Eurasian Journal of Economics and Finance, 5(1), 2017, 78-94
DOI: 10.15604/ejef.2017.05.01.006

EURASIAN JOURNAL OF ECONOMICS AND FINANCE
http://www.eurasianpublications.com

THE EFFECT OF VESSEL SUPPLY ON SHIP-DEMOLITION PRICES

Nikos Kagkarakis
University of Piraeus, Greece. Email: nkagkara@unipi.gr

Abstract

The ship-demolition is one of the four main markets that form the shipping industry and plays an important role on the seaborne trade, as it mitigates imbalances between supply and demand for transportation services by adjusting the merchant fleet supply. The aim of this study is to examine whether the factors that determine the supply of vessels for demolition are capable of affecting materially the ship-demolition price formation. The availability of ships for demolition is primarily a function of the fleet's age and the conditions on the freight and secondhand markets. The analysis is conducted on the crude tanker and the bulk carrier segments and the vector autoregressive model methodology is employed, whereby the effect of both the supply and the demand factors on the ship-demolition prices is examined. The results indicate that the supply side has limited effect on the price formation in the industry, which is driven by the demand for the steel-scrap commodity.

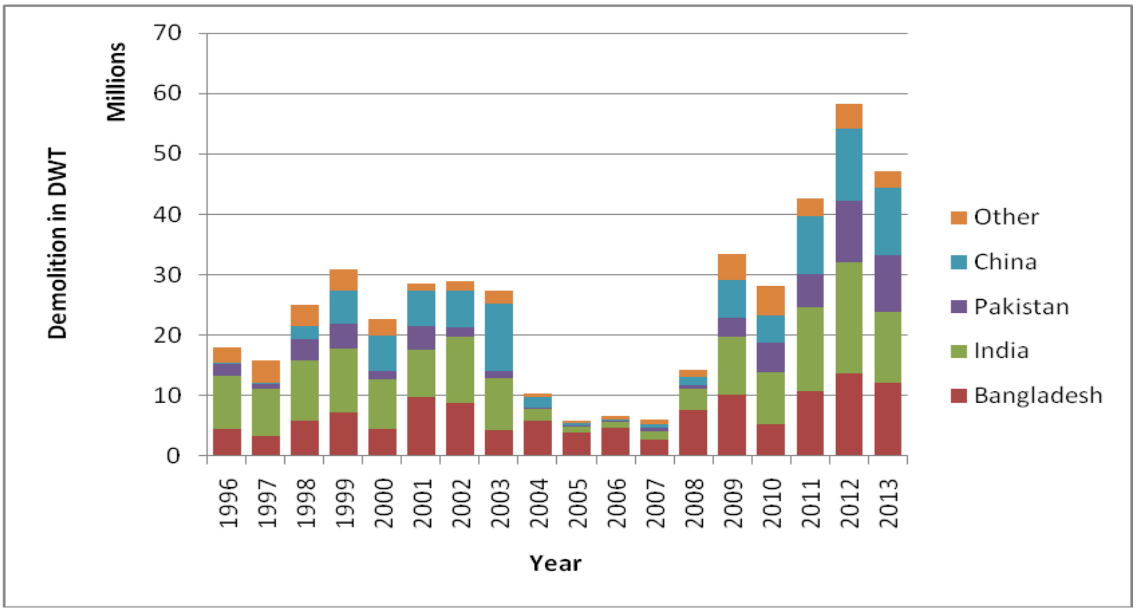
Keywords: Ship-demolition, VAR Model, Supply, Demolition Prices

1. Introduction

The disposal of vessels when their operation becomes inefficient or uneconomic is vital for the renewal of the merchant marine fleet. The decision to scrap a ship or continue its trading depends mainly on the conditions on the freight and secondhand markets and the ship-owners' expectations about their future course (Buxton, 1991). The vessel's age is also a significant factor because operating expenses increase significantly with the passage of time, primarily due to the escalating maintenance costs. Hence, when vessels are between the age of 20-30 years and both aforementioned markets are declining, the decision to scrap becomes an attractive alternative for ship-owners. On the other hand, the decision to buy a ship for demolition depends on the prospect of selling the vessel's steel and other reusable parts, and the recyclers' cost structure (Vedeler, 2006). If the internal demand for recyclable metal preserves steel prices at a level sufficient in order to create a profit, the recyclers will seek to increase their inventory. Therefore, the ship demolition market is an industry highly affected by 2 pillars, the shipping industry and the steel production (Mikelis, 2013). The first determines the supply of vessels for demolition and the latter the demand for the recyclable steel.

Since the 1970s the ship-demolition market has been oriented at the Southeast Asia in seek of the lowest labor costs (Stopford, 2009) and nowadays it is located in India, Pakistan, Bangladesh (forming the Indian subcontinent region) and China, which account for the vast majority of the recycled tonnage every year, as indicated in Figure 1. The process takes place on tidal beaches (in the Indian subcontinent) or dry docks (in China) and almost every part of the entire vessel is recycled and resold. The main product extracted is the steel-scrap which is recovered from the ship's hull and is used in the construction of reinforcing bars and rods.

These steel products are very important for the domestic growth in these regions as they are used in the construction industry and the development of the local infrastructure (Sarraf *et al.* 2010). Hence, the ship-demolition industry reduces the consumption of the natural resources and also produces income to the national economies through tax payments. In addition, the industry employs numerous workers both in a direct and indirect manner, thus providing further benefits to the regional communities.



Source: Clarkson Research Services Limited
Figure 1. Ship demolition by area

On the other hand, the industry has been widely criticized for causing environmental pollution and lacking safe labor practices. Hence, various initiatives by the international shipping community led to the establishment of the Hong Kong International Convention in 2009 which sets a regulatory framework in order to transform the ship-demolition market into an environmentally sound and labor safe industry. Although environmentalists and researchers have questioned the effective implementation of the convention's guidelines and disagreed with the permission of the beaching method (Matz-Luck, 2010; Chang *et al.,* 2010), important improvements have already taken place in the majority of the demolition centers (Mikelis, 2013). The studies of Neser *et al.* (2006) and Gregson *et al.* (2010) have recommended environmentally sound treatment of hazardous waste while Kusumaningdyah *et al.* (2013) have tried to capture the industry's tradeoff between benefits and losses by employing the system dynamics approach. In general, the main argument against the ship-demolition market is the inadequate legislative regime that permits the labor exploitation and the shift of waste from the developed countries to the developing ones, thus creating an ecological conflict (Sinha, 1998; Demaria, 2010; Yujuico, 2014; Cairns, 2014).

Despite the plethora of studies on the environmental aspect of the ship demolition market, little has been written about the economics and the price formation in the industry. Mikelis (2007) provided a statistical overview and informative data on the key economic relationships of the market and indicated a positive correlation between the freight rates and the ship-demolition prices. The same finding was also verified by Knapp *et al.* (2008) who conducted an econometric analysis whereby they examined by the use of logit models the dynamics of the ship-demolition market and the probability of scrapping a vessel. In particular, as a main result, the analysis confirmed the positive relationship of demolition prices with the probability of scraping a vessel, indicating that ship-owners more likely scrap vessels in periods of high demolition prices. On the contrary, there is a negative relationship between the vessels' earnings and the probability of scrapping. This finding is reasonable as in times of favorable freight conditions, ship-owners prefer to trade the vessels for as long as possible instead of scrapping them. As a consequence, the recyclers are inclined to increase the ship-demolition prices in order to attract tonnage; therefore the positive relationship between the vessels' earnings and the ship-demolition prices is confirmed. These results were also verified by Alizadeh *et al.* (2016) who employed similar methodology and also revealed the importance of the volatility of freight rates and the bunker prices on the probability of scrapping a bulk carrier vessel. Moreover, they argued that the effect of all the aforementioned factors on the probability of scrapping may differ across the various vessel classes, depending on the dynamics of each ship size.

