A NON-STRUCTURAL TEST FOR COMPETITION IN THE CONTAINER LINER SHIPPING INDUSTRY

Christa Sys, Ghent University, SHERPPA, University College Ghent, Faculty of Applied Business

Hilde Meersman, University of Antwerp, Department of Transport and Regional Economics

Eddy Van de Voorde, University of Antwerp, Department of Transport and Regional Economics

ABSTRACT

This paper examines the competitive conditions of the containerised liner shipping industry. The degree of competition prevailing in this industry will be assessed using the H-statistic proposed by Panzar and Rosse (1987). The properties of this non-structural methodology (e.g. using firm level data, robustness in small samples, no need to specify a relevant market, etc.) make it an excellent framework for assessing the degree of competition in the containerised liner shipping industry. The empirical specifications are based on an unbalanced panel of data regarding a sample of 18 major liner operators covering the period 1999-2008. The fact that we have found a significantly positive unscaled value of the H-statistic means that the hypothesis can be rejected that the containerised liner shipping industry market structures correspond to a neoclassical monopolist, collusive oligopolist or conjectural-variations short-run oligopolist.

Keywords: Containerised liner shipping industry, competition, Panzar-Rosse model

1 INTRODUCTION

The liner shipping industry has experienced fundamental changes in recent years due to globalisation, deregulation, horizontal/vertical integration, (increased) co-operation, rationalisation, developments in information technology, consolidation and increased concentration. These developments may affect competition. As in other industries, competition in the (containerised) liner shipping industry matters for a number of reasons: it encourages the level of innovation (e.g. vessel size, low emission ships, tracking and tracing of cargo, etc.) and the quality and efficiency of services rendered in the sector.

Besides these changes, the liner shipping industry was under the spell of the question whether the block exemption would be abolished. As from 18 October 2008 this abolishment is a fact (EEC Regulation n° 4056/86)[1]. The liner carrier association, European Liner Affairs Association, expects the liner shipping market to become even more competitive as soon as conferences and in particular conference surcharges[2] and ancillary charges[3] will disappear.

Remarkably, in publicly available reports of the European Commission - Directorate General of Competition (DG Comp - ec.europa.eu/comm/competition/antitrust/overview_en.html), the European Shipper Council (ESC - www.europeanshippers.com) and the European Liner Affairs Association (ELAA - www.elaa.net), the degree of competition has never been established neither by applying the structural nor the non-structural approach. Knowledge of the degree of competition is important for antitrust authorities. This offers an extra incentive to examine the degree of competition.

The main emphasis of the present paper is to examine the competitive conditions of the liner shipping industry, more specifically, the containerised liner shipping industry (hereafter CLSI). To do this, a non-structural measurement of competition is documented and estimated at the level of CLSI. For this purpose, and in function of data availability, a panel data set of 18 major liner operators with a global presence was set up. The evolution of the competitive structure of the CLSI will be studied over the period 1999-2008.

[1] Since 1986, the European Commission has granted a block exemption from the competition rules for conference liner operators. A Block Exemption Regulation defines certain categories of agreements which are compatible with EU competition rules provided that the agreements meet the conditions laid down in the Regulation. In March 2003, the European Commission's Directorate General for Competition announced a review of Regulation 4056/86. On 25th September 2006, the Council agreed to repeal Regulation 4056/86. By consequence, it puts an end to the coordination of prices, charges and surcharges as well as coordinated capacity management in European Union trades as of October 2008. Since that date, liner operators have to fix their own freight rates and any surcharge (European Commission, 1997 and 2007; ELAA, 2003).

[2] Surcharges relate to charges that are meant to cover uncertainties, such as the Bunker Adjustment Factor (BAF), Currency Adjustment Factor (CAF), Congestion Surcharges (CSC) and War Risk Surcharge (WRS) (Competition Commission of Singapore, 2006).

[3] Ancillary charges – such as terminal handling charges, demurrage costs, change of destination, special equipment and charges based on the nature of the cargo (dangerous, noxious, refrigerated etc.), … – cover the supplementary increase in charges that are triggered by or linked with the operation of moving containers, i.e. they are ancillary to the service provided by liner operators (Competition Commission of Singapore, 2006).

The paper will be structured as follows: Section 2 provides a brief overview of the literature. Section 3 is devoted to the non-structural methodology used to assess the degree of competition in the CLSI. Section 4 presents the data and selection criteria. Section 5 reports and discusses the econometric results. Ultimately, section 6 summarises and draws conclusions.

2 LITERATURE REVIEW

A scan of shipping literature reveals that a vast number of studies theoretically examined the issue of competition in the liner shipping industry (e.g. Molenaar, H.J. & Van de Voorde, E, 1994; Brooks, 2000; …). Few of these studies focused on modelling competition (e.g. Sjostrom, 2002). Additionally, literature has long focused on the regulation/deregulation of the liner shipping industry (for example: see European Commission, 1997 and 2007; Heaver, T., 2001; OECD, 2002; ELAA, 2003; Benacchio, M. et al., 2007).

In contrast, assessing empirically the degree of competition is a recurrent topic in the literature of other newly liberalised service sectors such as the banking industry, telecommunication, broadcasting, etc.. This literature shows two major approaches, viz. the structural and the non-structural approach. The structural approach is based on the structure-conduct-performance (SCP) hypothesis. The SCP hypothesis holds that observable structural characteristics of a market determine the conduct of firms operating in the market which in turn influences measurable aspects of market performance. In contrast, the non-structural approach attempts to draw interferences about market structure and competitive conditions from direct observations of conduct at firm level (see Martin, 2002, Lipcynski et al., 2005).

As a reaction to the theoretical and empirical shortcomings attributed to the structural approach, namely recognition of the need to endogenise market structure and the neglect of potential competition (Gischer & Stiele, 2009), non-structural models of competitive behaviour have been developed. These ‘New Empirical Industrial Organization (NEIO)’ approaches such as the Iwata-model (1974), Bresnahan (1982 and 1989) and Lau (1982) mark-up model, and Panzar and Rosse (1987) measure competition and analyse the competitive behaviour of firms without using explicit information about the structure of the market.

As the first two models are very data-intensive, the majority of the studies have investigated competition using the non-structural methodology put forward by Panzar and Rosse - the so-called H-statistic: *Newspaper industry*: Panzar & Rosse, 1987; *Banking*[4]: Shaffer, 1993; Vesala, 1995; Bikker & Groeneveld, 2000; De Bandt & Davis, 2000; Bikker & Haaf, 2002; Bikker, 2004; Claessens & Laeven, 2004; Bikker, Spierdijk, & Finnie, 2006 and 2008; Al-Muharrami, S. et al., 2006; Matthews, Murinde & Zhao, 2007; Chan et al, 2007; Goddard & Wilson, 2007; Gutiérrez, 2007; Gischer & Stiele, 2008; Bikker, Shaffer & Spierdijk, 2009;…; *Life insurance*: Bikker & Leuvensteijn, 2008; *Cigarette industry*: Sullivan, 1985; Ashenfelter &

[4] The booming of papers in the banking industry is fuelled by recent developments in the European banking industry (e.g. financial liberalisation, ongoing economic and regulatory integration, introduction of the Euro, developments in information technology, etc.).

