THE LNG MARKET AND A GAME THEORY APPROACH TO COMPETITION IN LNG SHIPPING[1]

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Abstract

The LNG (Liquefied Natural Gas) trade is one of the most promising sectors in energy shipping. It is expected that competition will increasingly develop in the shipping segment of the LNG chain, which at least in its first phases will have the characteristics of an oligopolistic market. The LNG shipping market context is appropriate for the adoption of a (non-cooperative) game theoretic analysis framework to support decision-making. This paper focuses on oligopolistic competition in LNG shipping over the transportation capacity supplied to a trade route by competing shipping companies. It also examines the possibility of non-cooperative collusion among the competing parties, in order for them to share higher profits. The conclusions concern the optimal level of capacity supply by the competitors, under certain interaction settings, and the conditions under which they can sustain Pareto efficient equilibria.

Key words:

LNG Shipping, Oligopolistic Competition, Game Theory

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INTRODUCTION – THE LNG MARKET AND ITS DYNAMICS

The Liquefied Natural Gas (LNG) trade is without doubt one of the most interesting areas in energy shipping, dominating the world bulk maritime transport. Recently, market developments have attracted companies and investors who are only now discovering its special characteristics.

Meeting the world's energy demands is one of the greatest challenges for the 21st century and, in many respects, natural gas is considered as the successor of oil. Maritime transport, a pillar of world trade, is expected to stand up to the challenges ahead. Indeed, while for many decades natural gas markets were localized and isolated, the LNG trade (that is the transport of natural gas by sea) has contributed to the development of a global competitive market (Foss, 2005) which presents similarities to the oil market, yet many differences as well.

The paper focuses on oligopolistic competition in LNG shipping, and specifically on competition over the capacity supplied to a market by LNG shipping companies, although competition over price is briefly considered. Also, the possibility of non-cooperative collusion among the competing players, in order to share higher profits, is examined. The present section introduces the reader to the developments taking place in the LNG market and its dynamics.

Basic information

Natural gas (NG) is a fossil fuel consisting mainly of methane. As a primary energy source, NG has been increasing its share in world energy consumption faster than any other source in the recent years (with the exception of coal, mainly because of its use in China) and it currently accounts for about 25% of world energy consumption.

Natural gas is traditionally transported from producing to consuming countries through pipelines. The importance of this trade from an economic and geopolitical point view often makes the headlines. The supply of western European markets with natural gas from Russia and the Caspian region is such an example of pipeline transport and its complex nature, especially since a number of countries have to be crossed before gas arrives to its final destination.

An alternative and direct way (without passing through third countries) to transport natural gas is by sea using the LNG technology. NG is liquefied at a temperature of -161^{o}C and, with its volume reduced by about 600 times under atmospheric pressure, it is contained in cryogenic tankers. The LNG chain also comprises liquefaction plants located nearby the exporting ports, and regasification units located at the import terminals. A system of pipelines is of course required to transport natural gas to and from the latter (see Figure 1).

