Scale Diseconomies and Efficiencies of Liner Shipping

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Abstract

In the context of liner shipping, carrying capacity can be seen as a key resource to strive for better firm performance. The liner shipping market nowadays has entered a phase in which liner shipping companies (LSCs) reap economies of scale. The concept of economies of scale has led the industry to grow by enlarging its capacity and firms allocate more ships to offer shipping services in the worldwide market. However, the results of enlarged capacity may be uncertain. By examining empirical data (from 1997 to 2008), this paper investigates the relationship between capacity and firm performance in the liner shipping industry and attempts to use an S-curve to describe their relationship. The findings suggest that the S-curve is robust. Furthermore, this study attempts to provide theoretical basis for shipping lines to determine the optimal carrying capacity.

Keywords: liner shipping, diseconomies of scale, S-curve, capacity, revenue

1. Introduction

From the perspective of the industrial organisation paradigm, Porter (1981) proposed that "*the industry structure determines the conduct of firms whose joint conduct then determined the collective performance of the firms in the marketplace*". This implies a strong tie between market structure, conduct and performance (SCP). According to Coase (1937), SCP can be defined as "*the observable structure characteristics of a market determine the behavior of firms within the market, and that the behavior of firms within a market, given structural characteristics, determines measurable aspects of market performance.*" In the context of liner shipping economic and political conditions shape its market structure. Koch (1974) defined market structure as "*the strategic elements of the environment of a firm that influence, and are influenced by, the conduct and performance of the firms in the market in which it operates*". Market structure can be investigated through such variables as economies of scale, entry barriers, industry concentration, and product differentiation (Lun et al., 2009). The market structure of the liner shipping industry affects firms' conduct in their business operations (Pepall et al., 2005). Market conduct involves the actual behaviours of firms in a market and how the firms respond to the conditions imposed by the market structure and how they interact with rivals. One of the most significant aspects of market conduct is pricing policy and capacity management. The performance of LSCs depends on their conduct when making such decisions as pricing and capacity level. The shipping market fluctuates from time to time. In some situations, LSCs confront intense price competition and under-utilisation of fleet capacity which results in low average profits. When there is a shortage of supply of shipping capacity, LSCs may charge a higher freight rate which results in high average profit (Lun et al., 2010a).

The liner shipping industry has, in recent years, gained increased attention from the government, trade associations and global traders (Notteboom and Rodrigue, 2008). Song et al. (2005) pointed out that there are two contemporary issues that need to be explored in the liner shipping area. One argument is that the LSCs face intense competition in the globalised liner shipping market. The second point raised is over-capacity of the LSCs. The overcapacity leads to lower freight rates. As a result, the liner shipping is currently characterised by low profit margin. The level of capacity utilisation depends on the growth of containerised cargo, the speed with which existing operators introduce new and larger vessels into liner shipping service, and the level of exits of operators from the market. On the track of liner shipping research, pervious works are mainly restricted to ship operations such as optimal speed and ship scheduling (e.g., Christiansen et al., 2004). Various mathematical programming models and optimisation techniques have been heavily developed that provided operating solutions by using deterministic models or stochastic models. However, recent studies in liner shipping management are rather limited. This paper attempts to fill the research gap by investigating the relationship between capacity and market share in liner shipping as well as determining a functional specification of this relationship. In this study, we attempt to present structural characteristics of the liner shipping industry by investigating internal and external factors as the basic parameters of the S-curve and testing it using the empirical data from 1997 to 2008. We further attempt to determine the shape of the S-curve so as to disclose the transition from scale economies to scale diseconomies.

2. Literature Review

It is well recognised that perceived growth and scale operations determine the performance of firms. The organisational growth stimulates economies of scale and expansion of firm size is closely related with prestige. To remain competitive, many firms intend to strive for growth in the dynamic operating environment (Lun et al., 2010b). LSCs nowadays enlarge their firm size to demonstrate their ability to confront traditional and new challenges. For instance, large sized operations induce an operational mechanism to facilitate cost efficiency over a high production volume (Dobrev and Carroll, 2003). Large firms are able to gain a better position to deter new competitors from entering into the market (Porter, 1999). Operating on a large scale prompts geographical expansion and encourages the globalisation of business (Lun et al., 2010b). LSCs extend their geographical coverage to attract sufficient cargo volume that allows them to reap economies of scale in vessel operations so as to diminish the unit cost of container handling (Midoro and Pitto, 2000). The enhancement of capability in the liner shipping context can create a potential source of competitive advantages (Lai, 2004). Apart from scale operations, many LSCs have taken initiatives to broaden and widen the range of services to enable them to exceed shippers' expectations (Yang et al., 2009). To exploit the business opportunities, LSCs offer comprehensive shipping services such as increasing the service frequency and the number of ports of call. Indeed, many LSCs enlarge their service scope to extend vertically by providing a wide range of related services include developing various logistics related services and expanding container terminal operations internationally (Lun and Browne, 2009).

