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Document Version
Accepted author manuscript

Published in:
Case Studies on Transport Policy

DOI:
10.1016/j.cstp.2019.03.012

Publication date:
2020

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Citation for published version (APA):

Link to publication in CBS Research Portal
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Journal article (Accepted manuscript*)

Please cite this article as:

DOI: 10.1016/j.cstp.2019.03.012

* This version of the article has been accepted for publication and undergone full peer review but has not been through the copyediting, typesetting, pagination and proofreading process, which may lead to differences between this version and the publisher’s final version AKA Version of Record.

Uploaded to CBS Research Portal: June 2020

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A Cliometric Approach to Market Structure and Market Conduct in the Car Carrier Industry

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Abstract

Today, products from the automotive industry represent an important share of international trade. Each year, millions of brand new and second-hand motor vehicles are being shipped in completely built-up condition by a variety of specialized deep-sea vessels called car carriers, with roro ramp access providing cargo space for more than 2,000 car equivalent units (CEU).

Following a cliometric approach, the paper examines this market of seaborne motor vehicle transportation over the last three decades from 1985 to 2016 backed by extensive historical data about seaborne motor vehicle trades and shipping operators active in this rather small, but very demanding segment of the maritime transport domain. More specifically, market structure and theoretical market conduct of these shipping operators active in a rather oligopolistic transport market environment firstly explored by common market structure metrics and further analysed by structural, parametric statistical methods in sense of the New-Empirical-Industrial-Organization (NEIO) Theory. Accordingly, the theoretical market conduct is estimated by a simultaneous equation model, which includes a demand function for seaborne vehicle trades, and a market conduct function of the shipping operators including an implicit cost or productivity function of the car carrier fleet employed.

For the given time frame, some interesting findings are as follows: (1) volatile demand for shipping of motor vehicles overseas can be explained well through shifts in trade flows to a high extent; (2) overall transport capacity, average size, operating speed and age of vessels in service are the main measures of the shipping operators available to adjust to this volatile demand on a short to medium run; (3) despite significant merger and acquisition activity, market exits and entries, this transport market got slightly less concentrated as today more shipping operators are active there than in the past; (4) estimated market conduct of the shipping operators seems to show a price setting slightly over their marginal costs with a strong trend towards a fully competitive market after 1996. Finally, the approach developed in this paper can be useful to get more insights about market structure and theoretical market conduct in similar rather concentrated transport markets.

Key words: Seaborne vehicle trade, car carrier industry, market structure, market conduct
A Cliometric Approach to Market Structure and Market Conduct in the Car Carrier Industry

1. Introduction

The automotive industry can be regarded as a driving force of modern industrialised economies giving jobs to four to seven percent of labour work force, and contributing four to twelve percent of value added created (Williams et al., 1994). The products are one of the most expensive, break-bulk, non-containerised commodities carried around the world and according to Williams et al. (1994:90), motor vehicles are “unique amongst all the consumer and producer goods entering into international trade because they are the only high priced item which is traded internationally in millions of units.” Embedded in the global supply chain of the automotive industry, the transport market for shipping completely built-up units (CBU) overseas is quite easy to define: today, almost all these motor vehicles traded overseas are shipped by highly specialized deep-sea vessels providing cargo space in excess of 2,000 car equivalent units (CEU). Commonly, a CEU is defined as about 7.4 sqm of deck space needed to store a 1966 Toyota Corona RT43 (Sorgenfrei, 2013).

In contrast to e.g. container liner shipping, this seaborne car carrier industry got only limited attention in academia so far (Ekberg, 2011). Indeed, it was rarely a topic in scholarly literature, with (1) Böhme (1989), Lionel-Marie (1999), Guillaume (2003) or Ekberg (2011, 2012) highlighting historic market developments; (2) Jones and North (1990), Hall (2004), Hall and Oliver (2005) or Quaresma Diaz et al. (2010) discussing organisational and geo-spatial issues of seaborne motor vehicle trades; (3) Neuwenhuis et al. (2007, 2012) addressing environmental impacts; (4) Kahveci and Nichols (2006) discussing working conditions on car carrier vessels; (5) Øvstebø et al. (2011a, 2011b), Kang et al. (2012) or Chandra et al. (2013) dealing with vessel loading and/or scheduling problems; and (6) Fischer and Gehring (2005), Mattfeld (2006), Mattfeld and Orth (2007) or Cordeau et al. (2011) concerning transshipment terminal operations. Apart from this, a constant stream of reports published by ship brokerage and consultancy firms like Clarkson Research Services, Drewry Shipping Consultants, R.S. Platou or Shippax commenting actual market development in the car carrier industry is notable.

Following a cliometric approach (Lyons et al., 2008; Greasley and Oxley, 2011; Diebolt and Haupert, 2016), the aim of this paper is to examine this market of seaborne motor vehicle transportation over the last three decades from 1985 to 2016 backed by extensive historical data about seaborne motor vehicle trades and shipping operators, active in this rather small but very demanding segment of the maritime transport domain. More specifically, market structure and theoretical market conduct of these shipping operators active in a rather oligopolistic transport market environment are explored by common market structure metrics like Concentration Ratios, the Herfindahl-Hirschman-Index and the Degree-of-Market-Share-Instability. This is followed by analysing the theoretical market conduct employing a structural, parametric statistical method in sense of the New-Empirical-Industrial-Organization (NEIO) theory.

Accordingly, the remainder of this paper is organized as follows: Firstly, the history of the car carrier industry including a market overview is briefly outlined along the extant literature, before the data sampling procedure to establish a consistent dataset for the car carrier industry for 1985 to 2016 is declared. Then the market structure of the car carrier industry is explored, before a simultaneous equation model to estimate theoretical market conduct is derived, which includes a demand function for
seaborne motor vehicle trades, and a market conduct function of the shipping operators including an implicit cost or productivity function of the car carrier fleet employed.