Sullivan, 1987; *Physician services industry*: Wong, 1995; *Security sector*: Tsutsui & Kamesakab, 2005.

Also, in the field of transport, two studies were found applying this methodology. First, Fischer and Kamerschen (2003) applied the Panzar-Rosse test to assess market performance in selected airport-pairs originating from Atlanta. Secondly, a report in Japanese studied the competitive nature of the liner shipping industry estimating Panzar-Rosse H statistic based on panel data of three major Japanese shipping companies between 1986 and 2002. The author concluded: "*Panzar-Rosse H statistic indicates that the three major Japanese liner carriers*[5] *do not behave as forming perfect collusion. This result is consistent with monopolistic competition. It seems that competition has been intensified following the introduction of competition promotion policy*" (Endo, 2005).

An extra advantage of the Panzar-Rosse model (hereafter, abbreviated to "the P-R model"), as well as other non-structural models, is that there is no need to specify a relevant market[6], since the behaviour of individual firms provides an indication of their market power. Furthermore, the P-R approach works well with firm-specific data on revenues and factor prices, and does not require information about equilibrium output prices and quantities for the firm and/or industry. In addition, while the Bresnahan-Lau model tends to exhibit an anticompetitive bias in small samples, the P-R approach is robust in small samples (Shaffer, 2004).

The properties of the P-R methodology (using firm-level data on revenues and factor prices, the robustness in small samples and the absence of a need to specify relevant market) make it an excellent framework for assessing the degree of competition for the CLSI.

3 METHODOLOGY

This section presents the theoretical background of the P-R model, the interpretation of the H-statistic, the debate regarding the dependent variable and subsequently focuses on the empirical implementation of the model.

3.1 Theoretical background of the P-R model

Rosse and Panzar (1977) and Panzar and Rosse (1987) developed a non-structural estimation technique to discriminate between oligopolistic, monopolistically competitive and perfectly competitive markets. To do this, the P-R model builds a competition marker also referred to as the H-statistic or revenue test. The H-statistic provides a quantitative evaluation of the competitive nature of a market. This statistic is calculated from reduced-

[5] Endo most likely studied the behaviour of Mitsui O.S.K Lines (MOL), Nippon Yusen Kaisha (NYK) and Kawasaki Kisen Kaisha (K-line). Their shipping business is wide-ranging, covering container, car, bulk and energy resources transport.

[6] Although the Guidelines on the application of Article 81 of the EC Treaty to Maritime Transport Services (European Commission, 2007) state that it is necessary to define the relevant product and geographic market(s), it is not possible to use data at product level and/or geographical markets level due to a shortage in data of input factor prices with respect to specific trades (e.g. the eastbound market differs from the westbound market), to products (niche products (dangerous goods, reefer,...) versus transportation of a box), etc. Applying the Panzar Rosse model solves this problem.

form revenue equations and measures the elasticity of total revenues with respect to changes in factor input prices (Bikker & Haaf, 2002; Lipczynski et al., 2005, Bikker et al., 2006, Gutiérrez de Rozas, 2007, Bikker et al., 2009, …).

The P-R model starts from a number of assumptions. Firstly, firms are treated as profit-maximising, single product firms. The single product firm assumption is consistent with the intermediation approach. We adopt the intermediation approach which describes liner operators as profit maximising firms that transport boxes (standardised TEU's) by using physical capital (assets i.e. ships), human labour and financial capital as input. Secondly, higher input prices must not be correlated with higher quality services that generate higher revenues because such a correlation would bias the calculated H statistic. Thirdly, the cost structure must be homogeneous and the price elasticity of demand must be greater than unity. Next, firms can enter or exit any market freely, without losing their capital, and potential competitors operate on the same cost functions as established firms[7]. A final crucial assumption is that the firm must be in long-run equilibrium[8] (Panzar and Rosse, 1987; De Bandt and Davis, 2000).

In this subsection, a short description of the P-R model is provided. Panzar and Rosse (1987) start with the firm's profit function. A firm maximises

$$\Pi = R - C = \Pi\,(x_i, z_i, w_i, t_i) \qquad (1)$$

where x_i, refers to the output of firm i, z_i and t_i denote resp. a vector of exogenous variables that shift the firm's revenue/cost function, w_i is a vector of m factor prices of firm i. The vectors z_i and t_i may or may not have variables in common (hereafter subscripts referring to firm i are dropped).

Next, they consider an equi-proportionate increase in all factor input prices, from w to (1+h) w. Let x° be the argument that maximises profit function (1) and x^1 the output that maximises Π (x, z, (1+h) w, t) with the scalar $h \geq 0$. Then, let $R° = R(x°, z) \equiv R^*(z,w,t)$ and $R^1 = R(x^1, z) \equiv R^*(z,(1+h)\,w, t)$. R* denotes the firm's reduced form revenue function. By definition

$$R^1 - C(x^1, (1+h)\,w, t) \geq R° - C(x°, (1+h)\,w, t) \qquad (2)$$

Costs are linearly homogeneous in factor input prices, so (2) can be rewritten as

$$R^1 - (1+h)C(x^1, w, t) \geq R° - (1+h)C(x°, w, t) \qquad (3)$$

which subsequently results in

$$(R^1 - R°)/h = [R^*(z, (1+h)\,w, t) - R^*(z, w, t)]/h \leq 0 \qquad (4)$$

Assuming that the reduced-form revenue equation is differentiable, taking the limit of (4) for h → 0 and dividing by R* yields

$$H = \sum_{j=1}^{m} \frac{\partial R_i^*}{\partial w_{j_i}} \cdot \frac{w_{j_i}}{R_i^*} \qquad (5)$$

[7] The Panzar Rosse methodology has been largely applied in the banking industry. Although to provide banking services, a bank license is a condition for a financial institution under most jurisdictions, every study accepted the assumption of free entry and/or exit. In contrast, the containerised liner shipping industry is not regulated. We also accept this assumption.

[8] See section 3.4.

Market power is measured by the amount to which a change in *m* factor input prices (∂w_{j_i}) is mirrored in the equilibrium revenues (∂R_i^*) realised by firm i.

In order to calculate the H-statistic, the following linear regression is used[9]:

$$\text{Ln } R_{i,t} = \beta_0 + \beta_1 \ln (w_{1,i,,t}) + \beta_2 \ln (w_{2,i,,t}) + \beta_3 \ln (w_{3,i,,t}) + \sum_{j=4}^{m} \beta_j FSF_j + \varepsilon_{i,t} \qquad (6)$$

The notation is as follows: the subscript i and t values represent firm i at time t. $R_{i,t}$ denotes the revenue of firm i in year t and $w_{j,i,,t}$ represents the price of factor input j paid by firm i in year t. If the price of factor inputs cannot be observed directly, they are usually imputed using the ratio of quantity of each factor employed to the level of expenditure on the same factor (Lipczynski et al., 2005). FSF_j stand for firm specific exogenous factors and $\varepsilon_{i,t}$ denotes an error term. With three factor inputs in the notation of Eq. (6), the Panzar-Rosse H-statistic is defined as $H = \beta_1 + \beta_2 + \beta_3$. Thus, Panzar and Rosse define a measure of competition H as the sum of elasticities of the reduced-form revenues with respect to factor prices.