Originating from the strategic management literature, a firm gathers organisational resources and uses its resources in an optimal pattern. Capacity can be seen as one of the key resources in the context of liner shipping (Yang et al., 2009). Based on Day (1994, p.38), it is proposed that capabilities are "*complex bundles of skills and accumulated knowledge, exercised through organizational processes, which enable firms to coordinate activities and make use of their assets.*" Makadok (2001) emphasised that the process of production is found to be scale optimal and fosters increasing economic returns. Economies of scale in the use of resources constitute a substantial competitive advantage of firms to gain survival and prosperity (Winter, 2000). In the context of liner shipping operations, low rates of return on capital and low freight rates have stimulated the LSCs to enlarge their capacity to spread fixed unit costs and increase profit (Fusillo, 2006; Yang et al., 2009). Based on that, the world's mega LSCs tend to increase their carrying capacity which has intensified the characteristic of concentration of operations in the overall liner shipping industry. Since 1995, the trends of merger and acquisition have spanned across shipping firms (Yang et al., 2009). Large LSCs swallow small LSCs with the aim to solidify their competitive position against other rivals (Fusillo, 2006). Examples include the takeover of CP Ships by Hapag-Lloyd in 2005 (now one of the top five LSCs in the world), the takeover of P&O Nedlloyd by Maersk in 2005, and the merging of CMA CGM and Delmas in 2006. These consolidations have created an extraordinary scale of consolidation in the liner shipping industry (Slack et al., 2002; Yang et al., 2009; Yip and Lun, 2009). From this perspective, returns on investment are determined by firm size.

3. Methodology

The analysis is divided into two steps. In the first step, the S-curve is used as the theoretical basis for production frontier analysis. The S-curve is an approximation of an unknown frontier function and the accuracy of the S-curve is verified by observed data. The S-curve will therefore be used to test for the presence of both economies and diseconomies of scale in the liner shipping market. In the second step, the macroeconomic data of the liner market are considered to determine the shape of the S-curve. We wish to explain the shape of the S-curve in view of the macro market conditions. We believe that insights can be achieved from a parametric model, which allows statistical testing and can be used to explain the diseconomies of scale.

The first step is to estimate the parameters of the S-curve for each year. The S-curve concept is employed here with the presence of the diseconomy of scale. When the capacity q is initially introduced into the production, the revenue r is low because operators of small capacity are competing for market share. As the operator acquires more capacity, the revenue r will increase until it reaches the maximum revenue r_∞. Without loss of generality, we assume that the relationship between capacity and revenue would be described by an S-curve. The standard equation for the S-curve can be defined as:

$$r(q) = \frac{r_\infty}{1 + a\exp(-bq)} + r_0 \tag{1}$$

where *r* is the revenue, *q* is the capacity, r_∞ is the saturation value or the upper limit at infinity, *a* the shape parameter, and *b* the scale parameter.

$$\ln\left(\frac{r_\infty}{r - r_0} - 1\right) = \ln a - bq \tag{2}$$

The shape parameter *a* indicates the position of curve initialization. A small value *a* means that the change from scale economies into scale diseconomies occurs at a small value of capacity *q*. Therefore, the problem of scale diseconomies will be observed at a small value of *q*. A large value *a* delays the occurrence of scale diseconomies along the capacity *q*. The scale parameter *b* indicates the growth rate of the curve. A small value *b* means that the change rate of scale economies into scale diseconomies is slow. Therefore, if *b* is small, the interface between scale economies and diseconomies spreads over a large range of capacity *q*. A large value *b* shows a flat S-curve. In the second step, we attempt to estimate the S-curve versus macro market data. Instead of remaining static, the liner market is dynamic over time. The liner market can be quantified by four primary components: (1) demand, (2) supply, (3) operating cost, and (4) profit. To investigate the hypothesis, the model specification is expressed as:

Parameters of S-curve = f (*Demand, Supply, Operating cost, Profit*) (3)

where *Demand* = seaborne trade; *Supply* = new delivery, new order, and scrapping; *Operating cost* = bunker price, and seamen wages; *Profit* = freight rate. The parametric model (3) allows for statistical testing and can be used to explain diseconomies of scale.