Mikelis (2013) employed statistical data in order to investigate the contribution of the ship-demolition industry to the steel production in the world's largest ship-demolition centers (Bangladesh, India, Pakistan, China and Turkey) and also to the global steel production from a general perspective. The study concluded that despite its little contribution at a global level, the industry is vital to the steel production and growth in the domestic ship-demolition regions. Finally, in a recent econometric analysis Kagkarakis *et al.* (2016) employed a vector autoregressive (VAR) model in order to examine the tanker demolition prices determination and conduct forecasts. The study modeled the demand side of the industry and indicated that the price of the steel-scrap which is exported overseas from the developed regions (US and EU) to Southeast Asia, lead the ship-demolition prices and contribute significantly to the price discovery in the sector. The lead-lag effect is justified by the larger volume of the imported steel-scrap compared to the steel-scrap obtained from ship dismantling, and the considerable time required to transport the steel-scrap overseas to its destination.

This aim of this paper is to examine by the use of econometric methods whether the supply side of the ship-demolition market contributes to the formation of the ship-demolition prices. The VAR model methodology employed by Kagkarakis *et al.* (2016) is adopted, but in this study, both supply and demand factors are included in order to test in pairs their causal effect on the ship-demolition prices. The effect of the supply variables will be benchmarked against the corresponding effect of the demand variable. Concerning the structure of the paper, the second part describes the theoretical background as well as the data and the employed methodology, the third part presents the empirical results and the final section concludes the article.

2. Data and methodology

2.1 Theoretical background

Since the employed methodology will involve both supply and demand factors, this section provides the theoretical basis of the data and the employed variables. The supply of vessels for demolition is mainly determined by the shipping markets, but can also be influenced by other factors like political and environmental decisions. For instance, the regulation of the International Maritime Organization (IMO) regarding the withdrawal of the single-hull tankers led to the increase of available tankers for demolition towards the end of the previous decade. Moreover, supply shocks were also observed during war periods, as many destroyed merchant vessels were led to their final destination. Although such exogenous factors can be crucial for the supply of vessels for demolition, this paper focuses only on the factors deriving from the shipping markets and their potential effect on the ship-demolition prices. The study further concentrates on the 2 main shipping segments, namely the tanker and the dry bulk.

According to economic theory and the relevant literature presented in the introductory section, the supply of vessels for demolition is primarily a function of 4 factors, as presented in the following equation:

$$S = f\,(Earn, Sec, Exp, Age) \tag{1}$$

where *S* represents the supply of vessels for demolition, *Earn* and *Sec* the conditions on the freight and secondhand markets respectively, *Exp* the ship-owners' expectations about the aforementioned markets' future course, and *Age* the age of the fleet. Accordingly, the demand of vessels for demolition is primarily a reflection of the demand for the steel-scrap obtained from the ship-recycling process, or

$$D = f\ (Scr) \qquad (2)$$

where *D* denotes the demand of vessels for demolition and *Scr* the price of the recycled scrap. The aim is to employ pertinent variables that will demonstrate the effect of the aforementioned forces on the demolition prices.

2.2 Data description

For the purpose of this study, monthly observations from June 2003 till September 2013 were collected in order to construct time series. The data employed to account for the ship-demolition prices and the variables determining the supply of vessels for demolition were collected from Clarkson Research Services Limited (CRS). In particular, the data included demolition prices for both oil tankers and bulk carriers in US dollars per light displacement ton (LDT) offered by recyclers in the Indian Subcontinent, the most important ship-demolition region. With reference to the ships' profitability, the Baltic Dirty Tanker Index (BDTI) and Baltic Dry Index (BDI) were employed to represent the tanker and the bulk carrier freight markets respectively. Accordingly, the Secondhand Prices Index and Newbuilding Prices Index for each segment were utilized to represent the sale and purchase and newbuilding markets. Vessels' newbuilding prices and secondhand prices are considered as good proxies for the investors' expectations, as a potential increase in these markets generally reflects the ship-owners' optimism about their future revenues.

Concerning the age factor, the tanker and bulk carrier fleets over the age of 20 years (in million deadweight tons) were collected from Clarksons' Oil and Tanker Trades Outlook and Dry Bulk Trade Outlook respectively. Tables 1 and 2 indicate the average age of the dismantled tankers and bulk carriers during the period covered by our data. It seems that the average age ranges from approximately 22 to 28 years for the tankers and 27 to 33 for the bulk carriers throughout the entire period. Therefore, this paper considers the fleet above the age of 20 as a good proxy for the available tankers and bulk carriers for demolition.

Table 1. Tanker average demolition age

Year End	Tanker Subcategory in '000 DWT					Total
	Over 200	120-200	80-120	60-80	10-60	
2003	26.8	25.1	25.0	25.8	28.6	**27.1**
2004	26.8	27.0	26.5	25	29.7	**28.1**
2005	29.2	24.0	25.7	25.3	28.2	**27.2**
2006	-	-	26.2	25.4	28.8	**28.2**
2007	-	-	25.1	27.3	28.7	**28.2**
2008	22.3	25.5	25.9	25.3	28.4	**27.3**
2009	20.4	23.7	22.7	24.6	26.5	**25.4**
2010	19.6	22.8	23.9	24.9	27.5	**26.2**
2011	21.3	21.1	20.9	23.5	27.3	**24.8**
2012	20.4	21.1	21.2	25.3	25.2	**23.1**
2013	18.2	20.4	21.7	22.0	25.4	**22.9**

Source: Clarkson Research Services Limited

Table 2. Bulk carrier average demolition age

Year End	Bulk Carrier Subcategory in '000 DWT				Total
	Over 100	65-100	40-65	10-40	
2003	28.7	27.2	27.0	28.0	**27.9**
2004	-	-	38.9	28.9	**29.6**
2005	25.5	30.1	29.5	32.3	**31.2**
2006	26.2	27.7	29.0	31.1	**30.3**
2007	-	27.6	31.1	34.7	**33.5**
2008	27.2	28.5	28.0	31.2	**29.9**
2009	26.1	28.6	30.9	32.2	**31.5**
2010	28.6	26.6	29.8	32.8	**31.6**
2011	26.3	29.3	30.2	32.4	**30.5**
2012	22.9	28.6	27.2	30.2	**28.5**
2013	23.2	26.8	26.9	30.0	**28.2**

Source: Clarkson Research Services Limited

With reference to the demand of vessels for demolition, the price of the steel-scrap metal exported from Rotterdam (the greatest steel-scrap exporting port in Europe) was used. The data was collected from Bloomberg and is quoted in US dollars per metric ton. The steel-scrap is transported by bulk carriers towards the Southeast Asian countries and, together with the ship scrap, is used to satisfy the region's increasing needs in steel. Therefore, the price of exporting scrap at its origins reflects accurately the demand for the scrap metal obtained from ships. In general, the variables that will be employed in the study are presented in Table 3. Table 4 denotes their key statistics and correlation per segment. Moreover Figures 2 and 3 provide the plot of the variables through time.

Table 3. List of Variables.