2. History and market overview

The beginnings of seaborne motor vehicle transportation probably dates back to the 1930s, when Arnold Bernstein GmbH of Hamburg rebuilt several ships for carrying passenger cars from the USA to Europe in 1932 (Drewry, 1984; Böhme, 1989). A next landmark was the early 1950s, when an increasing number of CBUs - especially from German manufacturers like Volkswagen - were exported from Europe to the USA (Böhme, 1989; Ekberg, 2011). In the mid-1960s, when Japanese car exports rapidly increased, the technology of loading CBUs on deep-sea vessels was revolutionized. Pure Car Carriers (PCC) were introduced in order to ease cargo handling by RoRo-technology over access ramps instead of conventional LoLo-technology by cranes (Fairplay, 1980; Packard, 1984; Drewry, 1984, 1994). Up to the mid-1980s, both techniques of loading/discharging CBUs were used in parallel, mostly because of the extremely unbalanced motor vehicle trades at that time. In addition to this, several hybrid types like Car-Bulkers, Car-Reefers and Container-RoRo (ConRo) vessels were introduced allowing almost full utilization on both legs of a voyage (Drewry, 1984; Packard, 1985; Böhme, 1989). However, a more flexible type of car carriers was developed in the late 1970s called Pure Car/Truck Carrier (PCTC) because more and more large motor vehicles or other sort of high-and-heavy equipment had to be shipped overseas (Fairplay, 1980; Drewry, 1984, 1994; Nieuwenhuis et al., 2007). This in turn led to a dominance of PCCs and PCTCs on high volume trades in the following years, while only a few hybrid types with RoRo-technology were still employed on selected markets (Ekberg, 2011). In sum, this development since the 1960s can be regarded as a truly second maritime handling revolution after containerization (Ekberg, 2011) and it parallels container liner shipping in many ways.

In addition, this came along with a steady growth of vessel capacity (see Fig. 1). The first PCCs were the Dyvi Anglia (a 725 dwt vessel which could transport 420 Volkswagen cars) built in 1964, the Dyvi Atlantic of 1965 (with 2,621 dwt and 1,400 CEU) followed by the Dyvi Oceanic (with 5,970 dwt and 2,500 CEU) already in 1968 (Drewry, 1977; Ekberg, 2011). The Tosca (with 15,311 dwt and 5,400 CEU) from Wallenius and the Nopal Mascot (with 17,406 dwt and 5,460 CEU) from Norwegian Specialised Auto Carriers (NOSAC) were then the first PCTCs introduced in 1978 (Lionel-Marie, 1999). In the following years, new buildings did not just become bigger and bigger: supply shortages in the mid-2000s led to a couple of conversions of former general-purpose RoRo (GenRo) vessels installing car space on weather decks or lengthening of PCTCs adding extra 1,400 to 2,000 CEU capacity to vessels already employed (Dupin, 2008). Today, the largest PCTC new buildings are Post-Panamax ships with a capacity of more than 8,000 CEUs. This development contributed to a considerable growth of vessels in service on deep-sea trades in the car carrier industry from 276 vessels with a total capacity of 1,037,533 CEU (or 3,759 CEU on average) in 1985 to 675 vessels with 3,862,755 CEU (or 5,073 CEU on average) in Mid 2017 (see Fig. 1). These figures also include some non-PCC/PCTC vessels with more than 2,000 CEU capacity representing 3.5% (1986) to 8.5% (2004) of total capacity in CEU - most of them are either ConRoses, converted GenRo vessels or PCTCs-like GenRoses (like the Mark V series built in 2011-12 with 43,878 dwt and 5,990 CEU being the largest GenRo vessels in the world at the moment, see Shippax, 2011).
Fig. 1: Total number of ships and total fleet capacity in CEU 1985-2017
(Source: own calculations; see Section 3 for more details)

Nowadays, PCTCs dominate the car carrier industry, as they are more versatile than normal PCC (Ekberg, 2011). Being equipped with hoistable decks and stronger quarter stern ramps, they are able to carry large volumes of neo-bulks, high-and-heavy equipment and even containers in addition to their main cargo of CBUs (Fairplay, 1985; Böhme, 1989; Drewry, 1999). In this respect, they are a constant competitor in the domain of the GenRo or ConRo vessels (Dynamar, 2010; Drewry, 2012), while at least some of these vessels are employed in seaborne motor vehicle trades, too.

Furthermore, many of these PCC/PCTCs employed in seaborne motor vehicle transportation are operating "round-the-world" in more or less regular liner trades, although there is a concentration on main East-West routes connecting the Triad regions in Far East, North America and Europe. Most of these shipments originate in Japan and South Korea, with a big portion of their motor vehicles produced there still distributed overseas (see Fig. 2). Another main route of seaborne motor vehicle trade is Europe to North America. In sum, this leads to heavily unbalanced trades within the Triad, as North America is the biggest importer of CBUs from Japan, South Korea and Europe with only a small amount of backhaul cargo available. Apart from this, other minor trade routes including other automobile manufacturing countries like Brazil, China, India, South Africa, Malaysia, Indonesia, Philippines and Thailand producing more and more CBUs for export considered to increase steady and brought a further dispersion of the trade routes since the mid-1990s as shown in Fig. 2 (Drewry, 1999; Mattfeld, 2006; Clarkson, 2007-2017). In addition to this, more and more used, second-hand motor vehicles are shipped overseas from Europe to Africa and the Middle East or from Japan and South Korea to other Asian countries, Middle East, Russian Federation and New Zealand (Nieuwenhuis et al., 2007). All these motor vehicle trades seem to compensate the slight decline of seaborne trades in CBUs within the Triad region, when Japanese and South Korean automobile manufacturers started assembling or manufacturing their products from scratch in transplants at North America or Europe in order to overcome trade barriers until the mid-1990s. After a parallel growth phase for about a decade, these other non-Triad related trade lanes increased considerably in the mid-2000s until the aftermath of economic crisis in 2008, with a rather flat further development until today.