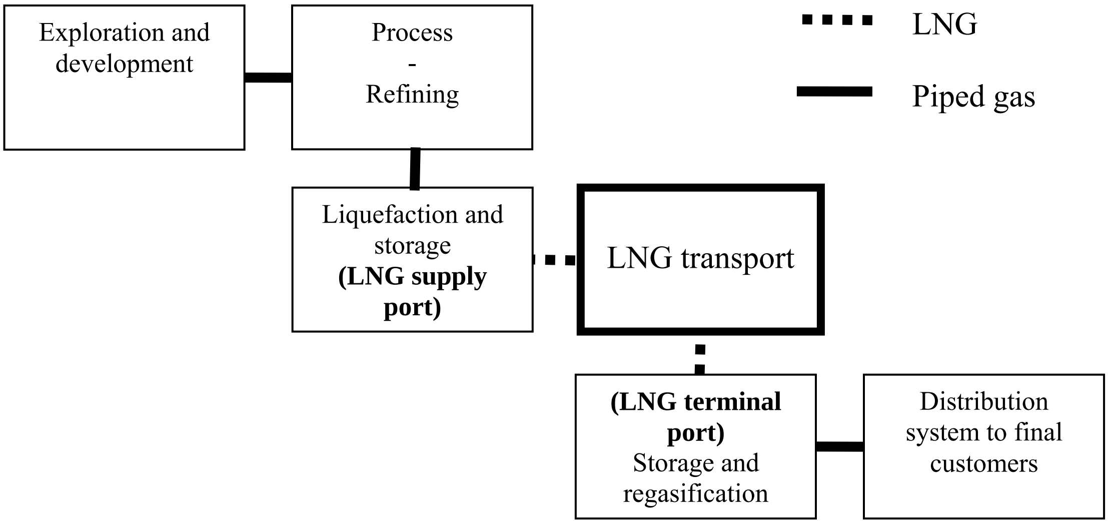

Figure 1: Schematic LNG chain

The largest reserves of natural gas are found in Russia, Iran and Qatar. The biggest producers are Russia, USA and Canada, followed by Iran, Norway, and Algeria. The biggest consumers are USA and Russia (BP, 2007).

Geographically, two main LNG markets can be distinguished, namely the Asia-Pacific and the Atlantic Basin ones (see Figure 2). In the former, predominantly Japan and South Korea (the biggest importers of LNG globally) are supplied with LNG mainly from Indonesia, Malaysia, and Australia. In the Atlantic Basin market, USA and Europe import LNG mainly from Africa (Algeria, Nigeria, Egypt), and Trinidad & Tobago (BP, 2007). The Middle East acts a swing supplier to both the above markets.

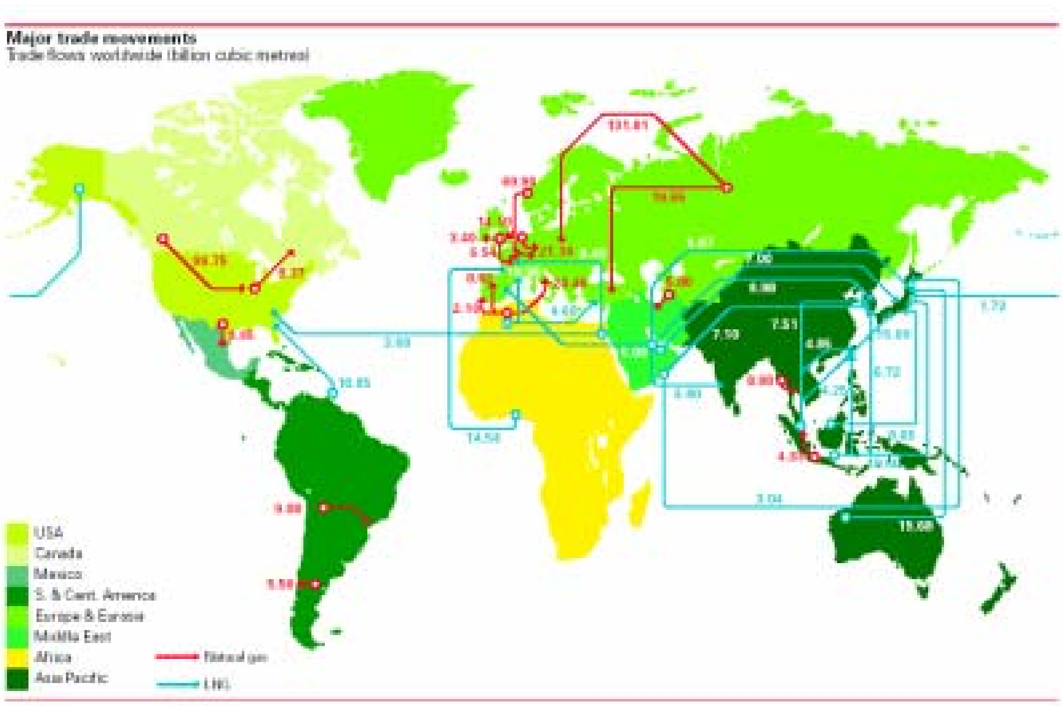

Figure 2: Global natural gas – LNG trade (source: BP, 2007)

Motives for the development of the LNG trade

The reduction in the volume of NG by 600 times, when liquefied, allows its transport as LNG on economically competitive terms compared to pipelines. Especially for transport over long distances (of the order of 3,000 miles or more, see Jensen, 2004), LNG is the advantageous option. Moreover, LNG allows trade among areas which otherwise would be technically or politically impossible to connect (IELE, 2003).