4. Data and Discussion

In this study, we mainly evaluate and measure the efficiency of LSCs. We consider the internal and external factors in examining the determinants of efficiency in the liner shipping industry. It is preferable to use empirical data to evaluate firm performance (Cho et al., 2008). To study the internal factor, the data of total revenue and total capacity of the top 20 ocean carriers from 1997 to 2008 were collated from Containerisation

International. Containerisation International is highly recognised within the maritime sector as a source of invaluable insight and statistics on the container market over the last 40 years (source: Containerisation International).

To examine the external factor of liner market, the data of seaborne trade, new delivery of container vessels, new order of container vessels, scrapping of container vessels, bunker price, seamen wages and freight rate from 1997 to 2008 were collected from the Review of Maritime Transport, Clarkson Research Studies, International Labour Organization (ILO) and Drewry, respectively. Since 1968, the Review of Maritime Transport has been one of UNCTAD's flagship publications. It highlights the worldwide evolution of shipping, ports and major transportation pertaining to liquid bulk, dry bulk and containers. The Clarkson Research Studies offers research, statistical and financial services to ship brokers and the maritime industry. The team of experienced researchers and analysts at Clarkson Research maintains comprehensive databases of the world's bulk, container and general cargo fleets comprising 30,000 vessels on a daily basis (source: www.clarksons.com). The ILO publishes research related to the changing nature of work and employment which brings insight and direction to policy makers. The ILO maintains integrity, independence and high professional standards and gathers, disseminates, analyses, and processes statistical data to the public. In doing so, the ILO is able to provide timely labour statistics and accurate economic analysis, facilitating increased awareness of common problems, explaining actions and mobilising interest (source: www.ilo.org). Drewry Shipping Consultants Limited offers a full range of economic, commercial and technical consulting and publishing services to the international maritime industry. Manned by a research team of dedicated, highly skilled and experienced analysts it has established comprehensive databases over three decades (source: www.drewry.co.uk).

Accordingly, we believe that these five sources provide relevant and objective data to measure our study variables, including individual liners in terms of total revenue and total capacity, seaborne trade, freight rate, bunker price, seamen wages, new delivery, new order, and scrapping. Our research uses several quantitative analytical tools to empirically test the efficiency of liner operators. We illustrate internal and external factors as the basic parameters of the S-curve to determine the optimal carrying capacity of shipping lines. The S-curve is widely used to describe actual costs, planned spending and the budgeted cost of work performed. The S-curve is helpful in conducting a risk analysis of shipping finances by showing the altered spending rates needed to attain profitability (Cioffi, 2005). To predict firm performance, the external variables of the liner market are considered into regression analysis.

4.1 The S-curve

When exhibited as a function of time, costs of projects or accumulated efforts are usually presented as an S-curve (Cioffi, 2005). In this study, there are two main factors for consideration, capacity and revenue, in exploring the tendency of liner shipping operations from the S-curve effect. To test the relationship between capacity and revenue, we use twelve years of data, from 1997 to 2008, gathered from Containerisation International. The empirical data of total capacity and total revenue of the top 20 liner operators are collected to plot an envelope graph. The recent consolidation among LSCs generates the S-curve effect. Between 1997 and 2008 the bigger LSCs captured a larger market share by enlarging capacity. The concentration ratio (CR4) increased significantly from 15.5% in 1997 to 32.8% in 2008 (Yip and Lun, 2009). Between 1997 and 2008, LSCs enlarged their tonnage to capture more market share. It is noticeable that the return of liner operators is in accordance with market share. Thus, accordingly, the market players have engaged in a strategy of acquisition or expansion over the past few years.

Our findings confirm that capacity and revenue are not linear correlated. In that case, we apply an S-curve to characterise the relationship between capacity and revenue each year from 1997 to 2008. Cioffi (2005) noted that the name of the S-curve stems from "*the S-like shape of curve (i.e., flatter at the beginning and end, steeper in the middle)*". In general, the S-curve is a form of the learning curve, which supposes that performance improvement eventually reaches a plateau (Ngwenyama et al., 2007). The S-curve is typically applied in economic production that scale economies exhibit below optimum scale and scale diseconomies above optimum scale (Coelli et al., 2005). The S-curve describes the frontier of each capacity level that generates the maximum revenue. On one hand, LSCs are on the frontier when they are efficient. On the other hand, LSCs are beneath the frontier when they are inefficient. Yip and Lun (2009) demonstrated that LSCs that occupy a capacity share between 4% and 9% are capable of attaining 8% to 20% of revenue share in the liner market. According to the 2008 data, it shows that the optimal firm size in liner shipping is between 4% and 6% of the size of capacity share. LSCs enjoy increasing returns of scale occurring at the capacity share below 4%, whereas decreasing returns of scale existing at the capacity share beyond 5%. It follows that LSCs increase revenue without expanding their capacity under the efficient frontier. The S-curve analysis is summarised in Table 1.