On the vessel owner and shipping operators side, a tight market dominated by Japanese, Scandinavian and South Korean companies running PCC/PCTCs on deep-sea trade lanes is present (see Tab. 1):

- Japanese companies like the big three Nippon Yusen Kaisha (NYK), Kawasaki–Line (K-Line), and Mitsui O.S.K. Lines (MOL) as well as some smaller shipping operators summing up to about 50% market share.
- Scandinavian companies like Swedish-Norwegian Wallenius Wilhelmsen Logistics (WWL) and Norwegian Hoegh Autoliners (HAL, formerly Hoegh Ugland Autoliners (HUAL)) emerged from a group of highly entrepreneurial Nordic shipping companies (Ekberg, 2011, 2012) with a current market share of about 30%, if we include Seoul headquartered EUKOR Car Liners (WWL is an
80% majority shareholder) as well as US-flagged vessels under the US Maritime Security Program (MSP) scheme (Guillaume, 2003; Herberger et al., 2016) operated by them.

Other shipping operators with a significant fleet of PCC/PCTCs with more than 2,000 CEU capacity are South Korean Hyundai Glovis, followed by Italian Grimaldi Lines. Traditionally, there are close connections with automobile manufacturers as the main shippers (Böhme, 1989; Lionel-Marie, 1999; Guillaume, 2003; Hall and Oliver, 2005). Accordingly, rather long-term contracts in the form of time charter agreements and contracts of affreightment (COAs) are prevalent (Böhme, 1989; Pirrong, 1993; Hall and Oliver, 2005; EU, 2006). More specifically, Hall and Oliver (2005) discussed four sorts of contractual shipper-carrier relationships in seaborne motor vehicle transport:

- **Vertically integrated shipping operations**, where the shipper operates its own vessels. Examples for this are Toyota (Toyofuji), Hyundai (Hyundai Glovis and Hyundai Merchant Marine (HMM) before), Nissan (Nissan Motor Car Carrier (NMCC)) and formerly Volkswagen Group (VAGT).
- **Network-based consignment guarantee agreements**, where a shipping operator as carrier makes vessels available to a shipper on a regular and exclusive basis. These sort of rather long-term COAs are quite common for Japanese automobile manufacturers like Toyota, Nissan, Mitsubishi, Mazda and Honda on one hand and the big three Japanese shipping operators NYK, K-Line and MOL on the other.
- **Quasi-market liner services**, where a shipping operator offers regularly scheduled services to shippers and closes typical arms-length COAs. This approach is quite common among the main European shipping operators like WWL, HAL and Grimaldi because they are also quite engaged in transporting high-and-heavy equipment, as well as offer advanced automotive logistics services.
- **Finally, ad hoc spot-market transactions of chartering whole vessels happen, too, especially when a sudden increase of demand on shippers’ side or a transport capacity shortage on shipping operators’ side appears.** Then single vessels are chartered for a specific shipment or voyage from other shipping operators or directly from vessel owners on a short-term basis.

### 3. Data sampling

Following Clarksons (2017), the fleet of PCC/PCTCs principally consists of four segments:

- **Deep Sea 6,000+ CEU vessels**: Generally utilized on the main deep-sea, higher volume trades.
- **Deep Sea 4-5,999 CEU**: Also typically utilized on the main deep-sea trades, but not particularly attractive today, as 6,000+ CEU vessels come along with higher economies of scale in operations.
- **Intermediate 2-3,999 CEU**: Generally utilized on deep-sea trades, too, but often limited to shorter, lower volume trades.
- **Short Sea < 2,000 CEU**: In general, vessels in this size range are used in short sea trades.

Accordingly, for the purpose of this study, all PCC/PCTCs as well as some GenRo/ConRo vessels with more than 2,000 CEU capacity were included, unless they are not employed in short sea or domestic services on a permanent basis. Hence, vessels operating solemnly in Intra-European/PanEuroMed, China or US domestic seaborne trades were discarded. Then panel data with vessel-specific figures was generated including technical characteristics, ownership, charter and flag status for all vessels in service as of mid-year published by Drewry (1985, 1995, 1999, 2006, 2012), Clarkson (2007-2017) or Shippax (2013-2017). As these ship registers always tend to be incomplete regarding vessel ownership, ship management and/or its technical characteristics, crosschecking of data over several data sources (including websites of shipping operators) was necessary. Moreover, for each vessel, the shipping operator was determined and all shipping operators with a market share of less than 1% in each year were subsumed as an artificial shipping operator labelled ‘Rest of Market’ (RoM) with a maximum compound market share between 2.64% (1987) and 6.36% (2016). This approach can be justified by assuming that competition between these small shipping operators and the other big ones is more likely than rivalry among them, as each of them either serves minor niche
trades and/or is a charter owner running vessel not chartered by shipping operators at that moment. Tab.1 shows the top 10 shipping operators by fleet capacity in CEU for Mid 1985, 1995, 2005 and 2015, respectively.

Tab.1: Top 10 shipping operators in the car carrier industry by fleet capacity in CEU 1985-2015

<table>
<thead>
<tr>
<th></th>
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<tbody>
<tr>
<td>1</td>
<td>NYK-Line</td>
<td>21.8%</td>
<td>MOL</td>
<td>18.8%</td>
</tr>
<tr>
<td>2</td>
<td>MOL</td>
<td>20.7%</td>
<td>NYK-Line</td>
<td>17.5%</td>
</tr>
<tr>
<td>3</td>
<td>K-Line</td>
<td>19.3%</td>
<td>K-Line</td>
<td>15.5%</td>
</tr>
<tr>
<td>4</td>
<td>WWL</td>
<td>9.4%</td>
<td>WWL</td>
<td>10.3%</td>
</tr>
<tr>
<td>5</td>
<td>NMCC</td>
<td>8.0%</td>
<td>Hyundai</td>
<td>8.3%</td>
</tr>
<tr>
<td>6</td>
<td>HUAL</td>
<td>6.5%</td>
<td>HUAL</td>
<td>7.4%</td>
</tr>
<tr>
<td>7</td>
<td>NOSAC</td>
<td>3.5%</td>
<td>NOSAC</td>
<td>6.8%</td>
</tr>
<tr>
<td>8</td>
<td>VAGT</td>
<td>2.7%</td>
<td>NMCC</td>
<td>4.1%</td>
</tr>
<tr>
<td>9</td>
<td>JapanLine</td>
<td>1.8%</td>
<td>Grimaldi</td>
<td>2.9%</td>
</tr>
<tr>
<td>10</td>
<td>Hyundai</td>
<td>1.5%</td>
<td>VAGT</td>
<td>2.0%</td>
</tr>
<tr>
<td></td>
<td>others</td>
<td>4.8%</td>
<td>others</td>
<td>6.3%</td>
</tr>
</tbody>
</table>

4. Market structure

In the following, the market structure of the car carrier industry is explored by common market structure metrics as described thoroughly by Lam et al. (2007) or Sys (2009) when they applied them in the context of the container liner shipping industry.