In its first stages, the LNG trade was taking place over specific routes, with ships fixed under long-term contracts. These attributes started changing in the end of 1990s.

The development of the international LNG trade was favoured by the turn to natural gas for electricity production, in order to meet the ever growing demand across developed and developing countries. NG-powered stations present economic advantages, are faster to build and are more environmentally friendly, when compared to electricity production from other fossil fuels. Moreover, NG can be burned directly as a fuel in the industrial and the household sectors with very high efficiency and minimal losses.

Significant cost reductions were achieved in all stages of the LNG chain with technological improvements (see Figure 3, where the evolution of newbuilding costs for a typical LNG vessel is shown). Moreover, contract terms had to become more elastic, in order to accommodate the need for greater flexibility in meeting the increasing demand. Gradually, a part of the market started to operate on competitive terms and to promise increasing returns. Last, but not least, LNG fits well in the security of supply considerations of national energy planning through the diversification of energy supply and sources (see for example Gkonis & Psaraftis, 2008a).

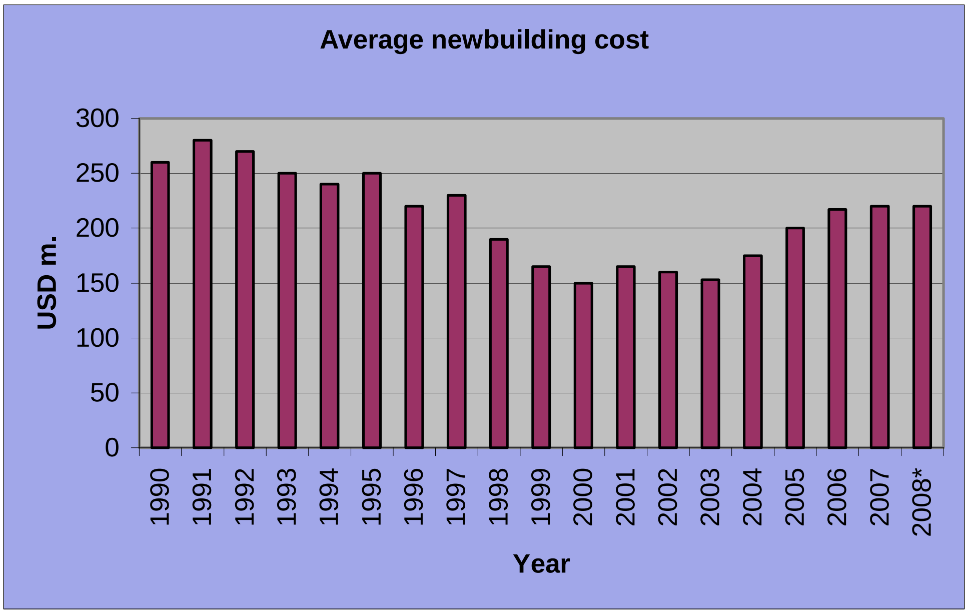

Figure 3: Typical LNG vessel average newbuilding cost (*up to July for the year 2008)

(data adapted from LNG One World website and the Shipping Economist magazine)

Characteristics and evolution of the LNG trade

The LNG trade started in the 1960s with a limited number of sailings towards European markets, soon moving to the Asia-Pacific area. As already mentioned, in the first decades it presented a rigid structure. Although most of the LNG trade is still taking place on "inelastic" terms, a growing short-term, spot, market currently represents 10-15% of the total market (PE, 2007a & SE, 2008a). In this regard, it is not unusual for cargoes to be diverted from their original destinations to take advantage of arbitrage opportunities, according to market conditions and prices. The NG prices (traditionally linked to oil prices) are increasingly indexed to NG reference prices (i.e. gas-to-gas competition develops, where NG prices are decoupled from oil prices, see Jensen, 2004).