Table 1: Results of S-Curve analysis

Year	*Shape Parameter ln a*	*Scale Parameter ln b*	*R-squared*
1997	5.121	4.772	0.930
1998	4.540	4.738	0.852
1999	5.330	5.058	0.856
2000	6.875	5.260	0.782
2001	6.627	5.281	0.701
2002	9.383	5.588	0.800
2003	5.476	4.961	0.884
2004	2.472	4.459	0.711
2005	2.758	3.978	0.965
2006	3.142	4.025	0.925
2007	3.950	4.382	0.929
2008	2.814	3.642	0.902

4.2 The regression model

The key findings are produced by regression analysis. To provide an understanding on how S-curve and market factors are associated, we carry out a parametric analysis to assess the relationships of these study factors (Lun and Quaddus, 2009). Market factors (i.e., seaborne trade, freight rate and scrapping) are tested with S-curve parameters. The results are reported in Table 2, while only significant variables are included.

Table 2: Results of regression analysis

		Dependent variables	
		Shape Parameter ln *a*	*Scale Parameter* ln *b*
	Independent variables		
Demand	ln Seaborne Trade	90.91 (3.842) **	29.63 (4.623) ***
	ln Container Throughput	−70.43 (−3.659) **	−25.49 (−5.085) ***
Supply	ln Fleet Capacity	-	-
	ln Delivery	−9.24 (−7.262) ***	−2.24 (−5.918) ***
	ln New Order	-	-
	ln Scrap	-	0.17 (3.547) **
Operating Cost	ln Bunker Price	19.62 (5.299) ***	5.62 (5.093) ***
	ln Seamen Wages	86.53 (3.047) **	38.47 (5.618) ***
Profit	ln Freight Rate	−34.13 (−5.559) ***	-
	Constant	−455.8 (−1.84)	−283.67 (−5.183) ***
	R-squared	0.971	0.960
	Adjusted R-squared	0.928	0.900
	F-statistic	22.35 ***	15.93 ***
	Akaike Info. Criterion	1.906	−0.501

Year: 1997-2007
*** (**, *) Significant at the 0.01 (0.05, 0.10) level (2-tailed)

For large values of shape parameter *a* and scale parameter *b*, the scale diseconomies are found at a large value of capacity q. The results in Table 2 show that when the operating costs increase (i.e., bunker cost and seamen wages), both parameters a and b will increase, and therefore the scale diseconomies will be found at a larger capacity q. It is common that a high setup industry has a higher value of scale economies, for example, power plants, container terminals, etc.

The shape parameter a depends on the freight rate. Given that the supply, demand and cost are unchanged, the increase of freight rate leads to a more profitable operation. Relatively, the portion of cost reduces, and the effect of freight rate is opposite to operating cost. The sign of freight rate is therefore assumed. On the other hand, Table 2 shows that more supply of liner shipping (i.e., delivery) will introduce the scale economies at a smaller capacity q, because both parameters a and b will decrease accordingly. It is well known that more supply implies more intensive competition and a higher potential of oversupply. The effect of scrapping is to reduce the supply, and so the scale parameter b increases if supply is reduced by scrapping. Thus, the diseconomies of scale may be observed at a smaller capacity, if more supply is available.

It is surprising that the existing fleet does not have significant impact on the S-curve statistically. A possible reason is that the delivery has reflected the effect of the fleet increase. It is implicit that *Current fleet = Previous fleet + Delivery – Scrap*. The signs of demand variables might raise some doubts at first glance, where the sign of seaborne trade is positive but container throughput negative. Actually the opposite signs represent the competing effects of scale economies and diseconomies. The increase of seaborne trade leads to higher values of both shape parameter a and scale parameter b. Expanding seaborne trade will encourage scale economies. The increase of container throughput implies a higher degree of coordination problems and scale diseconomies are the result.

5. Conclusions

In this paper, we consider a two-step approach that allows not only for frontier analysis of scale economies, but also a parametric analysis of the parameters of the frontier function. The S-curve is used to describe the frontier function and the fitness is confirmed with high values of R-squared statistic. Unlike other functions, the S-curve assumes the presence of scale economies and diseconomies. We further test the shape and scale parameters of the S-curve with market data. It is found that the shape parameter depends on the demand for liner shipping and the scale parameter depends on the cost of liner shipping.

