE | 0.005 | 0.000 | 0.000 | 1.944E-7 | 8.548E-7 | 0.452 | 0.000 | 0.000 |
| Llik | 2,048 | | | | | | | |
| AIC | -4,079 | | | | | | | |
| SIC | -4,095 | | | | | | | |

Period II

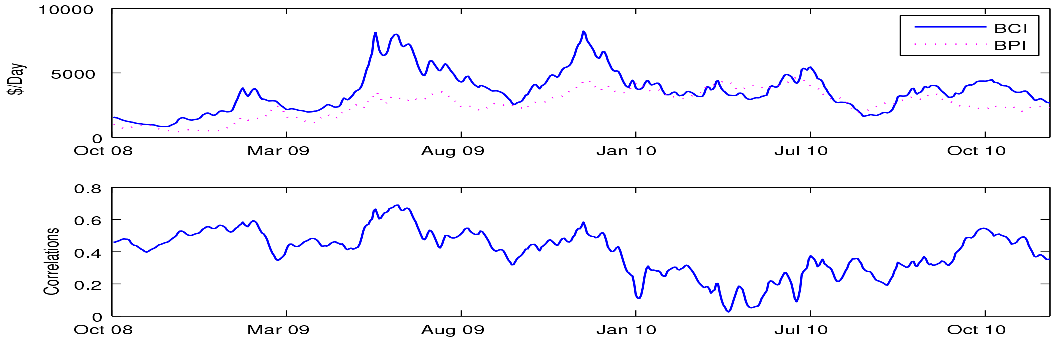
| | $a_1$ | $\bar{\sigma}_{CV}$ | $p$ | $q$ | $r$ | $k_2$ | $a_2$ | $\bar{\sigma}_{SV}$ |
|---|---|---|---|---|---|---|---|---|
| Est | 1.539 | 32668.054 | 53.110 | -1.618E-2 | -1.802E-3 | 1.124 | 0.869 | 358.496 |
| SE | 0.000 | 0.063 | 0.379 | 1.584E-4 | 2.250E-4 | 0.607 | 0.001 | 0.044 |
| Llik | 1,090 | | | | | | | |
| AIC | -2,165 | | | | | | | |
| SIC | -2,181 | | | | | | | |

All parameters except $k_2$ are statistically significant.

# Comparison between period I and period II

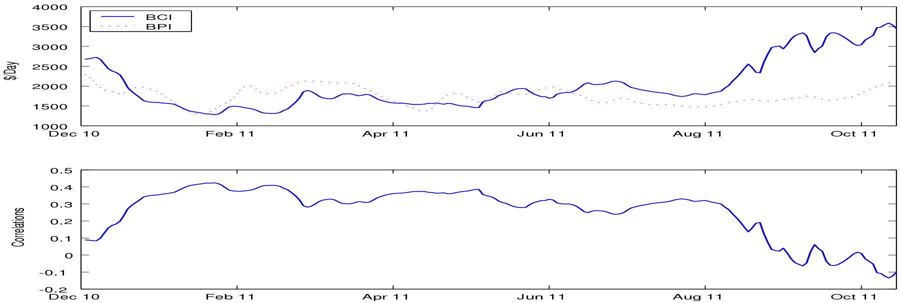
From $q$'s the cape price does influence on panamax demand positively for period I while not for period II.

Period I




The figure demonstrates the relationship between the two freight rates and the correlation for Period I. It implies that the correlation tends to increase in the BCI rates, which is the same to the previous figure using the whole sample. Thus the cape market may govern the panamax market before December 4, 2010.

## Period II




During the recent periods the correlation tends to decrease in the BCI and BPI rates.

The cape market does not trail the panamax market after December 4, 2010 and it may echo the recent market participant voices such that the market disintegration proceeds since the upsurge of Chinese and Indian trades need much smaller vessels than capesize vessels, in particular for the inland river carriages.

All estimated negative $r$ values explain well the frequent change from the panamax to the smaller vessel like handymax than the panamax when the panamax prices are high.

## Granger causality test

| Null Hypothesis: | F-Statistic | Probability |
|---|---|---|
| BPI does not Granger Cause BCI for Period I | 0.5072 | 0.4766 |
| BCI does not Granger Cause BPI for Period I | 3.0094 | 0.0834 |
| BPI does not Granger Cause BCI for Period II | 0.9836 | 0.32248 |
| BCI does not Granger Cause BPI for Period II | 1.1852 | 0.27757 |

It suggests that just after the commodity bubble and financial turmoil in 2008 where a large number of cape is planned to be built the cape market does granger cause the panamax market using the significance level if 9 % while the panamax market does not Granger cause the cape market using 10 % significance level.

Recently the cape market does not granger cause the panamax market and the panamax market does not granger cause the cape market.

The results may also be consistent with the recent disintegration trends in freight markets due to the upsurge of Chinese and Indian trades in that the both markets do not affect each other.

## Leverage effects in period I and period II

$a_1$ and $a_2$ are positive values, implying the existence of leverage effects.

Since $a_1$ and $a_2$ in the period I are smaller than $a_1$ and $a_2$ in the period II, the leverage effects in the Period I are weaker than the leverage effects in the Period II.

It may suggest that new entrants of both vessels into the markets changes the supply curve curvature in a way that the supply curve is further from the exponential function near the intersection between the supply and demand curves.

# 4. Conclusions

## The results regarding the model

(1) The model incorporates the market participant trading behavior in that high cape prices induce shipowners and charterers to switch from cape to panamax, resulting in the panamax demand rise, while high panamax prices tend to reduce panamax demand due to switching from panamax to much smaller ships like handysize vessels.

(2) It was shown that the model can also represent the negative relationship between the price and volatility, referred to as “leverage effect.”

## The results regarding empirical findings

(3) The model parameters using the BCI and BPI from the Baltic Exchange in the recent upward trend periods has demonstrated that the panamax demand increases in cape prices and decreases in panamax prices, which is consistent with the model we propose.

(4) It was also shown that the switching from cape to panamax in high cape prices is not observed in the recent periods. The violation may correspond to the recent market trends that the market disintegration proceeds since the upsurge of Chinese and Indian trades needs much smaller vessels than capesize vessels.

(5) We showed the leverage effects in freight markets often observed in security markets.

## Thank you.

E-mail: tkanamura@gmail.com