An LNG carrier is a technologically sophisticated ship, with double-hull special design and insulated storage tanks with metallurgical properties that allow them to withstand very low temperatures. The average size of an LNG vessel has increased in the last years and it currently is about 150,000 cu.m.[1] (i.e. about 60,000 tonnes of LNG or 0.09 bcm[2] of NG). As of July 2008, the building cost of such a ship was USD 225 million. The world fleet counted 307 ships and the orderbook 119 ships (SE, 2008b). Figure 4 shows the dramatic increase in the number of LNG vessels of the world fleet and the proportionally significant size of the orderbook from 1990 to 2008.

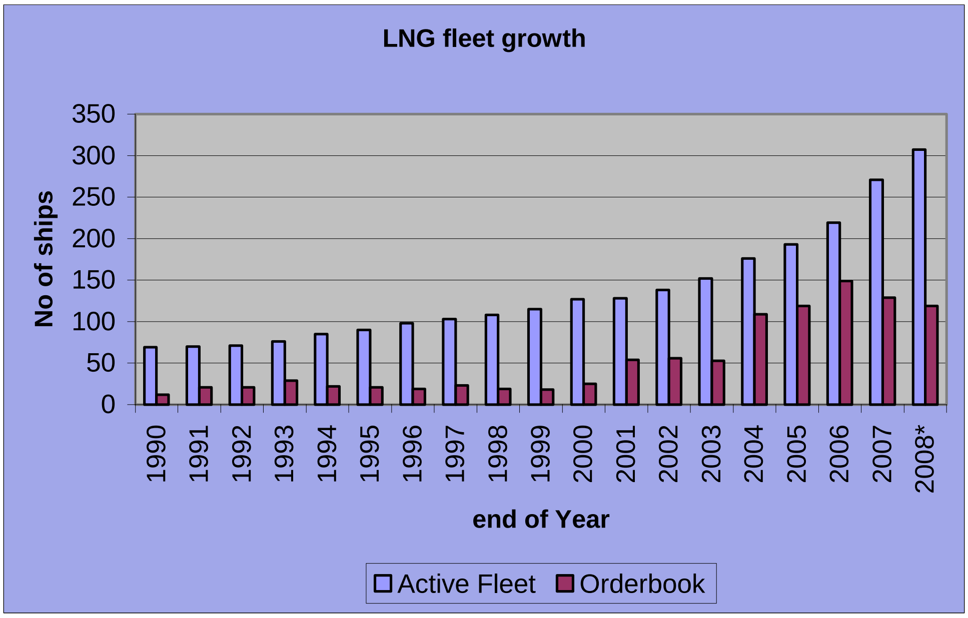

Figure 4: LNG fleet development (*as of July for the year 2008)

(data adapted from LNG One World website and the Shipping Economist magazine)

LNG market prospects

The long-term contracts between suppliers and importers will continue to dominate the international LNG trade, but they will increasingly become more flexible allowing cargoes to be traded in a growing short-term market.

In the traditional market model, the basic players in LNG shipping were integrated energy majors and national companies. The cost reductions and the versatility required by the market, in response to increased demand and new conditions in the international energy scene, opened up the “LNG club” to independent shipowners and other investors. Especially independent tanker owners showed great interest. The newcomers to the market currently own 10% of the world fleet. Their share is expected to rise as they represent 25% of orders (SE, 2007), many of which are uncommitted vessels to be launched in the short-term / high-returns market (see Gkonis & Psaraftis, 2008b, for an analysis of the strategic rationale behind such decisions).

The market projections for an oversupply of LNG shipping capacity in the next years (SE, 2007) and the recent rebound of investment costs (e.g. see Figure 3) and operational costs should be considered as temporary phenomena that will not halt the growth trend of the LNG trade in the coming decades (see Figure 5 for a projection of LNG demand in the Atlantic basin). Moreover, technological innovations, e.g. onboard regasification and FSRUs (Floating Storage Regasification Units), are expected to give a further boost to the market (PE, 2007b).