3.2 Interpretation of the H-statistic

In a very recent contribution, Bikker, Shaffer and Spierdijk (2009) interpret the value of the H-statistic differently than prior studies do. In the present study, all the previous literature is labelled 'traditional approach' while the paper of Bikker et al. seems to mark the beginning of a new approach[10].

In this subsection, we report firstly on the interpretation of the traditional approach, followed by an intuitive description for the polar cases of monopoly ($H \leq 0$) and perfect competition ($H = 1$). From this intuitive graphical description, it is easy to turn towards the new interpretation of the H-statistic where a distinction is made between either U-shaped and constant average cost curve.

Firstly, according to the traditional approach, the H-statistic ranges from minus infinity to unity. If firms pricing policies are consistent with the model of monopoly or a perfect colluding oligopoly, H is negative. In long-run equilibrium, the market structure is characterised by monopolistic competition, if H is positive but less than unity and by perfect competition if the H-statistic equals unity (Panzar and Rosse, 1977). Shaffer (1982) proved that a monopoly operating in a perfectly contestable market and a sales maximising firm subject to a break even constraint also are consistent with an H-statistic of unity. In 1983, Shaffer showed that a short-run conjectural variations oligopoly corresponds with $H \leq 0$. The numerical value of the H-statistic is interpreted as a continuous measure of the level of competition. So, an H-value closer to unity indicates a stronger competition than lower values (Vesala, 1995, p. 56, Bikker and Haaf, 2002, p. 2203).

[9] See Panzar & Rosse, 1987 and Bikker et al., 2006 for the translation of the theoretical P-R model into an empirical specification by using a simple single product monopoly model with a demand curve of constant price elasticity and a constant return to scale Cobb-Douglas technology.

[10] See also 3.3.

Table 1 summarises the interpretation of the H-statistic. To assure a valid interpretation of the PR model, the market has to be in a long-run equilibrium. The long-run equilibrium test or E-statistic (see section 3.4) is already integrated in this overview. For either monopoly or collusive oligopoly, the assumption of profit maximisation is sufficient (See Panzar and Rosse, 1987, p. 446).

<table>
<tr><td>Assumption</td><td colspan="4">profit maximising firm</td></tr>
<tr><td>H-statistic</td><td>$H \leq 0$</td><td colspan="3">$H > 0$</td></tr>
<tr><td>Property</td><td>revenu of the firm is independent of decision of rivals, actual or potential</td><td colspan="3">revenu of the firm is affected by the actions of others</td></tr>
<tr><td>Assumption</td><td></td><td colspan="3">long-run equilibrium</td></tr>
<tr><td>E-statistic</td><td></td><td>$E < 0$
disequilibrium</td><td colspan="2">$E = 0$
equilibrium</td></tr>
<tr><td>H-statistic</td><td></td><td>$H \leq 0$</td><td>$0 < H < 1$</td><td>$H = 1$</td></tr>
<tr><td>Property</td><td></td><td>without threat of entry</td><td colspan="2">free entry and exit result in zero profits in equilibrium</td></tr>
<tr><td>Market structure</td><td>monopoly
collusive oligopoly</td><td>short-run conjectural variation oligopoly</td><td>monopolistic competition</td><td>perfect competition

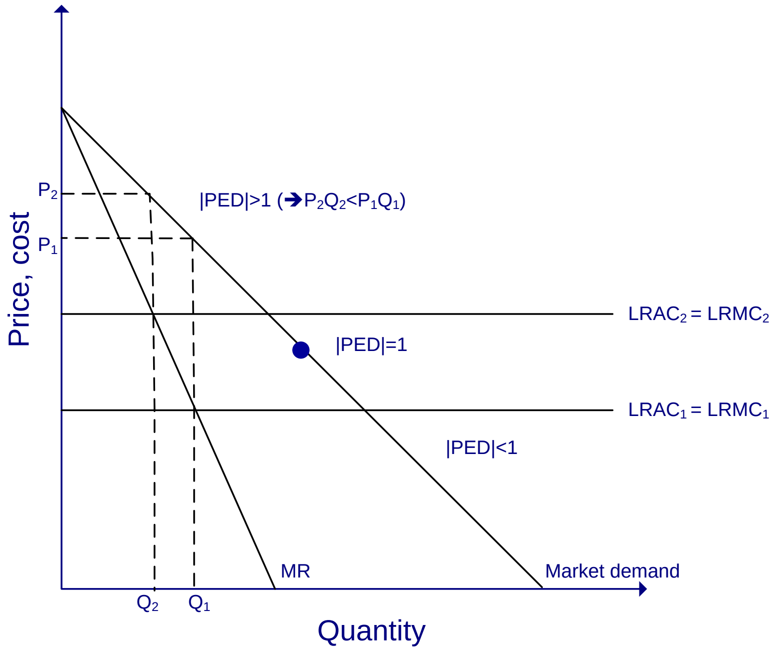
Natural monopoly in a contestable market

Sales maximising firm subject to a breakeven constraint</td></tr>
</table>

Table 1 – Interpretation of H-statistic and E-statistic

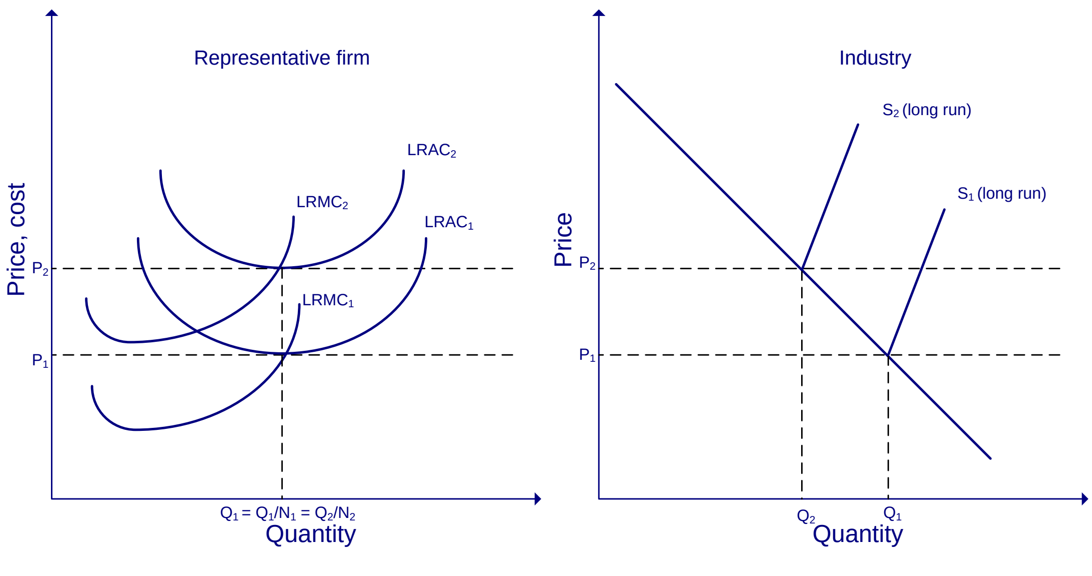
Secondly, an intuitive description is provided by Lipczynski et al. (2005)[11]. They describe graphically the proof of the result H $\leq$0 for monopoly (long-run average cost (LRAC) and long-run marginal cost (LRMC) functions are assumed to be horizontal) (see Graph 1). The starting point is the consideration of the impact of a simultaneous equi-proportionate increase in all of the firm's factor input prices. Panzar and Rosse (1987) proved that under monopoly, an increase in input price will increase marginal costs, reduce equilibrium output ($Q_1 \rightarrow Q_2$) and subsequently reduce revenue because a monopolist with non-zero costs always operates on the price elastic segment of the market demand function. Therefore, in monopoly, the H-statistic is negative.