First, the Concentration Ratio (CR_x) is the percentage of market share held by the x largest firms in an industry, or shortly \( CR_x = \sum_{i=1}^{x} s_i \) where \( s_i \) is the market share of the \( i^{th} \) firm. \( CR_x \) is usually used to show the extent of market control of the largest firms in an industry in order to illustrate the degree to which extent it is oligopolistic.

Another common market structure metric is the Herfindahl-Hirschman-Index defined as \( HHI = \sum_{i=1}^{K} s_i^2 \), where \( s_i \) is the market share of firm \( i \) in the market, and \( K \) is the number of firms. It is a measure of the size of firms in relation to the rest of the industry and an indicator of the amount of competition among them:

- An HHI score below 0.01 (or 100) indicates a highly competitive market.
- An HHI score below 0.15 (or 1,500) indicates an un-concentrated market.
- An HHI score between 0.15 to 0.25 (or 1,500 to 2,500) moderate market concentration.
- An HHI score above 0.25 (above 2,500) indicates high market concentration.

Furthermore, if all firms have an equal share, the reciprocal of the HHI shows the number of firms in the industry. When firms have unequal shares, it indicates the equivalent number of firms in the industry.

Moreover, Degree-of-Market-Share-Instability is a measure of the shift in the relative position of firms within an industry over time, which is an important indicator of competition intensity (Sys, 2009). A formal expression of this is the index by Hymer and Pashigan (1962). It is defined as the sum of the absolute value of the change between two points in time in the market share of each firm, or \( HPI = \sum_{i=1}^{K} |s_{i,t} - s_{i,t-1}| \), where \( s_{i,t} \) equals the market share of operator \( i \) at time \( t \). The value of HPI ranges
between zero and one. If it is close to zero, market shares can be regarded as relatively stable, and if it is close to one, market shares are relatively unstable.

In Fig. 3, all these common market structure metrics are depicted, based on CEU fleet capacity operated:

- \( CR_4 \) shows a steady downward trend of market share held by the top four ranked shipping operators since 1986 with 72.9% to 53.4% in 2017, whereas \( CR_8 \) suggests a more stable environment with the top 8 ranked shipping operators having a market share of 91.9% in 1985 and 89.3% in 2017.

- \( HHI \) peaks with a score of 1,515 in 1986 and goes down to 1,073 in 2017, which implies a move from a moderate to a more non-concentrated market. Accordingly, the reciprocal \( 1/HHI \) suggests that the car carrier industry should consist of 6.6 equivalent firms in 1986 - a number, which goes up to 9.3 in 2017 indicating a widening of the market by 2-3 more shipping operators of significant size over time. Tab.1 nicely reflects this widening of the market: as in 1985, 6 shipping operators showed a minimum of 6.5% market share, whereas in 2015, 8 had a minimum of 5.2% market share with others being much below this level.

- \( HPI \) indicates a rather calm and stable market environment with 2003 as an exceptional year. However, this is quite easy explainable: the year before, WWL acquired 80% of HMM and subsequently renamed it into EUKOR as an independently operating part of the WWL group of companies. Hence, from one year to another, one main shipping operator left the market (HMM) with a new one established of almost the same size (EUKOR), which leads directly to this spike of \( HPI \). Other, much smaller peaks stem from merger and acquisition activity like the formation of WWL as a joint shipping operator company of Swedish Wallenius and Norwegian Wilhelm Wilhelmsen in 1999 (Ekberg, 2011), market exits (e.g. Japan Lines in 1995, Norwegian NOSAC in 1999, German VAGT in 2004, and Mexican Grupo TMM in 2009) well as market entries (e.g. US-American Central Gulf in 1988, Japanese Cido in 1995, South Korean Glovis in 2010) in the group of car carrier operators with a market share of more than 1% of total CEU capacity as defined in Section 3.

In sum, these common market structure metrics show clearly, that the car carrier industry can be regarded as a rather stable but oligopolistic transport market environment with 6 to 8 shipping operators having more than 5% market share (see Tab.1), followed by a couple of smaller ones, which got slightly less concentrated and more competitive over the last three decades.

![Fig.3: Summary of market structure metrics for the car carrier industry 1985-2017](image-url)
5. Market conduct

Both market structure metrics (cf. Section 4) and commonality of long-lasting contractual relationships between shippers and shipping operators (cf. Hall and Oliver, 2005 or Section 2) in the car carrier industry suggest a wide oligopoly with some kind of Cournot competition. In such an oligopolistic environment, market conduct can be derived directly from company’s profit functions, taking the interplay of supply and demand explicitly into consideration. Accordingly, in the following a theoretical structural model is set up with a derived demand function for shipping of motor vehicles overseas and a market conduct function, including an implicit cost or productivity function of shipping operators being active in the car carrier industry. This approach is in line with the central ideas of NEIO summarized by Bresnahan (1989:1012) summarized as follows: (1) Firm’s price-cost margins are not taken to be observable and economic marginal costs (MC) cannot be observed directly or straightforwardly; (2) individual industries are taken to have important idiosyncrasies so that institutional detail at the firm industry level affect market conduct and even more likely affect the analysts’ measurement strategy; (3) market conduct is viewed as an unknown variable to be estimated by behavioural equations in which identifiable players set price and/or quantity. As a result, the nature of the interference of market power is made clear, since the set of alternative hypotheses considered is explicit. The alternative hypothesis of non-existence of market power and/or no strategic interaction (typically in form of a perfectly competitive outcome hypothesis with market prices close or equal to marginal costs) is clearly articulated as being one of the alternatives the data can choose.