Number of Variables	Symbol	Variable	
		Tanker market	**Bulk Carrier market**
1	DEM	Tanker demolition prices	Bulk carrier demolition prices
2	SCR	Steel-scrap prices	Steel-scrap prices
3	EAR	Baltic Dirty Tanker Index (BDTI)	Baltic Dry Index (BDI)
4	SEC	Tanker Secondhand Prices Index	Bulk Carrier Secondhand Prices Index
5	NEW	Tanker Newbuilding Prices Index	Bulk Carrier Newbuilding Prices Index
6	FL	Tanker fleet over 20 years old	Bulk Carrier fleet over 20 years old

It appears from Figures 2 and 3 as well as the correlation matrix that the series of SCR exhibits similar behavior and is closely related with the DEM both in the tanker and dry bulk segments. In fact, the scrap prices contribute to the price discovery in the demolition market by leading the demolition prices (Kagkarakis *et al.* 2016). Moreover, strong positive correlation is observed among the 4 supply variables (EAR, SEC, NEW and FL), particularly in the bulk carrier market, which is reasonable as an increase -for instance- in freight rates will trigger a raise in the vessels' secondhand and newbuilding values. Similarly, the age of the fleet will increase as the ship-owners will be reluctant to scrap the older units in favorable market conditions, thus the fleet tonnage over 20 years will increase.

Table 4. Key Statistics and Correlation

Panel A: Tanker market						
Key Statistics						
	DEM	*SCR*	*EAR*	*SEC*	*NEW*	*FL*
Mean	411.52	315.89	1,100.76	162.86	181.32	34.29
Median	410.00	296.00	1,027.15	147.18	166.74	36.90
Maximum	740.00	665.00	3,050.00	250.16	255.36	57.30
Minimum	222.00	115.50	447.84	98.71	123.30	19.00
Correlation						
DEM	1.00	0.8912 (0.00)	0.0652 (0.47)	0.2681 (0.00)	0.2911 (0.00)	-0.4557 (0.00)
SCR	0.8912 (0.00)	1.00	-0.1034 (0.25)	0.0004 (0.99)	0.1026 (0.25)	-0.6174 (0.00)
EAR	0.0652 (0.47)	-0.1034 (0.25)	1.00	0.5564 (0.00)	0.3581 (0.00)	0.5396 (0.00)
SEC	0.2681 (0.00)	0.0004 (0.99)	0.5564 (0.00)	1.00	0.9049 (0.00)	0.4500 (0.00)
NEW	0.2911 (0.00)	0.1026 (0.25)	0.3581 (0.00)	0.9049 (0.00)	1.00	0.2633 (0.00)
FL	-0.4557 (0.00)	-0.6174 (0.00)	0.5396 (0.00)	0.4500 (0.00)	0.2633 (0.00)	1.00
Panel B: Bulk carrier market						
Key Statistics						
	DEM	*SCR*	*EAR*	*SEC*	*NEW*	*FL*
Mean	392.33	315.89	3,382.64	216.30	157.35	97.63
Median	390.00	296.00	2,718.95	188.40	150.23	102.10
Maximum	660.00	665.00	10,843.65	499.66	239.62	117.90
Minimum	200.00	115.50	702.61	100.79	98.56	66.10
Correlation						
DEM	1.00	0.8631 (0.00)	0.3834 (0.00)	0.6061 (0.00)	0.4122 (0.00)	0.3755 (0.00)
SCR	0.8631 (0.00)	1.00	0.1678 (0.06)	0.4022 (0.00)	0.2395 (0.00)	0.4004 (0.00)
EAR	0.3834 (0.00)	0.1678 (0.06)	1.00	0.8724 (0.00)	0.7234 (0.00)	0.2232 (0.01)
SEC	0.6061 (0.00)	0.4022 (0.00)	0.8724 (0.00)	1.00	0.9095 (0.00)	0.5393 (0.00)
NEW	0.4122 (0.00)	0.2395 (0.00)	0.7234 (0.00)	0.9095 (0.00)	1.00	0.6488 (0.00)
FL	0.3755 (0.00)	0.4004 (0.00)	0.2232 (0.01)	0.5393 (0.00)	0.6488 (0.00)	1.00

Note: Figures in (.) are the corresponding p-values.

With the exceptions of the FL series which show mixed signs in the two sectors and the freight variable (BDTI) in the tanker market which exhibits insignificant correlation, the remaining supply variables display positive correlation with the demolition prices, with the relationships being stronger in the bulk carrier market. This is consistent with the notion that the favorable shipping market conditions urge ship recyclers to increase the demolition prices in order to attract tonnage, as mentioned earlier in the introductory section.

As far as the FL series is concerned, the correlation matrix indicates that the tanker demolition prices and the tanker fleet over the age of 20 years are negatively related, whilst the opposite is true in the dry bulk segment. Since the DEM series follows similar pattern in both shipping segments, the divergence is explained by examining the graphical presentation of the respective FL variables in Figures 2 and 3. Contrary to the bulk carrier aged fleet, the tanker aged fleet is consistently declining throughout the period covered by our data. The reasoning lays mainly on differences of technical nature between tankers and bulk carriers. For instance, the tanker fleet was highly affected during the last decade by the IMO regulation regarding the withdrawal of the single hull tankers. Therefore, irrespectively of the prevailing market conditions, the older tankers (mostly single hull) had to be upgraded or removed from the fleet, which caused a steady decline to the aged tanker fleet. Moreover, due to environmental and maintenance reasons, the tankers are scrapped at a younger age comparing to the bulk carriers, as verified by the data shown on Tables 1 and 2. On the other hand, as seen in Figure 3 the bulk carrier aged fleet rose significantly during 2004-2008, because of the favorable market conditions, and remained in firm levels up to 2011 when the increasing scrapping rates brought the decline. In brief, the different relationship between the demolition prices and the aged fleet of each segment is justified by the fact that the bulk carrier fleet is more directly affected by the shipping market conditions comparing to the tanker fleet, which is additionally affected to a greater extent by the environmental and technical regulations.