[11] Whereas the intuition is clear-cut in the case of monopoly and perfect competition, it is less straightforward in the intermediate case of imperfect competition. A more detailed algebraic derivation of the Panzar and Rosse model can be found in Panzar & Rosse (1987), Bikker et al. (2006) and Goddard and Wilson (2007).



Graph 1 – Effect of an increase in factor input prices on equilibrium in monopoly (Source: Lipczynski et al., 2005)

Proceeding with the intuitive description of Lipczynski et al (2005), Graph 2 illustrates that the sum of the elasticities of reduced form revenues with respect to factor prices equals unity when firms are observed in long-run equilibrium.



Graph 2 – Effect of an increase in factor prices on long-run post-entry equilibrium in perfect competition (Source: Lipczynski et al., 2005)

The H-statistic measures the impact of a proportional increase in all factor prices. Assume all factor prices rise by 1%, such an increase will shift both the LRAC/LRMC curve upward by 1% for all output levels, leaving its minimum point unchanged. Since, in long-run equilibrium, firms always operate at minimum LRAC, this means that Q_1 is unchanged. By consequence, in equilibrium, the market price must increase in exactly the same proportion. Thus equilibrium revenues also go up by 1%, the amount of the increase in factor prices and profits remain unaltered. Furthermore, an increase in market price brings about a reduction in the total quantity of output ($Q_1 \rightarrow Q_2$). A reduction in the number of firms ($N_1 \rightarrow N_2$) is required for the adjustment in total quantity of output. This is precisely the condition that H equals one.

Turning to the new interpretation of the H-statistic, Bikker, Shaffer and Spierdijk (2009) link the properties of the H-statistic with the shape of the average cost function (i.e. u-shaped versus constant average cost function) to allow meaningful interpretations. Table 2 sums up the properties of the H-statistic according to Bikker et al. (2009).

Assumption	average cost curve	
	U-shaped	Constant
Market structure		
Monopoly	Rosse and Panzar (1977): H < 0	H < 0
Oligopoly	Rosse and Panzar (1977): H < 0	H < 0
Long-run competition	Rosse and Panzar (1977): H = 1	H < 0 or 0 < H < 1
Short-run competition	Shaffer (1982, 1983): H < 0 possible Rosse and Panzar (1977): 0 < H < 1 possible	
Monopolistic competition	Rosse and Panzar (1977): 0 < H < 1 under conditions, but H < 0 possible	

Table 2: Properties of the H-statistic (Source: Bikker et al., 2009)

In the same study, they also show that the equilibrium test is a joint test for competitive conduct and long-run structural equilibrium, and the unscaled P-R test is a one-tail test of conduct. So, according to their findings, a positive unscaled value of the H-statistic is inconsistent with any form of imperfect competition, while a negative value may arise under various conditions, including short-run competition or even long-run competition with constant average cost (Bikker et al., 2009). In other words, a negative unscaled H-value cannot by itself discriminate between perfect and imperfect competition without information about the shape of the cost function.

For the containerised liner shipping industry, we assume a U-shaped average cost curve. While the presence of large and small liner operators might suggest that scale effects are not important, increased concentration (e.g. Hoffman, 1998; Sys, 2009), explosion in containership size (e.g. Cullinane & Khanna, 2000; Sys et al., 2008), etc. are indications that scale effects are important in this industry.

Ultimately, Bikker et al. (2009) also concluded that the numerical value of H is not a reliable indicator of the strength of competition.

3.3 Dependent variable

In the empirical banking literature on the Panzar-Rosse approach, there is a debate regarding the choice of the dependent variable, viz. scaled (i.e. revenue divided by total assets) versus unscaled (i.e. revenue). De Bandt & Davis, 2000; Bikker et al, 2006, Gischer & Stiele, 2008 and Bikker et al., 2009 agree with Vesala (1995, p75) that the use of a scaled dependent variable changes the nature of the P-R model from being a revenue equation into a price equation. The study of Bikker, Spierdijk & Finnie (2006) has investigated in detail whether the use of a price equation causes a misspecification of the P-R model. These authors concluded that scaling causes a bias of the H-statistic to be closer to perfect competition. More recent studies of Gisher & Stiele, 2008 and Bikker, Shaffer & Spierdijk, 2009 again confirm that empirical models that apply price rather than revenue equation direct towards biased results and that the price and revenue equation are only identical in the case of perfect competition. Both Gischer & Stiele, 2008 and Bikker, Shaffer & Spierdijk, 2009 address the discrepancy between the theoretical grounds of the P-R model and its empirical translation.

Gischer & Stiele, 2008 address the problem applying firstly the properties of logarithms. More specifically, the logarithmic expression of the scaled dependent variable ln (revenues/total assets) may be rewritten to ln(revenues) – ln(total assets)[12]. Next, it is assumed that the conditional expected value of the disturbance term, $E(\varepsilon_{i,t})$, follows the normal distribution with expected value of 0 and a constant variance of σ^2. So, changing ln(total assets) to the right-hand side of the equation, by assumption the conditional expected value $E(\varepsilon_{i,t} + \ln TA)$ needs to be zero. This is only the case if and only if E(lnTA) equals zero.

Bikker et al. (2009) explore more in detail the consequences of controlling for firm scale in the P-R test. They find that a price equation and scaled revenue function cannot make out imperfect competition in the same way that an unscaled revenue function can. By consequence, their finding disqualifies some empirical studies[13].

In accordance with these studies, this paper also opted to use an absolute unscaled dependent variable.

3.4 Empirical implementation of the P-R model

The P-R revenue test is implemented by estimating the following linear regression using container division level data, in line with Equation (6):

$$\begin{aligned}\ln TURN_{i,t} &= \beta_0 + \beta_1 \ln(PO_{i,t}) + \beta_2 \ln(PL_{i,t}) + \beta_3 \ln(PCE_{i,t}) + \\ &\gamma_1 \ln(EQTA_{i,t}) + \gamma_2 \ln(CAPVESSEL_{i,t}) + \gamma_3 \ln(DUMMY\_AL_{i,t}) + \gamma_4 \ln(DUMMY\_MA_{i,t}) + \varepsilon_{i,t}\end{aligned} \tag{7}$$

The variables are defined as follows: the dependent variable, $TURN_{i,t}$ denotes the turnover at container division level.