5.1. Model specification

A demand function for transport service should contain some measure of price and quantity, which stand in a special functional relationship. In this case, a unit price for seaborne transport service \( p_t \) from terminal to terminal (i.e. excluding port handling and storage as well as other value-added services usually provided in this context) can be assumed and derived from a total amount \( Q_t \) of motor vehicles to be shipped, supplemented by an additional vector \( Y_t \) of parameters to explain shifts of the demand function for identification purposes. Further, it is assumed, that no inter-temporal effects occur (i.e. there is no forward buying possible as transport service contracts closed for period \( t \) are fulfilled in the same period \( t \)). Demand for transport service from the worldwide automotive industry can then be seen as an inverse demand function of the form

\[
p_t = D(Q_t, Y_t) \quad \text{for all } t = 1, \ldots, T
\]

with \( p_t \) as a price per unit for transport service, \( Q_t \) the amount of motor vehicles to be shipped and \( Y_t \) a vector of parameters characterizing the pattern of seaborne motor vehicle trades (including trade imbalances) in period \( t \). Assuming, that these shipping operators as described before represent a fixed number of rational, individually profit maximizing players in the market for seaborne motor vehicle shipments in each period \( t \) setting quantities simultaneously in form of transport capacity offered to shippers in a competitive environment for homogeneous transport services while expecting that their decision making has not an impact on the decision of the others (but each decision has an impact on \( p_t \)), resulting market conduct can be described as a \( K \)-player Cournot game with the quantity of transport service \( q_{kt} \) offered as a strategic variable for all players \( k = 1, \ldots, K \) in period \( t = 1, \ldots, T \). The profit function \( \pi_{kt} \) of the \( k \)-th player is then a strict concave and more than twice in \( q_{kt} \) continuously differentiable function as follows:

\[
\pi_{kt} = q_{kt}p_t - C_k(q_{kt}, Z_t, W_{kt}) \quad \text{for all } k = 1, \ldots, K \text{ and } t = 1, \ldots, T
\]

with \( C_k(.) \) a convex cost function for the \( k \)-th player in \( t \). It represents an individual cost and productivity structure for each player, with \( W_{kt} \) as a vector of factor inputs of the \( k \)-th player and \( Z_t \) for other non-firm-specific costs coming along with production of a transport service in \( t \). Assuming, that the demand for seaborne transport service by the automobile industry is likely the same as the demand for seaborne transport service offered by shipping operators in seaborne car carrier industry, we can
define \( Q_t = \sum_{k=1}^{K} q_{kt} \) for all \( t = 1, \ldots, T \) (or in other words: it is assumed that in each period \( t \), transport service provided by all \( K \) shipping operators is enough to meet the amount of motor vehicles to be shipped). Inserting (1) in (2) gives

\[
\pi_{kt} = D(Q_t, Y_t) - C_k(q_{kt}, Z_t, W_{kt}) \quad \text{for all } k = 1, \ldots, K \text{ and } t = 1, \ldots, T
\]  

(3)

The assumption of Cournot-style competition in capacities includes a simultaneous profit maximising behaviour for each of the \( K \) shipping operators providing their own \( q_{kt} \), given \( q_{it} \) of the others in the market. Partial derivatives of (3) with \( q_{kt} \) give

\[
\frac{\partial \pi_{kt}}{\partial q_{kt}} = D(.) - \frac{\partial C_k(.)}{\partial q_{kt}} + \frac{\partial D(.)}{\partial q_{kt}} q_{kt} \quad \text{for all } k = 1, \ldots, K \text{ and } t = 1, \ldots, T
\]  

(4)

as the first order condition of the profit function for the \( k \)-th player, with \( \frac{\partial C_k(.)}{\partial q_{kt}} \) as MC of the \( k \)-th operator. The first two terms on the right side are the marginal profit of each quantity shipped, which equals the difference of \( p_t = D(.) \) and MC. The third term can be interpreted as the effect of an additional quantity shipped on the profit of all quantities already shipped. After rearranging (4) and using \( D(.) = p_t \)

\[
p_t = D(.) - \frac{\partial C_k(.)}{\partial q_{kt}} + \frac{\partial D(.)}{\partial q_{kt}} q_{kt} \quad \text{for all } k = 1, \ldots, K \text{ and } t = 1, \ldots, T
\]  

(5)

which describes exactly the market conduct of each of the \( K \)-players and so the intensity of competition in the car carrier industry:

- for \( \frac{\partial D(.)}{\partial q_{kt}} = 0 \) the price of transport service equals MC of the \( k \)-th player, and there exists no market power.
- for \( \frac{\partial D(.)}{\partial q_{kt}} > 0 \) there exist some market power for all \( k \)-th players, due to the fact that they can raise their prices over their MC.

Assuming, that the demand for overseas shipments of motor vehicles is a derived demand for transport service in the car carrier industry, a structured equation system with a transport demand

\[
p_t = D(Q_t, Y_t)
\]  

(6)

and \( K \) market conduct equations

\[
p_t = \frac{\partial C_k(.)}{\partial q_{kt}} + \frac{\partial D(.)}{\partial q_{kt}} q_{kt} \quad \text{for all } k = 1, \ldots, K
\]  

(7)

for each player in the market under the condition of

\[
Q_t = \sum_{k=1}^{K} q_{kt}
\]  

(8)

Taking into account that fleet structure and so the way of transport service production of all \( K \) shipping operators is quite homogeneous (see Section 2), (7) can be rewritten as follows:

\[
p_t = MC_t(q_{kt}, Z_t, W_{kt}) - \frac{\partial D(Q_t, Y_t)}{\partial q_{kt}} \cdot q_{kt}
\]  

(9)

with \( MC_t = \frac{\partial C_k(.)}{\partial q_{kt}} \) as an average MC for each shipping operator. For empirical implementation purposes in Section 5.2., (6) and (9) can be slightly reformulated to a transport demand function

\[
p_t = D(Q_t, Y_t; \delta_t) + \nu_t
\]  

(10)

and a market conduct function

\[
p_t = MC_t(q_{kt}, Z_t, W_{kt}; \varphi_m) - \theta \frac{\partial D(Q_t, Y_t; \delta_t)}{\partial q_{kt}} \cdot q_{kt} + \nu_t
\]  

(11)
with $\delta_i$, $i = 1,...,L$ as coefficients for demand, $\gamma_m$, $m = 1,...,M$ as coefficients for average MC and $\theta$ for the average market conduct of all $K$ shipping operators to be estimated. In addition to this, $\nu_t$ and $\nu_t$ are both iid-distributed, not auto-correlated, and both with all variables and each other non-correlated structural disturbances. The equation (8) is not estimated, because it is deterministic and therefore contains fixed coefficients equal to one and no disturbance term.

