Overtonnaging in Liner Shipping Cooperative Agreements: A *Non-cooperative* Game Theory Approach

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1 Introduction

With most of international trade transported via ships, the shipping industry is an essential part of the international economy. As production and consumption become more globalised, shipping becomes more important. Shipping is both a facilitator and promoter of globalised trade. Shipping facilitates the distribution of both factors of production and final goods and as such, production is made more efficient and final goods are valued higher. Firms can tap resources from other low cost territories and at the same time sell their final goods to countries with higher marginal valuations. Consumers from almost any part of the world are able to access a wide variety of goods that are sometimes better and yet have lower costs. Furthermore, decrease in shipping costs through improved transport technology and logistics also stimulates new trade lanes to open and promotes a more globalised economy.

The Shipping industry is a good case study for economists. On the one hand, the bulk shipping aspect of the industry can be approximately claimed as a perfectly competitive industry. On the other hand, the liner shipping business involves a highly cooperative and concentrated industry. In this paper, we shall focus on the liner shipping industry.

The literature on liner shipping can be grouped into two main areas. One focuses on the instability of cooperative agreements in liner shipping while the other studies the excess capacity phenomenon and economies of scale inherent in the business. The former is often studied using cooperative game theory and more recently, the Theory of the Core (Sjostrom, 1989; Pirrong, 1992; Telser, 1996). The latter is usually explained using predatory pricing and entry deterrence arguments (McGee, 1960; Fusillo, 2003; Lim, 1998). The goal of this paper is to incorporate the two using a non-cooperative framework. Specifically, we aim to create a model that incorporates excess capacity within a cooperative setting. Following the empirical results of Fusillo (2003) for which predatory pricing and entry deterrence explanations of excess capacity receive weak empirical support, we attempt to explain excess capacity as an inherent result or by-product of the strategic interactions of seemingly cooperating firms and not merely as a conscious or deliberate mechanism to drive out potential entrants. Though we are modeling excess capacity within a cooperative industry, the model is basically non-cooperative. The main rationale is that cooperative agreements rarely cover capital (in terms of capacity and ships) investment and procurement decisions of firms included in the coalition.

The next section develops the main model of excess capacity. The aim of the model is to formally show that strategic complementarities in capacity decisions can occur in a cooperative agreement which uses an internal price cost rule in vessel sharing, allows for short run losses, and has no explicit agreements on capacity investments. The final section presents some recommendations and finally concludes.

2 The Model[1]

Capacity decisions will be modeled as a simultaneous, multi-period differential game. To our knowledge, differential games have not been applied to capacity decision-making in the liner shipping business. A close but more technical and theoretical application of differential games to excess capacity is Cellini and Lambertini (2003) which also provides justification for using differential games in capacity decision modeling. In our model, we assume that firms price according to an average slot cost pricing rule that allows for short run losses. This is the price for which members of

[1] This section relies on Optimal Control Theory (OCT) or Pontryagin's Maximum Principle as applied to Differential Games. Recommended references for OCT are Leonard and Long (1992) and Chiang (1992). For differential games applied to business, refer to Jøorgensen and Zaccour (2004) and Dockner, *et al.* (2001)

the alliance can buy slots from other members. We also incorporate economies of scale by setting the slot cost of each individual firm to be decreasing in its own capacity. When solving for the optimal investment rule, we derive open-loop solutions for computational convenience. This can be justified by assuming that in the short run, firms pre-commit their optimal decision rules at the intial period such that the rules are functions of time, initial conditions (beginning capital stock) and parameters only.

Assume that price at time t is equal to the current average slot cost:[2]

$$P(t) = \frac{\sum_{j=1}^{n} c_j(t)}{n} \qquad (1).$$

A firm's slot cost is decreasing in its own capacity due to economies of scale. For simplicity, assume it has the form given by

$$c_j(t) = \frac{1}{k_j(t)} \qquad (2)$$

where $k_j(t)$ is the total capacity of the firm measured in TEUs[3]. A firm's total capacity follows the law of motion

$$\dot{k}_i = I_i(t) - \delta k_i(t) \qquad (3).$$

Assume for simplicity that ships can last long enough such that δ is equal to zero for the decision period. Therefore increase in capital stock is simply equal to gross investment, $I_i(t)$. Moreover, assume that demand grows linearly in time with drift set equal to g and that total capacity is greater than total demand (excess capacity):

$$Q(t) \equiv gt \leq \sum_{j=1}^{n} k_j \qquad (4).$$

Finally, assume that quantity supplied by each firm is proportional to the ratio of its capacity to the alliance's total capacity.

[2] We assume that there is a binding commitment to share vessels.
[3] For simplicity, we ignore integer restrictions on capacity.