The set of explanatory variables embraces three factor input prices. As the three input prices cannot be observed directly, the factor input prices are commonly proxied by ratios of expenses to respective volumes: $PO_{i,t}$ is calculated as the ratio of operating expenses to transported TEU (proxy for input price of operation). $PL_{i,t}$ is measured by the ratio of staff expenses to the number of employees (proxy for input price labor) and $PCE_{i,t}$ is obtained by dividing the non-operating expenses by total assets for the business segment container shipping (proxy for input price of capital expenditure). Fixed assets (proxied by depreciation) might be a better denominator than total assets. As segmented figures for container division were only available for some liner operators, we use total assets for the business segment container shipping in the denominator.

[12] A property of logarithms is that they reduce division to subtraction, in order words the log of a quotient is the difference of the logs, by the formula $\log_a (x/y) = \log_a x - \log_a y$.

[13] See Bikker et al., 2009, p. 14.

Next, a set of CLSI-specific variables are added in essence to catch differences in risk and business profile. The first control variable, $EQTA_{i,t}$ (Equity to Total Assets) accounts for the leverage reflecting differences in risk preferences. Secondly, the business profile is proxied by the ratio of TEU capacity to the number of ships ($CAPVESSEL_{i,t}$). This variable is included to control for differences in deployed ship sizes. A positive coefficient value is expected since larger ship size should provide economies of scale, hence a higher return. In addition, two dummy variables taking on the values 1 and 0 are included to capture the effect of being a member of an alliance (DUMMY_AL) and/or to study the impact of mergers and acquisition (DUMMY_MA) on turnover.

Ultimately, $\varepsilon_{i,t}$ is a stochastic disturbance term which is assumed to follow a normal distribution ($\varepsilon_{i,t} \sim N(0, \sigma^2)$). The subscript i denotes liner operator i and the subscript t denotes year t. All variables are taken in natural logarithms.

3.5 Equilibrium test

A key assumption underlying the P-R model is that the H-test must be undertaken on observations that are in long-run equilibrium. In long-run equilibrium, rates of return should be uncorrelated with input prices. The equilibrium test is based on a regression in which the dependent variable TURN in Eq. (7) is replaced by a measure of profitability such as return on assets (ROA). Since ROA can take on small negative values, following Claessens and Laeven (2004), the dependent variable is calculated as ln(1 + ROA) where ROA is the unadjusted return on assets. The data set allows for the estimation of the equilibrium test as shown in the following equation:

$$\begin{aligned} \ln(1+ROA)_{i,t} &= \beta_0 + \beta_1 \ln(PO_{i,t}) + \beta_2 \ln(PL_{i,t}) + \beta_3 \ln(PCE_{i,t}) + \\ &\gamma_1 \ln(EQTA_{i,t}) + \gamma_2 \ln(CAPVESSEL_{i,t}) + \gamma_3 \ln(DUMMY\_AL_{i,t}) + \gamma_4 \ln(DUMMY\_MA_{i,t}) + u_{i,t} \end{aligned} \tag{8}$$

The long-run equilibrium test measures the sum of the elasticity of return on assets with respect to input prices ($E = \beta_1 + \beta_2 + \beta_3$). If the E-statistic equals zero, it implies that the CLSI is in long-run equilibrium[14]. If rejected, the market is assumed not to be in equilibrium. Table 1 gives an overview of the tests (equilibrium test and competitive environment test) and the relation with the market structure.

4 DATA DESCRIPTION

Data has been obtained from Liner Intelligence financial analysis (www.ci-online.co.uk) and from investor/annual reports published on the publicly available internet websites of the selected liner carriers[15]. In the notes to financial statement as well as fact books, Powerpoint presentations, etc. more information at the level of the container shipping division was

[14] It should be noted that equilibrium does not mean that competitive conditions are not allowed to change during the sample period. It only implies that changes are to be taken as gradual (Shaffer, 1982; Claessens and Laeven, 2004).

[15] Data incurred in currencies other than US dollars were translated into US dollar using the currency convertor www.oanda.com/currency/convertor at the currency exchange rate prevailing at the balance sheet data (End of March or December).

available. Subsequently, extra data (e.g. number of staff, staff costs, etc.) also has been obtained from these complementary files. The resulting panel of container-related financial results (in millions of USD) is unbalanced as (for a variety of reasons) not all liner operators submit information for all the variables throughout the entire period.

First, adjustments to the resulting panel were made excluding all observations where liner operators reported missing values for operating income and net profit (e.g. Hamburg Süd, Pacific International Line, United Arab Shipping Company). Next, some liner operators were deleted as segmented figures for container division were not available (e.g. Evergreen, Hyundai Merchant Marine). Ultimately, because the test for the nature of competitive conditions is based on the properties of a reduced form log-linear revenue equation and logarithms of negative values do not exist, observations with negative values were dropped.

Despite the above modifications, the small sample should be regarded as fairly representative and comprehensive. As far as the authors are concerned, this is the most 'exhaustive' data sample ever employed in the implementation of the P-R methodology for the CLSI.

In sum, the empirical specifications at container division level are based on an unbalanced panel data for a sample of 18 major liner operators covering the period 1999-2008.

Ranked 2010	Liner operator	Webpage	TEU 01/01/2010	MS100	Total revenu at container level (2008-USD million)	Alliances	M&A
5	APL/NOL	www.nol.com.sg	549508	4,41%	7945	NWA	
29	CCNI	www.ccni.cl	36712	0,30%	972		
8	China Shg C.L. (CSCL)	www.cscl.com.cn	453009	3,64%	5070		☑
3	CMA CGM	www.cma-cgm.com	1031327	8,29%	13393		☑
7	COSCO Container L.	www.coscon.com	453204	3,64%	6391	CHKY	
13	CSAV	www.csav.com	328721	2,64%	4887		
9	Hanjin Shipping	www.hanjin.com	440299	3,54%	6559	CHKY	☑
6	Hapag Lloyd	www.hapag-lloyd.com	462288	3,72%	8767	GA	☑
11	K-Line	www.kline.com	342043	2,75%	11421	CHKY	
1	Maersk Line	www.maerskline.com	2044981	16,44%	28666		☑
36	Matson	www.matson.com	29074	0,23%	1024		
21	MISC Berhad	www.misc.com.my	125101	1,01%	3727	GA	
12	Mitsui-OSK L. (MOL)	www.mol.co.jp	341820	2,75%	6529	NWA	☑
10	NYK	www.nykline.com	375925	3,37%	6061	GA	
14	OOCL	www.oocl.com	324209	2,61%	6502	GA	
25	RCL	www.rclgroup.com	53435	0,43%	584		
15	Yang Ming Line	www.yml.com.tw	312962	2,52%	3573	CHKY	
17	ZIM	www.zim.co.il	305523	2,46%	4325		
CHKY	CHKY Alliance						
GA	Grand Alliance						
NWA	New World Alliance						
MS100	market share based on TOP100						
Liner operators in bold are Europe-based carriers							

Table 3 – Sample of selected liner operators

Table 3 lists the selected ocean carriers. As the study uses firm-level data aggregated from raw balance sheet data, it is noteworthy that the second largest liner operator, Mediterranean Shipping Company (MSC) is not integrated in the sample. It is common knowledge that MSC does not report its financial results. As Panzar and Rosse models behaviour, having no data of MSC will not alter the conclusions. Assuming that the outcome is that liner operators are 'in competition', it is likely that MSC will also act competitively.