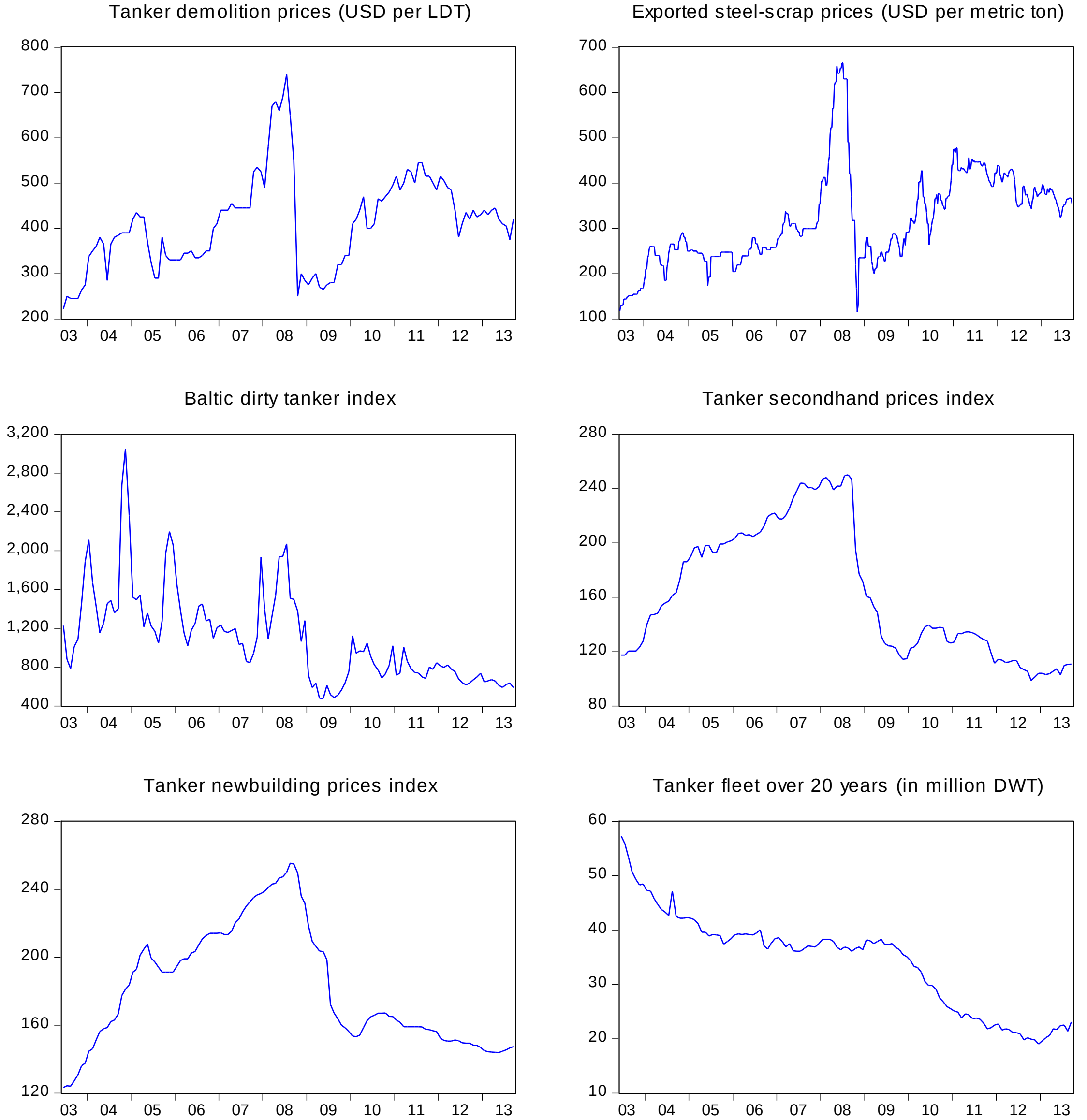


Figure 2. Tanker market-data graphical presentation.

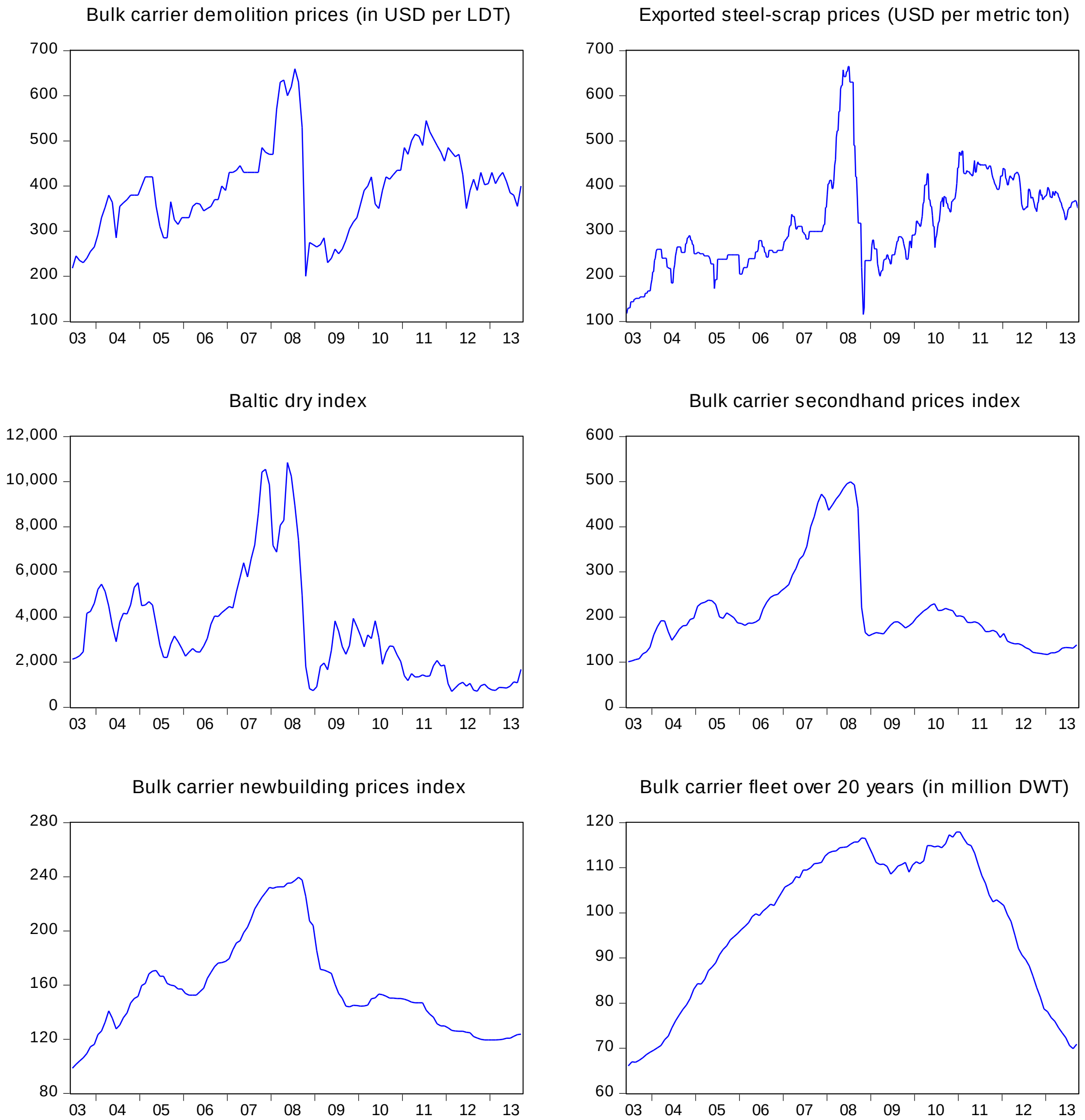


Figure 3. Bulk carrier market-data graphical presentation.