Acknowledgements

This study was supported in part by The Hong Kong Polytechnic University under grant number A-PD0B.

References

Cho, J.J., Ozment, J. and Sink, H. (2008), Logistics, capacity, logistics outsourcing and firm performance in an e-commerce market, *International Journal of Physical Distribution and Logistics Management*, 38(5), 336-359.

Christiansen, M., Fagerholt, K. and Ronen, D. (2004), Ship routing and scheduling: status and perspectives, *Transportation Science*, 38(1), 1-18.

Cioffi, D.F. (2005), A tool for managing projects: an analytic parameterization of the S-curve, *International Journal of Project Management*, 23(3), 215-222.

Coase, R. (1937), The Nature of Firms, *Economica*, 4(16), 386–405.

Coelli, T., Prasada, R.D.D., O'Donnel, C.J., and Battese, G.E. (2005), *An Introduction to Efficiency and Production Analysis*, Springer.

Day, G.S. (1994), The capabilities of market-driven organizations, *Journal of Marketing*, 58(4), 37-52.

Dobrev, S.D. and Carroll, G.R. (2003), Size (and competition) among organizations: modeling scale-based among automobile producers in four major countries 1885-1981, *Strategic Management Journal*, 24(6), 541-558.

Fusillo, M. (2006), Some notes on structure and stability in liner shipping, *Maritime Policy and Management*, 33(5), 463-475.

Koch, J. (1974), *Industrial Organization and Price*, Prentice-Hall, New Jersey.

Lai, K.H. (2004), Service capability and performance of logistics service providers, *Transportation Research Part E*, 40(5), 385-399.

Lun, Y.H.V. and Browne, M. (2009), Fleet mix in container shipping operations, *International Journal of Shipping and Transport Logistics*, 1(2), 103-118.

Lun, Y.H.V., Lai, K.H. and Cheng, T.C.E. (2009), The container shipping market, *Shipping and Transport Logistics Book Series*, Volume 1, pp. 1-15.

Lun, Y.H.V. and Quaddus, M.A. (2009), An empirical model for the bulk shipping market, *International Journal of Shipping and Transport Logistics*, 1(1), 37-54.

Lun, Y.H.V., Lai, K.H. and Cheng, T.C.E. (2010a), *Shipping and Logistics Management*, Springer, London.

Lun, Y.H.V., Pang, K.W. and Panayides, P.M. (2010b), Organizational growth and firm performance in the international container shipping industry, *International Journal of Shipping and Transport Logistics*, 2(2), 206-223.

Makadok, R. (2001), Toward a synthesis of the resource-based and dynamic-capability views of rent creation, *Strategic Management Journal*, 22(5), 387-401.

Midoro, R. and Pitto, A. (2000), A critical evaluation of strategic alliances in liner shipping, *Maritime Policy and Management*, 27(1), 31-40.

Ngwenyama, O., Guergachi, A. and McLaren, T. (2007), Using the learning curve to maximize IT productivity: a decision analysis model for timing software upgrades, *International Journal of Production and Economics*, 105(2), 524-535.

Notteboom, T. and Rodrigue, J.P. (2008), Containerization, box logistics and global supply chains: The integration of ports and liner shipping networks, *Maritime Economics and Logistics*, 10(1/2), 152-174.

Pepall, L., Richards, D. and Norman, G. (2005), *Industrial Organization, Contemporary Theory and Practice*, Thomson South-Western, Ohio.

Porter, M. E. (1981), The contributions of industrial organization to strategic management, *Academy of Management Review*, 6(4), 609-620.

Porter, M. E. (1999), *Strategy: Seeking and Securing Competitive Advantage*, Harvard Business School, Boston, MA.

Slack, B., Comtois, C. and McCalla, R. (2002), Strategic alliances in the container shipping industry: a global perspective, *Maritime Policy and Management*, 29(1), 65-76.

Winter, S.G. (2000), The satisficing principle in capability learning, *Strategic Management Journal*, 21(10/11), 981-996.

Yang, C.C., Marlow, P.B. and Lu, C.S. (2009), Assessing resources, logistics service capabilities, innovation capabilities and the performance of container shipping services in Taiwan, *International Journal of Production and Economics*, 122(1), 4-20.

Yip, T.L. and Lun, Y.H.V. (2009), Business risk in container shipping, In: Wagner, S. and Bode, C. (Eds.), *Managing Risk and Security: The Safeguard of Long-Term Success for Logistics Service Providers*, Kuehne Foundation Book Series on Logistics, Haupt Publisher: Berne, Switzerland, pp. 153-174.