Each firm will choose an infinite sequence of gross investments in order to maximise the present value of profits given by

$$\Pi_i = \int_0^\infty e^{-\rho t}\left[\left(\frac{\sum_{j=1}^{n} c_j(t)}{n} - c_i(t)\right)\left(\frac{k_i(t)}{\sum_{j=1}^{n} k_j(t)}\right)Q(t) - I(t)\right]dt \qquad (5)$$

while taking into consideration the strategies of other firms.

Let $n = 2$ for simplicity. Incorporating (1)-(5), the Current-Value Hamiltonian of each firm is as follows:

$$H_i(\circ) = (c_j(t) - c_i(t))\frac{gtk_i(t)}{2(k_i + k_j)} - I_i(t) + \lambda_i(t)(I_i(t)) \qquad (6)$$

for i, j = 1, 2 and $i \neq j$.

Together with the law of motion, (3), the necessary conditions and transversality condition are the following:

$$\frac{\partial H_i}{\partial I_i} = -1 + \lambda_i = 0 \qquad (7)$$

$$\dot{\lambda}_i = \rho\lambda_i - \frac{\partial H_i}{\partial k_i} \qquad (8)$$

$$\lim_{t\to\infty} e^{-\rho t}\lambda_i(t) = 0 \qquad (9).$$

From the maximality condition, (7), we can easily see that the co-state variable is constant and hence the transversality condition, (9) satisfied. Furthermore, (8) simplifies to the following form:

$$0 = \rho - \frac{\partial H_i}{\partial k_i} \qquad (10).$$

Expanding (10), taking its derivative with respect to time, and finally using the law of motion, (3), we derive firm *i*'s reaction function:

$$I_i(t) = \Theta_i I_j(t) \qquad (11)^4$$

$$where\ \Theta_i = \frac{2(gt-1) - 2\rho k_i(k_i + k_j)}{\rho(k_i + k_j)(5k_i + k_j) - gt(2k_i + k_j + 1)}.$$

Note that Θ_i is positive for values of the discount rate that satisfy the following condition:

$$\frac{gt-1}{k_i(k_i + k_j)} < \rho < \frac{gt(2k_i + k_j + 1)}{(5k_i + k_j)(k_i + k_j)} \qquad (12)$$

If the discount rate satisfies (12), then investment decisions are strategic complements meaning, if one company decides to have a positive investment in the current period, the best response of other firms would be to do so as well. However, the strategic complementary from the derived reaction functions does not yield a stable equilibrium for certain conditions. We can see this clearly by graphing the reaction functions given by (11):

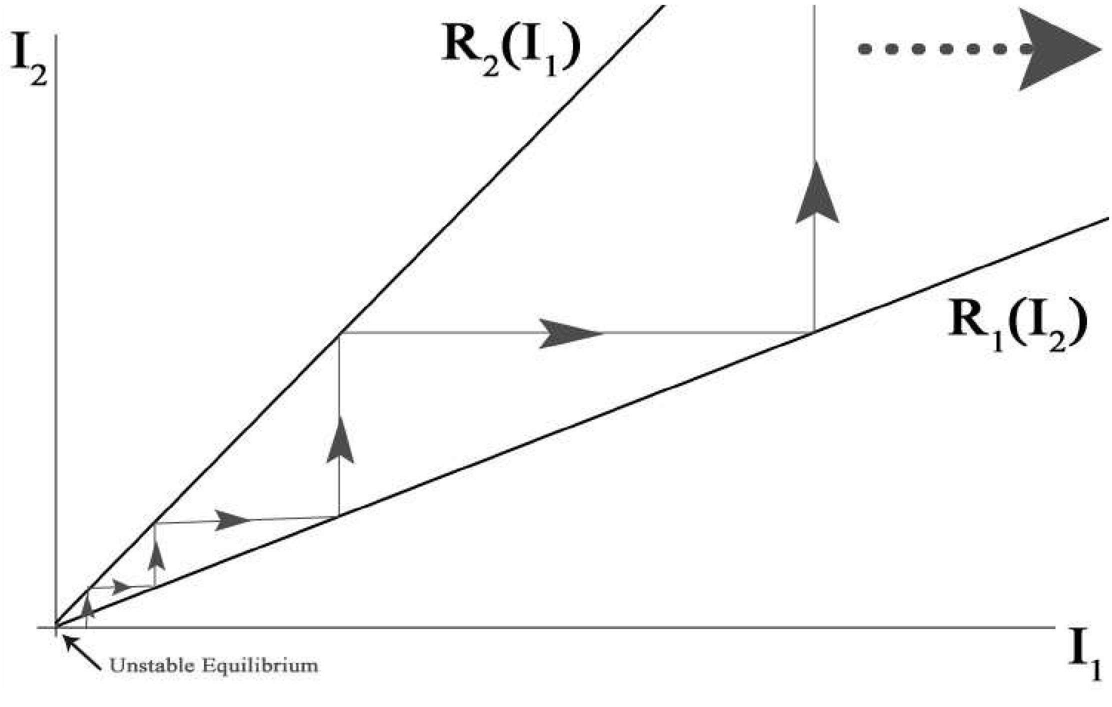

Figure 3 Reaction Functions based on (11)

Note: Given certain conditions are satisfied, the unique pure strategy equilibrium (origin) is unstable as can be seen from the above dynamics (red lines).