2.3 Methodology

The VAR model methodology will be employed in order to capture the causal relationships between the variables. In particular, the study will examine by the use of VAR models in pairs, the effects that the supply variables have on the tanker and bulk carrier demolition prices, and will compare the results with the corresponding effect of the proxy variable for the demand side. Since high positive correlation is exhibited among the supply variables, it is preferable to conduct pairwise comparisons instead of constructing a single VAR model that would contain all the variables, in order to avoid the effects of multicollinearity. Suppose a VAR model of the following generic form:

$$y_t = A_1 y_{t-1} + \ldots + A_k y_{t-k} + e_t \qquad (3)$$

where y_t is a vector of the stationary endogenous variables, $A_1,\ldots,A_k$ are matrices of coefficients to be estimated, k is the optimal lag length and e_t is a vector of innovations uncorrelated with all the right-hand side variables or their lagged values. The variables SCR, EAR, SEC, NEW and FL are treated in pairs as endogenous to the DEM, thus 5 VAR models consisting of the following linear equations are estimated for each vessel segment:

$$DEM_t = c_1 + \sum_{h=1}^{k} \alpha_{1h} DEM_{t-h} + \sum_{i=1}^{k} \beta_{1i} SCR_{t-i} + \varepsilon_{1t}$$

$$SCR_t = c_2 + \sum_{h=1}^{k} \alpha_{2h} DEM_{t-h} + \sum_{i=1}^{k} \beta_{2i} SCR_{t-i} + \varepsilon_{2t} \qquad (4)$$

$$DEM_t = c_3 + \sum_{j=1}^{q} \gamma_{1j} DEM_{t-j} + \sum_{l=1}^{q} \delta_{1l} EAR_{t-l} + v_{1t}$$

$$EAR_t = c_4 + \sum_{j=1}^{q} \gamma_{2j} DEM_{t-j} + \sum_{l=1}^{q} \delta_{2l} EAR_{t-l} + v_{2t} \qquad (5)$$

$$DEM_t = c_5 + \sum_{m=1}^{r} \zeta_{1m} DEM_{t-m} + \sum_{n=1}^{r} \theta_{1n} SEC_{t-n} + u_{1t}$$

$$SEC_t = c_6 + \sum_{m=1}^{r} \zeta_{2m} DEM_{t-m} + \sum_{n=1}^{r} \theta_{2n} SEC_{t-n} + u_{2t} \qquad (6)$$

$$DEM_t = c_7 + \sum_{g=1}^{s} \kappa_{1g} DEM_{t-g} + \sum_{p=1}^{s} \lambda_{1p} NEW_{t-p} + z_{1t}$$

$$NEW_t = c_8 + \sum_{g=1}^{s} \kappa_{2g} DEM_{t-g} + \sum_{p=1}^{s} \lambda_{2p} NEW_{t-p} + z_{2t} \qquad (7)$$

$$DEM_t = c_9 + \sum_{w=1}^{d} \chi_{1g} DEM_{t-g} + \sum_{y=1}^{d} \psi_{1p} FL_{t-p} + \varphi_{1t}$$

$$FL_t = c_{10} + \sum_{w=1}^{d} \chi_{2g} DEM_{t-g} + \sum_{y=1}^{d} \psi_{2p} FL_{t-p} + \varphi_{2t} \qquad (8)$$

where DEM_t denotes the demolition prices, SCR_t the exported steel-scrap prices, EAR_t the BDTI and BDI for the tanker and the bulk carrier segments respectively, SEC_t the secondhand prices index, *NEW* the newbuilding prices index, FL_t the fleet over 20 years old, and ε_t, v_t, u_t, z_t and φ_t the vectors of the corresponding error terms of the respective VAR models containing all residual information that may have an effect on the endogenous variables. The *k*, *q*, *r, s* and *d* are the orders of the respective VAR models and denote the optimal lag length which is usually chosen on the basis of Schwarz Bayesian (SC), Akaike (AIC) or Hannan Quinn (HQ) information criteria. These selection criteria are used to avoid over-parameterization of the models caused by the selection of unnecessary lags and achieve parsimony. In many occasions, the three criteria produce conflicting results, as SC is more conservative, HQ is mediocre and AIC is more generous. In our study, the optimal lag length in each VAR will be determined on the basis of the following process. The model is initially estimated based on the selection criterion indicating the fewest number of lags and then is tested for serial correlation and stability. In case that the model does not satisfy the required conditions, it is then re-estimated by using the number of lags indicated by the second most conservative criterion, and so on. The notion is to construct parsimonious models that can explain the dynamics among the employed variables.

The next step is to conduct pairwise investigations about the causal relationships between the endogenous variables by employing the VAR-based Granger causality test. Such test examines, in each equation of the VAR models presented above, whether each variable has any predictive ability on the other variable of interest. Since we are interested to see if SCR, EAR, SEC, NEW and FL are capable of forecasting DEM, we test in the first equation of the models (4) to (8) for each vessel segment whether the coefficients of their lags are jointly zero. For instance, the null hypothesis in the first equation of model (1) is H_o: $\beta_{11} = \beta_{12} = ... = \beta_{1i} = 0$. If the null hypothesis is not rejected, then we conclude that *SCR* does not Granger-cause *DEM*. The same test will be applied in each vessel segment for all other variables pairing with *DEM.*

After having examined the causal effects of the variables on the ship demolition prices, a dynamic analysis will be conducted by employing the Impulse response functions (IRF) on our estimated models. The IRF trace the effect of a one-time shock to one of the innovations on current and future values of the endogenous variables, as a shock to one variable is also transmitted to all of the other endogenous variables through the lag structure of the VAR. Therefore, we are interested in observing the reaction of *DEM* after a shock on the other endogenous variables. In general, the dynamic analysis is used supplementary in order to verify the results from the Granger causality test and gauge the strength of the relationships among our variables.

3 Empirical findings

3.1 Unit root test

The stationarity of the employed series is a prerequisite for the construction of the VAR models described in the previous section because the existence of non-stationarity may result in spurious regressions. Hence, we begin the analysis by using the Augmented Dickey Fuller Test (ADF) in order to examine whether the original series has a unit root or, equivalently, if the series is non-stationary. The results of the test for each segment are presented in Table 5 and indicate that DEM and SCR are stationary at their levels whilst EAR, SEC and NEW are stationary at their first differences both in the tanker and the dry bulk segments. The FL variable needs to be differenced once in the tanker market and twice in the dry bulk market in order to achieve stationarity.

Table 5. Unit root test results

Panel A: Tanker market						
	DEM	*SCR*	*EAR*	*SEC*	*NEW*	*FL*
Level	-2.90*	-3.56*	-2.32	-1.09	-1.83	-2.67
1st difference			-6.72*	-7.30*	-4.27*	-11.47*
Panel B: Bulk carrier market						
	DEM	*SCR*	*EAR*	*SEC*	*NEW*	*FL*
Level	-2.89*	-3.56*	-1.36	-2.33	-1.99	-1.98
1st difference			-4.17*	-6.59*	-4.20*	-2.51
2nd difference						-7.38*

Notes: *denotes the rejection of null hypothesis at the 5% level. The critical value is -3.49 at the 1% level, -2.88 at the 5% level and -2.58 at the 10% level.

3.2 Pairwise Granger causality tests

After having found the order of integration of our variables, we estimate the models (4) to (8) for each vessel segment (estimation is provided in the Appendix) and conduct the Granger causality tests in pairs. The results of the Granger causality tests are presented in Table 6 and indicate that the SCR is capable of predicting the DEM at the 1% level of significance in both segments. With reference to the supply variables, the FL and NEW do not Granger cause the

DEM, whilst the SEC shows significance at a 10% level in the wet segment but insignificance in the dry segment. The only supply variable that is capable of predicting DEM in both segments - albeit at a 10% level of significance- is the proxy for the freight market, as both the BDTI and BDI seem to exert some level of influence on the ship-demolition prices.

Table 6. Pairwise Granger causality test results

Panel A: Tanker market			
H_o	χ^2 statistic	df	p-value
SCR does not Granger cause *DEM*	32.60	3	0.000*
ΔEAR does not Granger cause *DEM*	5.10	2	0.078**
ΔSEC does not Granger cause *DEM*	5.48	2	0.064**
ΔNEW does not Granger cause *DEM*	0.83	2	0.657
ΔFL does not Granger cause *DEM*	0.93	1	0.334
Panel B: Bulk carrier market			
H_o	χ^2 statistic	df	p-value
SCR does not Granger cause *DEM*	44.08	3	0.000*
ΔEAR does not Granger cause *DEM*	2.85	1	0.090**
ΔSEC does not Granger cause *DEM*	0.59	1	0.440
ΔNEW does not Granger cause *DEM*	1.85	4	0.761
Δ'FL does not Granger cause *DEM*	0.18	2	0.913

Notes: *denotes significance at 5% level, **denotes significance at 10% level. df represents the degrees of freedom. *Δ* denotes variables differenced once and *Δ'* variables differenced twice.