Simultaneous estimation of (10) and (11) as the final structural model takes then explicitly the interrelatedness of both markets into account: the automotive industry as shippers of motor vehicles influence the shipping operators (and vice versa) due to their vertical integration when it comes on seaborne transportation of CBUs. Omitting (10), (11) can be interpreted as a vertical relationship, too, where the shipping operators perform their profit maximising behaviour based on the demand for transport service set by the automotive industry. Then, the downstream market of the seaborne car carrier industry has no possibility to adjust to demand given by the automotive industry. However, shipping operators can react to some certain extent by adjusting price and/or quality of their transport service offered on a short to medium run. The later can be done by reshuffling vessels from lower to higher demand trades, short term chartering vessels from non-operating vessel owners and/or other shipping operators, speeding up vessels in operation (resulting in more voyages completed p.a.), as well as postponing of scrapping older vessels in their fleet (leading to a higher average age of vessels in service). The execution of such measures in time of high markets prices is obvious, if we compare time charter indexes for vessels denominated in USD for one CEU per day on sea for PCC/PCTCs of 6,000-6,500 CEU capacity (Platou, 1995-2015; Clarksons, n.d.) with fleet characteristics like average ship size, age and productivity of all vessels in service for each year 1985-2017 as shown in Figure 4.

Fig.4: Time charter rate and fleet characteristics the car carrier industry 1985-2017

Analogous to (5), $\hat{\theta}$ as an estimator for $\theta$ plays in (11) an important role to estimate the theoretical market conduct. Different values of $\theta$ can be interpreted as different forms of market performance with corresponding degrees of market power and collusion among them in the car carrier industry:

- If $\hat{\theta} = 0$, price of transport service is equal to MC and this stands for a perfect competition outcome.
- if $\hat{\theta} > 0$, price of transport service is above MC and so there exists some market power.
• if $\theta = 1$, there is a Nash-equilibrium of a symmetric oligopoly.
• if $\theta > 1$, some collusion occurs with a cartel solution for $\theta = K$.

All these a-priori specified outcomes are possible, if this structural equation system is estimated simultaneously in order to obtain $\hat{\theta}$ as an estimator for a supposed market performance in the car carrier industry.

5.2. Data sampling and model description

For the purpose of estimating (10), annual seaborne motor vehicle trade data denominated in Mio. CEU was collected mainly from Clarkson (2007-2017) and Clarkson (n.d.), supplemented by figures originating from automotive industry associations, shipping operators in the car carrier industry, as well as external trade statistics at USA, Canada, Mexico and EU whenever necessary. WORLDTRADE, means a total sum of all seaborne motor vehicle shipments, FETRADE, seaborne shipments originating from Japan and South Korea, EWTRADE, motor vehicles shipped on East-West trade lanes between Japan, South Korea, Europe and NAFTA region, and NSTRADE, seaborne shipments on other trade lanes – mostly in North-South direction (see Tab.2).

Unfortunately, due to the usual contractual shipper-carrier relationships in the car carrier industry outlined in Section 2, a unit price $p_i$ for transport service is not directly observable as like in the container liner shipping industry. However, there are time-charter indexes for vessels available from Platou (1995-2015) and Clarksons (n.d.) to serve as a proxy, so that TCRATE $t$, can be expressed by the yearly average of a time charter index denominated in USD for one CEU per day on sea for PCC/PCTCs of 6,000-6,500 CEU capacity.

Furthermore, AVBUNKER, as a non firm-specific cost of delivering transport service is an average bunker price in USD per ton for 380 cst heavy fuel oil (HFO) in $t$ delivered at Rotterdam, Singapore and Houston collected by OceanConnect and retrieved from Clarkson (n.d.). TRANSshare$_{kt}$ is an expression for overall transport capacity of the $k^{th}$ shipping operator in $t$ and was calculated by using

$$\text{TRANSshare}_{kt} = \frac{\sum_{k=1}^{K} \text{SPEED}_{skt} \text{CCK}_{skt}}{\sum_{k=1}^{K} \text{SPEED}_{skt} \text{CCK}_{skt}} \text{WORLDTRADE}_t$$

for all $k=1,...,K$ (12)

with $S_o$ as the number of vessels employed by the $k^{th}$ shipping operator in $t$, assuming constant economies of scale in delivering transport service in the car carrier industry. $\text{SPEED}_{skt}$ is then the maximum permanent speed and $\text{CCK}_{skt}$ the cargo space provided in CEU by the $s^{th}$ vessel employed by the $k^{th}$ shipping operator in $t$. Moreover, technical characteristics of the vessels employed by the $k^{th}$ shipping operator in $t$ are $\text{FLEETCAP}_{kt}$ as a total sum of cargo space provided in CEU, $\text{AVSIZE}_{kt}$ as average cargo space per vessel in CEU, $\text{AVSPEED}_{kt}$ as an average maximum permanent speed of vessels in knots and $\text{AVAGE}_{kt}$ as an average age of vessels in service. In addition to this, $\text{FOCSHARE}_{kt}$ is the share of vessels of the $k^{th}$ shipping operator under flag of convenience, and $\text{CHARTERSHARE}_{kt}$ the share of vessels chartered from non-operating vessel owners in $t$, weighted by the vessel size in CEU. Last but not least, $\text{THETA}_{kt}$ was calculated using $\text{THETA}_{kt} = - (\text{TCRATE}_t / \text{WORLDTRADE}_t) \text{TRANSshare}_{kt}$ for all $k=1,...,K$ in $t$.