5 EMPIRICAL RESULTS

In this section, the econometric results are reported and discussed. The reduced-form revenue function expressed in equation 7 is linear in its unknown parameters and, therefore, amenable to estimation by least squares regression methods (OLS).

Table 4 summarises the results of the E-statistic (RE1: ROA) and the estimated values of H-statistic of three regressions (RE2/3/4: TURN) (including t-values and p-values). The reported standard errors are based on White's heteroskedasticity robust covariance matrix. The test results for the hypothesis H = 0 and 1 are also reported.

	RE1: ROA			RE2: TURN			RE3: TURN			RE4: TURN		
	coefficient	t-value	p-value	coefficient	t-value	p-value	coefficient	t-value	p-value	coefficient	t-value	p-value
Intercept	0,1646	0,4675	0,6416	0,9481	0,4053	0,6865	0,7771	0,2910	0,7719	1,0083	0,4370	0,6635
lnPO	-0,0206	-1,3051	0,1963	0,4757	3,7910	0,0003	0,3783	2,9430	0,0045	0,4034	3,7053	0,0004
lnPL	0,0033	0,3087	0,7585	0,2046	3,9849	0,0002	0,1559	2,4864	0,0154	0,1611	2,7854	0,0069
lnPCE	0,0002	0,0294	0,9766	0,1899	3,1127	0,0027	0,1486	2,5172	0,0142	0,1639	2,4366	0,0173
lnEQTA	0,0288	1,9615	0,0539	0,2130	5,6220	0,0000	0,1638	3,9435	0,0002	0,1826	5,5712	0,0000
lnCAPVESSEL	-0,0287	-0,7946	0,4296	1,5616	7,3504	0,0000	1,4140	6,0141	0,0000	1,4204	6,5167	0,0000
DUMMY_AL	0,0499	2,3516	0,0216	-0,5211	-3,4714	0,0009	-0,1475	-0,8861	0,3787	-0,1843	-1,1261	0,2639
DUMMY_MA	0,0170	0,5020	0,6173	0,4920	3,5161	0,0008	0,4642	3,7745	0,0003			
DUMMY_MA(-1)							0,7904	4,0800	0,0001			
DUMMY_MA(-2)							0,7056	4,7507	0,0000			
DUMMY_MAb										0,7671	3,9950	0,0002
E-value	-0,01709											
H-value				0,870286			0,682809			0,728384		
Wald test (F-statistic) for testing E = 0	0,686783		0,4102									
Wald test (F-statistic) for testing H = 0				45,19442		0,0000	16,27835		0,0001	30,52431		0,0000
Wald test (F-statistic) for testing H = 1				1,004009		0,3197	3,512809		0,0653	4,244583		0,0430
R^2				0,741267			0,809388			0,782356		
Adj. R^2				0,715758			0,783784			0,760898		
N° of observations	76			79			77			79		

Table 4 – Panel estimation results of the P-R model

We experimented with different coding of the variable dummyMA. In the regressions 2 and 3, the dummy variable, dummyMA was equal to one in year of the merger and zero in other years. In regression 4, the dummy variable, dummyMAb was coded one for liner operators involved in a merger and acquisition in the year of the merger and all consecutive years, zero otherwise (i.e. before mergers and for liner operators not involved in mergers).

5.1 Interpretation of the H-statistic

Given the very recent publication of the working paper of Bikker, Shaffer and Spierdijk (2009), we will discuss the H-statistic both in the traditional way and according to the method of Bikker et al (2009).

Firstly, we interpret the H-statistic in accordance with the recent going approach (i.e. the traditional approach). Prior to estimating the H-statistic, an equilibrium test was conducted to satisfy the long-run equilibrium assumption of the P-R model. The left hand panel of Table 4 reports the empirical results. The test for long-run equilibrium yields an E-statistic that is close enough to zero. Based on a Wald test applied to the model based on ROA (Eq. 8), the null hypothesis of long-run equilibrium cannot be rejected at a 5% significance level. Consequently, the H-statistic can be interpreted for all the market models. The equilibrium test was also conducted for the regressions 3 and 4. In each scenario the null hypothesis of long-run equilibrium cannot be rejected at a 5% significance level.

As noted above, according to the traditional way, the P-R model shows that the H-statistic can be used to identify the market structure in which a carrier operates. An unscaled H-statistic of 0.87 would suggest that the CLSI could be described as displaying monopolistic competitive behaviour. Or, an increase in costs causes turnover to increase at a lower rate ($0 < H < 1$) (see Table 1).

The usual statistical framework is applied to test the value of H. Following Bikker et al. (2006), a t-test for the one-sided hypotheses and a Wald-test for the two-sided ones are used. The one-sided test for monopoly (H_0: $H \leq 0$ versus H_1: $H > 0$) rejects the null hypothesis. To test whether or not the calculated H-statistic is statistically different from zero and unity, the Wald test (F-statistics) was conducted. The null hypothesis of the two-sided test for the value of H (H_0: $H = 0$ versus H_1: $H \neq 0$) can be rejected at 1% significance level. The F-statistic of 1.004 for $H = 1$ cannot be rejected at the 5% significance level.

So, the H-statistic suggests that the CLSI operates in a monopolistic competitive environment, but perfect competition, sales maximising firm subject to breakeven constraint or natural monopoly in a contestable market cannot be rejected. Adding lagged variables to capture the post-merger effect, the market structures (perfect competition, sales maximising firm subject to breakeven constraint or natural monopoly in a contestable market) can be rejected at a 10% significance level. The regression with dummyMAb rejects these market structures at 5% significance level.

Over the regressions, the H-statistic varies from 0.68 to 0.87.

Secondly, following Bikker et al. (2009), the interpretation of the H-statistic deviates from prior studies. The estimate of the H-statistic based on an unscaled revenue equation is significantly positive in all regressions (RE2/3/4). According to Table 2, a significantly positive unscaled value of H is inconsistent with any form of monopoly or collusive oligopoly but under certain conditions, it is consistent with monopolistic competition. Based on the unscaled PR model, we reject the null hypothesis ($H < 0$) based on a one-sided t-test. Then, according to the study of Bikker et al. (2009), no further tests are required to rule out the possibility of neoclassical monopolist, collusive oligopolist or short-run conjectural variation oligopolist.

5.2 Interpretation of the other variables

Firstly, regressions 2 up to 4 (see Table 4) show that the dependent variable TURN positively relates to the input factors. All three factor input prices show a statistically significant influence on the dependent variable. The resulting P-R statistic is mainly driven by the price of operations.