3.3 Impulse response functions

The Granger causality tests provided useful information on whether the employed variables are capable of causing the demolition prices. In this section, we exploit the dynamic properties and the transmission mechanism of the VAR models in order to observe the relative responses of the ship-demolition prices on one-standard error shocks on the other employed variables. Figures 4 and 5 visualize these effects for each vessel segment by showing in 10 separate graphs the relative responses. The horizontal axis denotes the time profile of the reactions (in months) and the vertical axis the effect in USD per LDT.

It is evident that the SCR largely affects the DEM in both segments as a shock in the prices of the international steel-scrap causes a positive reaction on the demolition prices. In particular, the effect on the demolition prices reaches its maximum at USD 25 and USD 27 per LDT for the wet and dry sector respectively after approximately 3 months, and it diminishes gradually thereafter. On the contrary, the effect of the supply variables on the demolition prices is less important. With reference to the freight market, it appears that a shock on the BDI and BDTI cause an increase on the demolition prices for dry and wet cargo vessels by 8 and 7 USD per LDT respectively. Moreover, the relevant graphs illustrate that a shock on the aged fleet as well as on the secondhand and newbuilding prices cause a weak response of less than USD 6 per LDT in both segments, thus leaving the demolition prices almost unaffected.

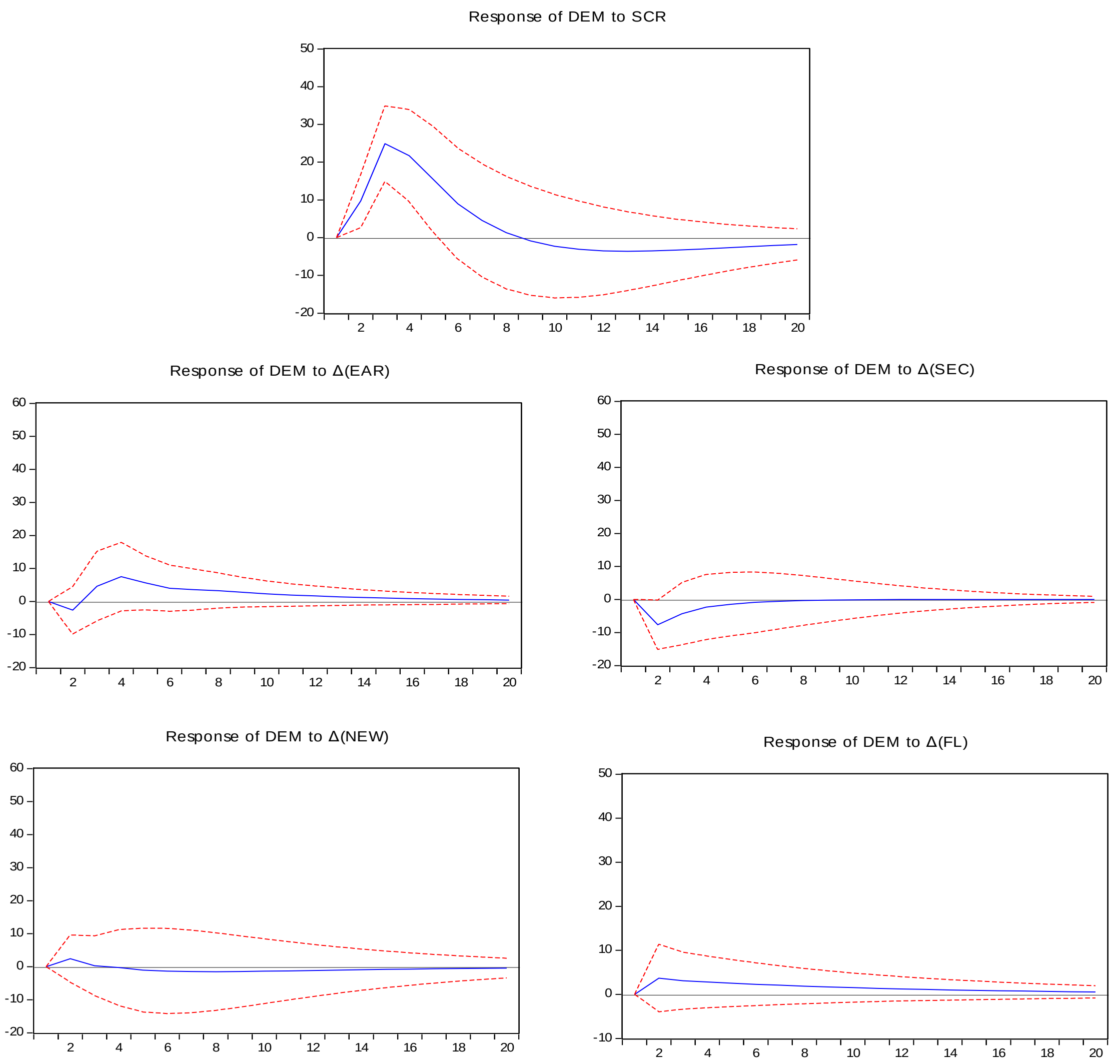


Figure 4. Tanker market-IR to one standard deviation shocks.