Tab.2: Description of full dataset 1985-2016 ($N=405$)

<table>
<thead>
<tr>
<th></th>
<th>Max</th>
<th>Min</th>
<th>Mean</th>
<th>STD</th>
</tr>
</thead>
<tbody>
<tr>
<td>WORLDTRADE</td>
<td>21.04</td>
<td>6.36</td>
<td>12.81</td>
<td>5.68</td>
</tr>
<tr>
<td>FETRADE</td>
<td>12.64</td>
<td>4.41</td>
<td>7.57</td>
<td>2.39</td>
</tr>
<tr>
<td>EWTRADE</td>
<td>7.13</td>
<td>3.79</td>
<td>5.48</td>
<td>0.92</td>
</tr>
<tr>
<td>NSTRADE</td>
<td>15.15</td>
<td>1.09</td>
<td>7.33</td>
<td>5.24</td>
</tr>
<tr>
<td>TCRATE</td>
<td>6.83</td>
<td>2.26</td>
<td>3.54</td>
<td>1.18</td>
</tr>
<tr>
<td>AVBUNKER</td>
<td>646.06</td>
<td>67.82</td>
<td>227.69</td>
<td>183.31</td>
</tr>
</tbody>
</table>
Inserting these figures described in Tab.2 into (10) and (11), a linear simultaneous equation model with two endogenous variables \( p_t \) and \( q_{kt} \) can be established, consisting of a log-linear transport demand function

\[
\ln(TCRATE_t) = \delta_1 \ln(e) + \delta_2 \ln(WORLDTRADE_t) + \delta_3 \ln(FETRADE_t) + \delta_4 \ln(EWTRADE_t) + \delta_5 \ln(NSTRADE_t) + \nu_t \tag{13}
\]

and a linear market conduct function with the specification

\[
\ln(TCRATE_t) = \varphi_1 \ln(AVBUNKER_t) + \varphi_2 \ln(TRANSSHARE_{kt}) + \varphi_3 \ln(FLEETCAP_{kt}) + \varphi_4 \ln(AVSIZE_{kt}) + \varphi_5 \ln(AVSPEED_{kt}) + \varphi_6 \ln(AVAGE) + \varphi_7 \ln(FOCSHARE_{kt}) + \varphi_8 \ln(CHARTERSHARE_{kt}) + \varphi_9 \ln(AVDTWTOCEU_{kt}) + \Theta \ln(\text{THETA}_{kt}) + \nu_t \tag{14}
\]

with \( \Theta = \theta \delta_2 \text{THETA}_{kt} \) to be seen as a non-linear combination of both endogenous variables, which is well defined by means of the deterministic relationship

\[
\text{THETA}_{kt} = \frac{1}{\delta_2} \frac{\partial Q_t}{\partial q_{kt}} = \frac{p_t}{Q_t} q_{kt} \quad \text{for all } k = 1, \ldots, K \tag{15}
\]

Using test procedures for identification purposes by Johnston (1984: 460) and Judge et al. (1988:614), it can be shown, that this linear simultaneous equation model is over-identified, if (8) and (15) are taken into account. According to Bresnahan (1982), it can also be shown, that \( \hat{\theta} \) is identified and can be calculated simply by \( \hat{\theta} = \hat{\Theta} / \delta_2 \). Due to the fact, that the model is over-identified, a Three-Stage-Least-Squares (3SLS) estimation method was applied (cf. Zellner and Theil, 1962).

5.2. Results and discussion

Tab.3 shows overall highly statistically significant results from 3-SLS-estimations of the linear simultaneous equation model consisting of (13) and (14). Model 1 includes all periods of the timeframe 1985-2016 and Model 2 takes the last two decades since 1996 into consideration, when global motor vehicle trades got more dispersed (cf. Section 2). As some initial estimates in Model 1 and 2 were either less statistically significant than the others (namely \( \ln(\text{FOCSHARE}_{kt}) \) and \( \ln(\text{CHARTERSHARE}_{kt}) \)), they were excluded in Model 1a and 3a with a more restricted model specification, which led to slightly better coefficients of determination. The results of the 3-SLS-estimations summarized in Tab.3 can be interpreted as follows:

- \( \ln(\text{WORLDTRADE}_t) \), \( \ln(\text{FETRADE}_t) \), \( \ln(\text{EWTRADE}_t) \), and \( \ln(\text{NSTRADE}_t) \) are all statistically highly significant and therefore, it can be asserted that the interplay of these motor vehicle trade flows explain price movements for transport service in the seaborne car carrier industry to a high extent.
- \( \ln(\text{AVBUNKER}_t) \) is statistically highly significant and shows a positive sign, which means that raising average bunker prices as a major cost driver in maritime shipping consequently result in an increase of price for transport service in the car carrier industry.
- \( \ln(\text{FLEETCAP}_t) \) shows a negative sign, so that we can say, that a scarcity of fleet capacity offered by shipping operators lead to an increase in price for transport service (and vice versa).
On the contrary, \( \ln(\text{TRANSSHARE}_{it}) \), \( \ln(\text{AVSIZE}_{it}) \), \( \ln(\text{AVSPEED}_{it}) \) and \( \ln(\text{AVAGE}_{it}) \) as vessel fleet characteristics increase when price for transport service increases. A rather simple explanation for these effects is that higher price levels for transport service tend the shipping operators to offer more transport capacity by employing vessels with a higher CEU capacity, higher average speed, and/or keeping older vessels longer in service instead of sending them to the scrap yard. Concerning \( \ln(\text{TRANSSHARE}_{it}) \), it could be suspected that higher transport volumes of motor vehicles of a shipping operator may improve its bargaining power vis-à-vis shippers.

However, other issues like ownership vs. chartering (\( \ln(\text{FOCSHARE}_{it}) \)) or registration of vessels under flag of convenience (\( \ln(\text{CHARTERSHARE}_{it}) \)) play a minor role and their impact on the unit price of transport service can be regarded as minuscule – at least when we look on the full timeframe of 1985-2016. In addition to this, \( \ln(\text{AVDITOCEU}_{it}) \) is then statistically significant with a positive sign, too, which reflect to some extent the rising share of PCTCs as well as similar vessels categorized as GenRos and ConRos in the car carrier fleet over time.