The estimated coefficients for the explanatory variables have the expected signs apart from lnEQTA and dummyAL. Estimation results show a positive value for lnEQTA or equity to total assets which accounts for the leverage reflecting differences in risk preferences[16]. Presumably an explanatory hypothesis may state that capital buffers encourage risk-taking (i.e. to order larger ship sizes).

The aim of testing the dummy variable, dummyAL was to verify whether or not they are in a positive relationship to the dependent variable, turnover. The dummy variable, dummyAL, assigns value 1 to liner operator's member of an alliance and 0 otherwise. This variable displays a statistically significant negative relationship to turnover. At this stage of the research, this finding might suggest that buying slots from alliance partners is less efficient.

Next, the variable dummyMA contributes positively to turnover. But for some liner carriers the effect of mergers and acquisition on turnover might manifest itself in later years. In order to test the impact of mergers and acquisition on turnover, we extended the baseline regression (RE2 - Eq. 7) including a range of lag terms, viz. dummyMA(0 to -3). The lagged variable, dummyMA(-3) turned out to be insignificant. The results up to a two-period lag are reported in Table 4 (RE3).

Looking now at the explanatory variables one point of interest is that the dummyAL is no longer statistically significant. The outcome remains when running the regression with the dummy variable, dummyMAb.

In all regressions, the R-squared is high (>70%) which means that we are able to explain a large fraction of the variation in turnover.

5.3 Other regressions

We also ran several regressions to test alternative variables (e.g. non-operating expenses to transported teu, dummy variable indicating liner operators quoted on the stock exchange, etc.) and to test whether any explanatory variables have been left out. Neither of these tests had any significant effect. Next, macro data (e.g. GDP, world container traffic to GDP,…) was included in the P-R model (Bikker et al., 2008). The outcomes were not statistically significant.

In addition, we worked with a time-dependent coefficient since liberalisation, deregulation, etc. may cause changes in the competitive structure of a market over time. For that reason, Bikker and Haaf (2002) add a time-dependent coefficient, assuming that the long-run equilibrium market structure changes gradually over time. The reduced form revenue equation is then written as

$$\begin{aligned}\ln TURN_{i,t} &= \beta_0 + \left[\beta_1 \ln(PO_{i,t}) + \beta_2 \ln(PL_{i,t}) + \beta_3 \ln(PCE_{i,t})\right] e^{\delta\,\mathrm{TIME}} + \\ &\gamma_1 \ln(EQTA_{i,t}) + \gamma_2 \ln(CAPVESSEL_{i,t}) + \gamma_3 \ln(DUMMY\_AL_{i,t}) + \gamma_4 \ln(DUMMY\_MA_{i,t}) + \varepsilon_{i,t}\end{aligned} \tag{9}$$

A situation where the competitive structure is constant over time is equal to $\delta = 0$. The time-dependent variable equals H(TIME) = $(\beta_1 + \beta_2 + \beta_3)\exp(\delta\ \mathrm{TIME})$. For the CLSI, the test yields a not significant δ, indicating no significant changes in competitive conditions.

[16] Molyneux et al. (1994) expect a negative coefficient for EQTA, because less equity implies more leverage and hence more revenue.

Ultimatelty, to identify whether individual liner operators' features have a significant effect on the competitive structure, a series of specification tests were run between pooled OLS, fixed effects and random effects. It comes as no surprise that the fit of the P-R model with fixed effects (measured by $\bar{R}^2$) is higher. Based on the Hausman test, the random effects model was rejected in favour of fixed effects. However, fixed effects estimation of a static revenue equation results in an upward bias of the unscaled H-statistic (see also Goddard and Wilson, 2007). Goddard and Wilson suggest a dynamic panel estimation method. In this stage of the research, the small number of observations does not allow the estimation of a dynamic revenue equation.

6 CONCLUDING REMARKS

This paper is the first to investigate in detail the competitive conditions of the containerised liner shipping industry for the period 1999 to 2008, viz. the period before the abolishment of the conferences in liner shipping industry.

To assess the degree of competition at the level of the container liner shipping industry, a modern empirical analysis based on the non-structural method developed by Panzar and Rosse (1987) was conducted. This method is also known as the H-statistic or revenue test. It examines whether the conduct of a liner operator is in accordance with the models of perfect competition, imperfect or monopolistic competition, or monopoly. A new study of Bikker, Shaffer & Spierdijk (2009) adds that only an unscaled revenue equation yields a valid measure for competitive conduct. The methodology has been applied to several sectors ranging from banking systems to airline industries. To test the impact on firm-level revenues of variations in the prices of factors of production, a sample of 18 liner operators was observed.

The main findings of the study is that the significantly positive unscaled value of the H-statistic for the containerised liner shipping industry means that the hypothesis can be rejected that the CLSI market structures correspond to a neoclassical monopolist, collusive oligopolist or conjectural-variations short-run oligopolist. An equilibrium test was also conducted to satisfy the long-run equilibrium assumption of the P-R model.

An interesting avenue for future research might be to focus on applying the Panzar-Rosse model between port pairs, at trade level, at terminal level, on enlarging the period to investigate the impact of the abolishment, on observing how the P-R indicator varies over longer periods of observation, on the increasing competition with NVOCC's and global forwarders and to investigate the competition still alive and well among members in most vessel/slot sharing agreements. In this stage of the research, due to a shortage of data, these aspects could not be examined.

ACKNOWLEGMENT

Very helpful comments on an earlier draft version of this paper were provided by Prof. dr. J. A. Bikker, Prof. dr. G. Everaert and Prof. dr. R. Vander Vennet. The authors remain solely responsible for the article's content.

REFERENCES

Al-Muharrami, S., K. Matthews and Y. Khabari (2006). Market structure and competitive conditions in the Arab GCC banking system. Journal of Banking and Finance, 30, 3487-3501.

Ashenfelter, O. and D. Sullivan (1987). Nonparametric Tests of Market Structure: An Application to the Cigarette Industry. Journal of Industrial Economics, 35, 483-498.

Benacchio, M., C. Ferrari and E. Musso (2007). The liner shipping industry and EU competition rules. Transport Policy, 14(1), 1-10.

Bikker, J. A. (2004). Competition and Efficiency in a Unified European Banking Market. Edward Elgar Publishing Limited, Cheltenham.

Bikker, J. A. and J.M. Groeneveld (2000). Competition and concentration in the EU banking industry. Kredit und Kapital, 33, 62-98.

Bikker, J. A. and K. Haaf (2002). Competition, concentration and their relationship: An empirical analysis of the banking industry. Journal of Banking and Finance, 26, 2191-2214.

Bikker, J. A. and M. van Leuvensteijn (2008). Competition and efficiency in the Dutch life insurance industry, Applied Economics, 40(16), 2063 - 2084.

Bikker, J.A., L. Spierdijk and P. Finnie (2006). Misspecification of the Panzar-Rosse Model: Assessing Competition in the Banking Industry. DNB WP No. 114, De Nederlandsche Bank, Amsterdam.