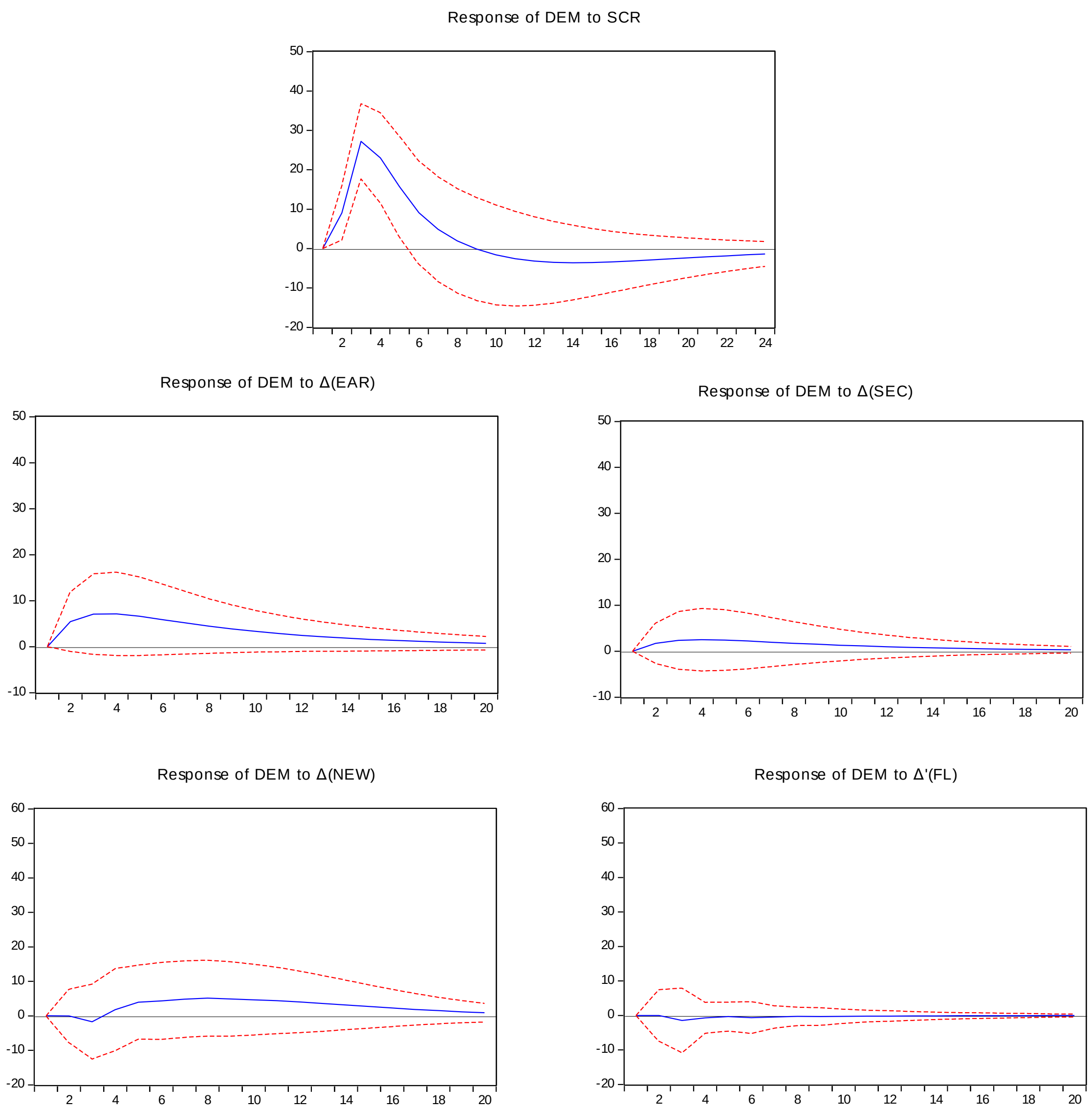


Figure 5. Bulk carrier market-IR to one standard deviation shocks.

In general, the results of the dynamic analysis verify the findings from the Granger causality test. The variables that determine the supply of vessels for demolition cause a minor effect on the ship-demolition prices for both tankers and bulk carriers, in comparison with the effects caused by the proxy variable for the demand side. Among the supply variables, the proxies for the freight market seem to contribute the most, thus verifying that an increase in freight rates is possibly followed by a raise in the demolition prices, whilst the remaining variables are incapable of affecting materially the demolition prices.

4. Conclusion

This study investigates whether the supply of vessels for demolition contributes to the price determination in the ship-demolition market, one of the four major markets of the shipping industry. For this purpose, key variables representing both the supply and the demand of vessels for demolition were selected, in line with the economic theory and the relevant literature. The analysis was conducted for the two main segments by vessel type, namely the tankers and the bulk carriers. Furthermore, the VAR model methodology was employed, whereby five VAR models were constructed for each vessel segment in order to examine in pairs the effect of each particular variable on the ship-demolition prices. The causal effects and the relative strength between the variables were captured by applying the Granger causality test and the impulse response functions.

The findings reveal that the variables employed to account for the supply side have limited effect on the ship-demolition price determination, comparing to the impact of the steel scrap, the proxy variable for the demand side. Such inference was confirmed both in the tanker and the bulk carrier segments. In particular, as evidenced by the IRF, out of the four supply variables the vessels' profitability (represented by the BDTI and BDI for the tanker and bulk carrier markets respectively) showed the greatest effect, whilst the effects of the secondhand prices, the newbuilding prices and the size of the aged fleet appeared immaterial. Therefore, the results indicate that the ship-demolition market is a demand-driven industry, as the pricing in the sector is formulated mostly by the internal demand for the steel-scrap metal, rather than the supply of vessels for demolition. For practical application, the findings alert the investors involved in the ship-demolition market that reliance solely on the conditions of the shipping markets is not adequate to predict the future price trends in the industry. Hence, investing decisions should be made after taking into consideration the conditions on the commodity trade, particularly the scrap and steel products.

References

Alizadeh, A.H., Strandenes S.P., Thanopoulou H., 2016. Capacity retirement in the dry bulk market: A vessel based logit model. Transportation *Research Part E: Logistics and Transportation Review,* 92, pp. 28-42. https://doi.org/10.1016/j.tre.2016.03.005

Buxton, I.L., 1991. The market for ship demolition. *Maritime Policy and Management,* 18(2), pp. 105-112. https://doi.org/10.1080/03088839100000034

Cairns, G., 2014. A critical scenario analysis of end-of-life ship disposal: The bottom of the pyramid as opportunity and graveyard. *Critical perspectives on international business,* 10(3), pp. 172 – 189. https://doi.org/10.1108/cpoib-10-2012-0049

Chang, Y.C., Wang, N., Durak, O.S., 2010. Ship recycling and marine pollution. *Marine Pollution Bulletin,* 60(9), pp. 1390-1396. https://doi.org/10.1016/j.marpolbul.2010.05.021

Demaria, F., 2010. Shipbreaking at Alang- Sosiya (India): An ecological distribution conflict. *Ecological Economics,* 70(2), pp. 250-260. https://doi.org/10.1016/j.ecolecon.2010.09.006

Gregson, N., Crang, M., Ahamed, F., Akhter, N., Ferdous, R., 2010. Following things of rubbish value: End-of-life ships, 'chock-chocky' furniture and the Bangladeshi middle class consumer. *Geoforum,* 41(6), pp. 846-854. https://doi.org/10.1016/j.geoforum.2010.05.007

Kagkarakis, N.D., Merikas, A.G., Merika A., 2016. Modelling and forecasting the demolition market in shipping. *Maritime Policy and Management,* 43(8), pp. 1021-1035. https://doi.org/10.1080/03088839.2016.1185181

Knapp, S., Kumar, S.N., Remijn, A.B., 2008. Econometric analysis of the ship demolition market. *Marine Policy,* 32(6), pp. 1023-1036. https://doi.org/10.1016/j.marpol.2008.02.004

Kusumaningdyah, W., Eunike, A., Yuniarti, R. 2013. Modeling tradeoff in ship breaking industry considering sustainability aspects: A system dynamics approach. *Procedia Environmental Sciences,* 17, pp. 785-794. https://doi.org/10.1016/j.proenv.2013.02.096

Matz-Luck, N., 2010. Safe and sound scrapping of 'Rusty Buckets'? The 2009 Hong Kong ship recycling convention. *Review of European, Comparative & International Environmental Law*, 19(1), pp. 95-103.

Mikelis, N., 2007. A Statistical Overview of Ship Recycling. In: *International Symposium on Maritime Safety, Security & Environmental Protection,* Athens, September 2007.

Mikelis, N., 2013, Ship Recycling Markets and the Impact of the Hong Kong Convention. In: *International Conference on Ship Recycling*, World Maritime University, Malmo, Sweden, April 2013.

Neser, G., Unsalan, D., Tekogul, N., Stuer-Lauridsen, F., 2008. The shipbreaking industry in Turkey: environmental, safety and health issues. *Journal of Cleaner Production,* 16, pp. 350-358. https://doi.org/10.1016/j.jclepro.2006.08.018

Sarraf, M., Stuer-Lauridsen, F., Dyoulgerov, M., Bloch, R., Wingfield, S., Watkinson, R., 2010, Ship Breaking and Recycling Industry in Bangladesh and Pakistan. *Report No 58275-SAS*, International Bank for Reconstruction and Development/The World Bank.