Finally, Tab.3 shows, that \( \text{THETA}_{it} \) is statistically highly significant. To find out the value \( \hat{\theta} \) determining the theoretical market conduct, only a systematic testing of linear restrictions is possible due to the present specification of the 3SLS estimation as a linear structural equation system:

For a market outcome of perfect competition with \( p = MC \), \( \theta \) should be zero. For this to be true, \( \bar{\theta} = 0 \) or \( \bar{\theta} / \delta_2 \rightarrow 0 \) with \( \delta_2 \rightarrow +\infty \), which may be the case in Modell 2 and 2a, where the estimator of \( \text{THETA}_{it} \) is close to zero and \( \ln(\text{WORLDTRADE}_{it}) \) is high at the same time.

When \( \bar{\theta} \) and \( \delta_2 \) show an equal sign, \( \bar{\theta} = \bar{\theta} / \delta_2 > 0 \) and so prices are set over MC. A Nash equilibrium of a symmetric oligopoly situation is then the case, when \( \bar{\theta} = \bar{\theta} / \delta_2 = 1 \) or \( \bar{\theta} = \delta_2 \). Furthermore, collusive market conduct occurs, when \( \bar{\theta} = \bar{\theta} / \delta_2 > 1 \) or \( |\bar{\theta}| > |\delta_2| \) with a cartel solution for \( \bar{\theta} = K \). The estimators of \( \text{THETA}_{it} \) and \( \ln(\text{WORLDTRADE}_{it}) \) in Model 1 and 1a show an equal sign, but as \( |\bar{\theta}| < |\delta_2| \), some price setting over MC can be asserted, which comes along with some market power on the shipping operators’ side in last two decades after 1996 – but not more.

**Tab.3: Results of 3-SLS-estimations**

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Constant</strong></td>
<td>1.81394</td>
<td>4.45907</td>
<td>1.84983</td>
<td>4.48474</td>
</tr>
<tr>
<td>( \ln(\text{WORLDTRADE}_{it}) )</td>
<td>-5.20155**</td>
<td>-8.26271**</td>
<td>-5.30920**</td>
<td>-8.29551**</td>
</tr>
<tr>
<td>( \ln(\text{FETTRADE}_{it}) )</td>
<td>2.77421**</td>
<td>2.50277**</td>
<td>2.83267**</td>
<td>2.50694**</td>
</tr>
<tr>
<td>( \ln(\text{EWTRADE}_{it}) )</td>
<td>2.24172**</td>
<td>3.22324**</td>
<td>2.27600**</td>
<td>3.23208**</td>
</tr>
<tr>
<td>( \ln(\text{NSTRADE}_{it}) )</td>
<td>1.75793**</td>
<td>3.80711**</td>
<td>1.79110**</td>
<td>3.82481**</td>
</tr>
<tr>
<td>\ln(\text{AVBUNKER}_{it})</td>
<td>0.103042**</td>
<td>0.094686**</td>
<td>0.101445**</td>
<td>0.099310**</td>
</tr>
<tr>
<td>\ln(\text{TRANSSHARE}_{it})</td>
<td>0.452542**</td>
<td>0.949578**</td>
<td>0.457018**</td>
<td>0.898201**</td>
</tr>
<tr>
<td>\ln(\text{FLEETCAP}_{it})</td>
<td>-0.66746**</td>
<td>-1.08599**</td>
<td>-0.668365**</td>
<td>-1.04203**</td>
</tr>
<tr>
<td>\ln(\text{AVSIZE}_{it})</td>
<td>0.310566**</td>
<td>0.255846**</td>
<td>0.306355**</td>
<td>0.254559**</td>
</tr>
<tr>
<td>\ln(\text{AVSPEED}_{it})</td>
<td>1.76835**</td>
<td>3.53331**</td>
<td>1.79530**</td>
<td>3.37396**</td>
</tr>
<tr>
<td>\ln(\text{AVAGE}_{it})</td>
<td>0.161034**</td>
<td>0.315409**</td>
<td>0.167278**</td>
<td>0.349643**</td>
</tr>
<tr>
<td>\ln(\text{FOCSHARE}_{it})</td>
<td>0.0172369\dagger</td>
<td>0.0514693\dagger</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>
6. Conclusions

Following a cliometric approach, this paper dealt with the market of seaborne motor vehicle transportation from 1985 to 2016. An initial exploration of market structure by means of common market structure metrics showed clearly that the car carrier industry can be regarded as a rather stable but oligopolistic transport market environment with 6 to 8 shipping operators having more than 5% market share, and a couple of smaller ones, which got slightly less concentrated and more competitive over the last three decades. The estimation of a theoretical market conduct by a simultaneous equation model reinforced these results. For the given time frame of the last three decades, i.e., 1985 - 2016, the main findings are as follows: (1) volatile demand for shipping of motor vehicles overseas can be explained well, through shifts in trade flows to a high extent; (2) overall transport capacity, average size, operating speed and age of vessels in service are the main measures of the shipping operators available to adjust to this volatile demand on a short to medium run; (3) despite a significant amount of merger and acquisition activity, market exits and entries, this transport market got slightly less concentrated as today more shipping operators are active there than in the past; (4) the estimated market conduct of the shipping operators shows a price setting slightly over their marginal costs with a strong trend towards a fully competitive market after 1996, when global motor vehicle trades got more dispersed.

Overall, this cliometric approach resulted in detailed insights about the car carrier industry over three decades since 1985. Especially the NEIO-style approach of simultaneous equation modelling allowed exploiting data available concerning motor vehicle trade flows and fleet characteristics of the car carrier industry in a very useful way. Of course, this came along with extensive data sampling efforts followed by some critical assumptions, but it may be worthwhile for other researchers to follow this way in order to explore market structure and theoretical market conduct in similar rather concentrated transport markets in the future.

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Highlights

- Seaborne car carrier industry is a rather oligopolistic transport market environment
- RoRo-Technology employed there can be regarded as a second maritime handling revolution
- Despite significant merger and acquisition activity, market exits and entries, the market got slightly less concentrated with today more shipping operators active than in the past
- Estimated market conduct seems to show a price setting slightly over marginal costs with a strong trend towards a fully competitive market after 1996.