Bikker, J.A., L. Spierdijk and P. Finnie (2008). How Banking Competition Changed over Time. DNB WP No. 167, De Nederlandsche Bank, Amsterdam.

Bikker, J.A., S. Shaffer and L. Spierdijk (2009). Assesing Competition with the Panzar-Rosse Model: The Role of Scale, Costs, and Equilibrium. DNB WP No. 225, De Nederlandsche Bank, Amsterdam.

Bresnahan, T.F. (1982). The oligopoly solution identified. Economic Letters, 10, 87-92.

Bresnahan, T.F. (1989). Empirical studies of industries with market power. In: Handbook of Industrial Organisation (R. Schmalensee and R.D. Willig, eds.), Vol 2, pp 1012-1055. Elsevier, Amsterdam.

Brooks, M.R. (2000). Sea Change in Liner Shipping: Regulation and Managerial Decision-Making in a Global Industry. Pergamom, Oxford.

Chan, D., C. Schumacher and D. Tripe (2007). Bank competition in New Zealand and Australia. 12th Finsia-Melbourne Centre for Financial Studies Banking and Finance Conference, Melbourne, 24-25 September 2007, pp.1-22.

Claessens, S. and L. Laeven (2004). What drives bank competition? Some international evidence. Journal of Money, Credit, and Banking, 36(3), 563-583.

Competition Commission of Singapore (2006). Explanatory Note on the Competition (Block Exemption for Liner Shipping Agreements) Order 2006. Online available on http://www.ccs.gov.sg > Legislation > Block Exemption Order – consulted 7/12/2009.

Cullinane, K. & M. Khanna (2000). Economies of scale in large containerships: optimal size and geographical implications. Journal of Transport Geography, 8(3), 181-195.

De Bandt, O. and E.P. Davis (2000). Competition, contestability and market structure in European banking sectors on the eve of EMU. Journal of Banking and Finance, 24, 1045-1066.

Endo, N. (2005). Analysis of competitive nature of liner shipping industry. Journal of Transport Policy Studies' Review, 8(30), pp. n.a (In Japanese).

European Liners Affairs Association – ELAA (2003). The European Commission Consultation Paper on the Review of Council Regulation (EEC) 4056/86 of 22nd December 1986. Response by the European Liner Affairs Association, June.

European Commission (1997). Commission Notice on the definition of relevant market for the purposes of Community competition law. Official Journal C 372, 0005-0013. Online available on http://ec.europa.eu/competition/mergers/legislation/notices_on_substance.html - consulted 7/12/2009

European Commission (2007). Guidelines on the application of Article 81 of the EC Treaty to maritime transport services - draft, Official Journal C 215/03, 0003-0015. Online available on http://ec.europa.eu/maritimeaffairs/subpage_mpa_04_en.html - consulted 7/12/2009

Fischer, T. and D.R. Kamerschen (2003). Measuring competition in the U.S. Airline industry using the Rosse-Panzar test and cross sectional regression analyses. Journal of Applied Economics, VI(1), 73-93.

Gisher, H. and M. Stiele (2008). Competition Tests with a Non-structural Model: the Panzar-Rosse Method Applied to Germany's Savings Banks. German Economic Review, 10(1), 50-70.

Goddard, J. and J. Wilson (2007). Measuring Competition in Banking: A Disequilibrium Approach. Financial Management Association, Barcelona, 30 May 2007, pp. 1-38.

Gutiérrez de Rozas, L. (2007). Testing for competition in the Spanish banking industry: the Panzar-Rosse approach revisited. Documentos de Trabajo n° 0726, Bancode Espana, Spain.

Heaver, T.D. (2001). The Shipping Conferences Exemption Act: Review and Suggestions of Positions Appropriate for the Panel. Canada Transportation Act Review Commission, 30 April 2001.

Hoffman, J. (1998). Concentration in Liner Shipping—Its Causes and Impacts for Ports and Shipping Services in Developing Regions. ECLAC, Santiago.

Iwata, G. (1974). Measurement of conjectural variations in oligopoly. Econometrica, 42, 947-966.

Lau, L. (1982). On identifying the degree of competitiveness form industry price and output data. Economics Letters, 10, 93-99.

Lipczynski, J., J. Wilson and J. Goddard (2005). Industrial Organisation, an analysis of competitive markets. Prentice Hall, Essex.

Martin, S. (2002). Industrial Economics, Economic Analysis and Public Policy. Blackwell Publishing Company, Oxford.

Matthews, K.,V. Murinde and T. Zhao (2007). Competitive conditions among the major British banks, Journal of Banking and Finance, 31, 2025–2042.

Molenaar, H.J. and E. Van de Voorde (eds.) (1994). Competition policy in liner shipping. UFSIA: Antwerp.

Molyneux, P., D.M Lloyd-Williams and J. Thornton (1994). Competitive conditions in European banking, Journal of Banking and Finance, 18, 445-459.

OECD (2002). Competition Policy in Liner Shipping. Paris.

Panzar, J. C. and J.N. Rosse (1987). Testing for monopoly equilibrium, Journal of Industrial Economics, 35(4), 443-456.

Rosse, J. N. And J.C. Panzar (1977). Chamberlin vs Robinson: An empirical study for monopoly rents. Bell Laboratories Economic Discussion Paper.

Shaffer, S. (1982). A non-structural test for competition in financial markets. In: Banking Structure and Competition, Conference Proceedings, Federal Reserve Bank of Chicago, 225-243.

Shaffer, S. (1983). Non-structural measures of competition: Toward a synthesis of alternatives. Economic Letters, 12, 349-353.

Shaffer, S. (1993). A test of competition in the Canadian Banking. Journal of Money, Credit, and Banking, 25, 49-61.

Shaffer, S. (2004). Comment on “What drives banking competition? Some international evidence, by Stijn Claessens and Luc Laeven. Journal of Money, Credit, and Banking, 36(3), 585-592.

Sjostrom, W. (2002). Liner shipping: modelling, competition and collusion. In: Grammenos, C. (Ed.), The Handbook of Maritime Economics and Business, LLP, London, pp. 307-345.

Sullivan, D. (1985). Testing Hypotheses about Firm Behavior in the Cigarette industry. Journal of Political Economy, 93, 586-598.

Sys, C. (2009). Is the container liner shipping industry an oligopoly?. Transport Policy, 16(5), pp.259-270.

Sys, C., G. Blauwens, E. Omey, E. Van De Voorde and F. Witlox (2008). In Search of the Link between Ship Size and Operations. Transportation Planning and Technology, 31(4), 435-463.

Tsutsui, Y and A. Kamensakab (2005). Degree of competition in the Japanese securities industry. Journal of Economics and Business, 57, 360-374.

Vesala, J. (1995). Testing for competition in banking: behavioural evidence from Finland, Bank of Finland Studies E:1, Finland.

White, H. (1980). Heteroskedasticity consistent covariance matrix estimator and a direct test for heteroskedasticity. Econometrica, 48, 817-838.

Wong, H. (1996). Market structure and the role of consumer information in the physician services industry: an empirical test. Journal of Health Economics, 15, 139-160.