[4] The terms k_i and k_j are actually solutions to the respective differential equations hence Θ is a function of the initial states and time which is a characteristic of open-loop solutions.

For the case that investment decisions are strategic complements (*i.e.* both Θ_1 and Θ_2 are positive), if $\Theta_2 > (\Theta_1)^{-1}$, then the only equilibrium is zero investment for both companies (the origin) and this equilibrium is unstable. In other words, even a small inclination by other firms to have a positive level of investment for upcoming periods can trigger a series of investment decisions by other companies and therefore can result in significant overbuilding even in the short run, until structural conditions are changed. Presented in the table below are some results from a simulation of the model:

k_1	k_2	*gt*	ρ	Θ_1	Θ_2	*Stability*	*Description of Industry*
70	60	100	0.3	1.280292	0.959743	Unstable	**Moderately Patient; Excess Capacity**
80	60	100	0.3	2.346043	1.169565	Unstable	
90	60	100	0.3	6.871304	1.465352	Unstable	
70	60	100	0.8	-0.63718	-0.63375	-	**Very Patient; Excess Capacity; Strategic Substitutes**
80	60	100	0.8	-0.60238	-0.58958	-	
90	60	100	0.8	-0.57687	-0.55261	-	
50	50	100	0.3	0.459344	0.459344	Stable	**Moderately Patient; No Excess Capacity**
40	60	100	0.3	0.349524	0.57661	Stable	
30	60	100	0.3	0.221151	0.491438	Stable	

Table 2. Results from a Simulation of Reaction Functions given by (11)

As we can see, for "normal" conditions—moderate degree of patience and excess capacity[5], investment decisions are strategic complements and are unstable. This lack of a stable equilibrium due to the reaction functions can serve as an alternative explanation of persistent excess capacity that does not rely on predatory pricing or

[5] Some form of excess capacity is necessary in the business in order to provide regular and frequent service as mentioned earlier. However the main issue is the growth of excess capacity that may seem to be irrational.

even Empty Core arguments. The alternative explanation implies that chronic excess capacity is not due to a deliberate attempt of carriers to deter entry of potential firms, but is a by-product of the type of industry and the nature of competition and cooperation inherent in liner shipping. Also, the non-existence of Pareto efficient or Walrasian prices can be explained by the model instead of relying on Empty Core explanations (Sjostrom, 1989) since freight rates are deeply tied to capacity levels (Fusillo, 2003, Stopford, 2004). Because of the inelastic nature of supply and demand in liner shipping, prices fluctuate with changes in capacity and the lack of a stable equilibrium in capacity translates to a nonexistence of a stable equilibrium in prices

3 Recommendation and Conclusion

As we have seen from the model, an agreement without explicit control of investments can lead to overinvestment in capacity. This basically occurs because firms within a coalition in a way, compete in cost efficiency. Because of economies of scale in liner shipping operations, increasing capacity can provide substantial cost savings and improve cost efficiency assuming capacity is adequately utilised. Thus, the excess capacity problem might have been slightly exacerbated by the advent of strategic alliances that aim to improve capacity utilisation across different routes since carriers feel that their added capacity can be easily utilised. However, adequate capacity utilisation assumes that international trade grows at par with carriers' optimism. Whether carriers are overly optimistic or not, is another issue. Nonetheless, persistent and uncontrolled growth in capacity still remains a problem.

The model in this paper has shown that excess capacity can be an inherent result of the nature of competition and cooperation in the liner shipping business. Since there is only limited evidence of capacity-building being used as a predation strategy, competition authorities should not see coordination in capacity investments and explicit agreements on capacity-building as anti-competitive. However, whether carriers would be delighted to coordinate their investment decisions is another question. Nonetheless, it seems that explicit agreements on capacity investments might improve the stability of alliances and other forms of agreements since as the model has shown, a stable non-cooperative investment equilibrium might not exist. Stability of alliances not only benefits carriers but also shippers and consumers as well. Therefore, a move to improve stability in cooperative agreements and in the liner shipping service as a whole is definitely welfare-enhancing.

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