Sinha, S., 1998. Ship scrapping and the environment - The buck should stop! Maritime Policy and Management, 25(4), pp. 397-403. https://doi.org/10.1080/03088839800000062

Stopford, M., 2009. Maritime Economics, 3rd edition. Oxon: Routledge. https://doi.org/10.4324/9780203891742

Vedeler, K.V., 2006. From cradle to grave- Value chain responsibility in the ship scrapping industry. Master thesis, Norwegian School of Economics and Business Administration.

Yujuico, E., 2014. Demandeur pays: The EU and funding improvements in South Asian ship recycling practices. *Transportation Research Part A: Policy and Practice*, 67, pp. 340-351. https://doi.org/10.1016/j.tra.2014.07.015

Appendix. Estimation of VAR models.

Panel A: Tanker market														
	DEM_t	SCR_t		DEM_t	ΔEAR_t		DEM_t	ΔSEC_t		DEM_t	ΔNEW_t		DEM_t	ΔFL_t
DEM_{t-1}	0.736* (0.112) [6.571]	-0.119 (0.117) [-1.015]	DEM_{t-1}	1.054* (0.090) [11.704]	0.852 (0.543) [1.568]	DEM_{t-1}	1.171* (0.107) [10.925]	0.038* (0.016) [2.396]	DEM_{t-1}	1.040* (0.092) [11.257]	0.026* (0.007) [3.452]	DEM_{t-1}	0.900* (0.036) [24.369]	0.0005 (0.0008) [0.662]
DEM_{t-2}	-0.079 (0.148) [-0.547]	0.153 (0.153) [0.998]	DEM_{t-2}	-0.169** (0.089) [-1.899]	-0.907** (0.538) [-1.686]	DEM_{t-2}	-0.288* (0.106) [-2.709]	-0.048* (0.015) [-3.007]	DEM_{t-2}	-0.150 (0.091) [-1.645]	-0.025* (0.007) [-3.410]	ΔFL_{t-1}	3.766 (3.902) [0.965]	-0.062 (0.092) [-0.678]
DEM_{t-3}	0.201 (0.109) [1.849]	0.103 (0.114) [0.900]	ΔEAR_{t-1}	-0.010 (0.014) [-0.731]	0.206* (0.088) [2.321]	ΔSEC_{t-1}	-1.471* (0.710) [-2.071]	0.214* (0.106) [2.013]	ΔNEW_{t-1}	0.716 (1.060) [0.675]	0.382* (0.087) [4.373]			
SCR_{t-1}	0.312* (0.111) [2.807]	1.145* (0.116) [9.798]	ΔEAR_{t-2}	0.032* (0.014) [2.231]	-0.246* (0.088) [-2.791]	ΔSEC_{t-2}	1.216** (0.627) [1.939]	0.121 (0.094) [1.288]	ΔNEW_{t-2}	-0.925 (1.059) [-0.873]	0.230* (0.087) [2.637]			
SCR_{t-2}	0.214 (0.156) [1.371]	-0.088* (0.164) [-0.539]												
SCR_{t-3}	-0.482* (0.118) [-4.067]	-0.312* (0.124) [-2.506]												
Constant	44.834* (15.590) [2.875]	25.519 (16.386) [1.557]	Constant	48.972* (15.837) [3.092]	19.383 (95.587) [0.202]	Constant	49.571* (15.968) [3.104]	3.825 (2.398) [1.595]	Constant	46.780* (16.622) [2.814]	-0.222 (1.371) [-0.162]	Constant	43.579* (15.841) [2.751]	-0.527 (0.376) [-1.401]
Adj. R^2	0.865	0.848		0.835	0.083		0.836	0.192		0.829	0.353		0.832	0.009
Autocorrelation LM-stat		3.149		1.911			5.310			9.146			6.520	
p-value		0.533		0.752			0.256			0.057			0.163	

Panel B: Bulk carrier market														
	DEM_t	SCR_t		DEM_t	ΔEAR_t		DEM_t	ΔSEC_t		DEM_t	ΔNEW_t		DEM_t	$\Delta' FL_t$
DEM_{t-1}	0.692* (0.103) [6.674]	-0.176 (0.109) [-1.614]	DEM_{t-1}	0.888* (0.039) [22.346]	-1.473* (0.650) [-2.264]	DEM_{t-1}	0.881* (0.040) [21.616]	-0.056* (0.020) [-2.806]	DEM_{t-1}	0.968* (0.098) [9.804]	0.030* (0.007) [4.191]	DEM_{t-1}	0.976* (0.093) [10.496]	-0.001 (0.002) [-0.708]
DEM_{t-2}	-0.129 (0.134) [-0.963]	0.131 (0.141) [0.930]	ΔEAR_{t-1}	0.008** (0.005) [1.691]	0.410* (0.081) [5.015]	ΔSEC_{t-1}	0.124 (0.161) [0.772]	0.507* (0.079) [6.367]	DEM_{t-2}	-0.087 (0.136) [-0.636]	-0.037* (0.010) [-3.700)	DEM_{t-2}	-0.108 (0.091) [-1.177]	0.001 (0.002) [0.527]
DEM_{t-3}	0.295* (0.102) [2.882]	0.168 (0.108) [1.555]							DEM_{t-3}	-0.016 (0.142) [-0.113]	0.025* (0.010) [2.405]	$\Delta' FL_{t-1}$	-0.033 (3.929) [-0.008]	-0.504 (0.088) [-5.702]
SCR_{t-1}	0.280* (0.104) [2.674]	1.165* (0.110) [10.541]							DEM_{t-4}	-0.014 (0.104) [-0.137]	-0.023* (0.007) [-3.048]	$\Delta' FL_{t-2}$	-1.559 (3.922) [-0.397]	-0.374 (0.088) [-4.241]
SCR_{t-2}	0.319* (0.151) [2.114]	-0.044 (0.159) [-0.281]							ΔNEW_{t-1}	-0.016 (1.274) [-0.013]	0.413* (0.093) [4.401]			
SCR_{t-3}	-0.562* (0.112) [-5.016]	-0.350* (0.118) [-2.960]							ΔNEW_{t-2}	-0.535 (1.342) [-0.399]	0.032 (0.098) [0.327]			
									ΔNEW_{t-3}	1.345 (1.266) [1.061]	0.218* (0.093) [2.336]			
									ΔNEW_{t-4}	0.237 (1.190) [0.199]	-0.031 (0.087) [-0.363]			
Constant	43.888* (15.637) [2.806]	25.185 (16.503) [1.526]	Constant	45.220* (16.097) [2.809]	579.579* (263.438) [2.200]	Constant	47.896* (16.488) [2.904]	22.436* (8.151) [2.752]	Constant	60.419* (19.175) [3.150]	1.913 (1.412) [1.354]	Constant	53.335* (17.212) [3.098]	0.151 (0.387) [0.390]
Adj. R^2	0.849	0.852		0.804	0.192		0.801	0.255		0.780	0.494		0.790	0.220
Autocorrelation LM-stat p-value	3.158 0.531			4.280 0.369			2.869 0.579			2.396 0.663			5.020 0.285	

Notes: Figures in (.) are standard errors; figures in [.] are t-statistics. *denotes significance at 5% level; ** denotes significance at 10% level. *Δ* denotes variables differenced once and *Δ'* variables differenced twice.