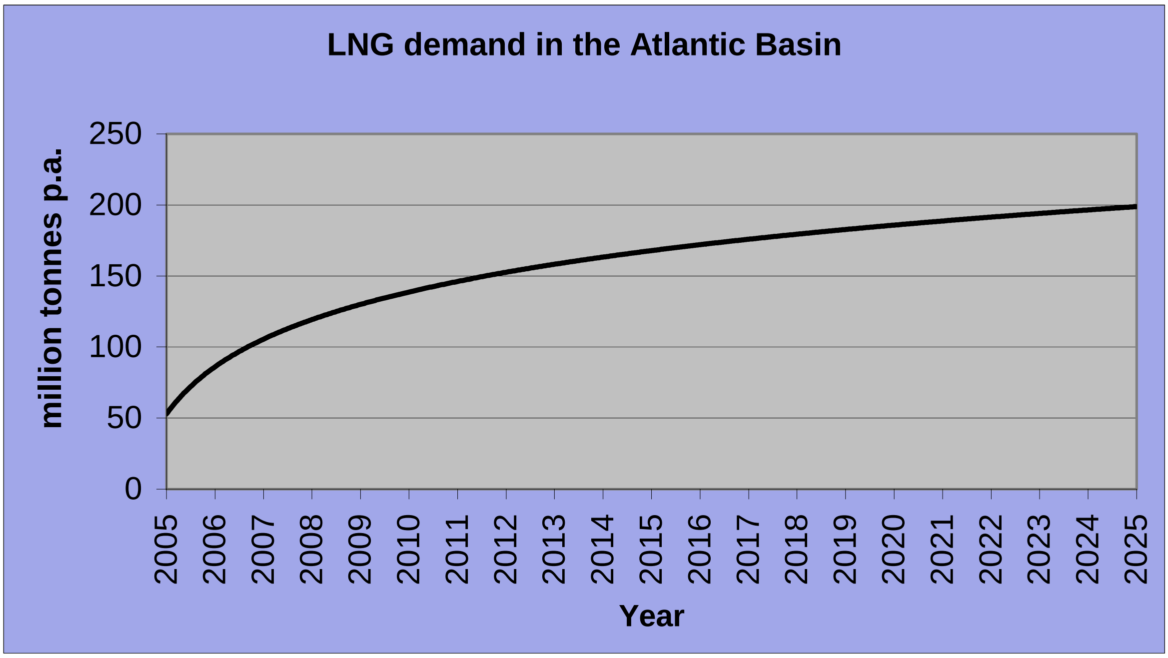

Figure 5: Atlantic basin LNG demand (in million tonnes per annum) (market estimations)

The LNG trade is growing rapidly in the Atlantic Basin market which is likely to overtake the Asia-Pacific market. Large natural gas fields are to be exploited in the Arctic zone by Russia and Norway (LL, 2007). Russia, also with the development of its fields in Siberia, may play a role in the natural gas market, similar to that of Saudi Arabia in the oil market (Chevalier, 2004). The Middle East (especially Qatar) will enhance its exporting role to both the Atlantic and Asia-Pacific market (PE, 2007b). Moreover, the energy demand in China and India will create new challenges. Security of supply considerations, through the diversification of sources, will influence the choices for the supply of energy to markets around the globe in the coming future.

In this dynamic environment, the traditional players in energy shipping, the independent tanker owners, are trying to position themselves. Investments in LNG shipping are capital intensive and relatively few and large players are able to enter and stay in the market. Consequently, the decisions of a market player are likely to influence to a significant degree the position of other players; therefore strategic decision-making is crucial at this stage.

Because of its distinctive idiosyncrasies, methodologies applicable to other shipping markets fail to support decision-making in the LNG shipping business. The LNG shipping market context is appropriate for the adoption of a game theoretic analysis framework, as it was argued in Gkonis & Psaraftis (2007). It is expected that competition will increasingly develop especially in the shipping segment of the LNG chain, which at least in its first phases will have the characteristics of an oligopolistic market.

OLIGOPOLISTIC COMPETITION IN LNG SHIPPING

An oligopoly is a market dominated by few companies. A distinctive characteristic of oligopolistic markets is that the companies - players are interrelated, in the sense that the behaviour of one player affects the positioning (in the end the profits) of other players. This interrelationship makes oligopolistic markets suitable for a game theoretic analysis. Under this perspective, competition in LNG shipping is analysed with the use of non-cooperative[3] game theory. The market actors make their decisions independently, yet knowing that these decisions are likely to influence the strategic positioning of other players.

In this paper, the Cournot and Stackelberg competition models are used to analyse oligopolistic interaction over the decision variable of capacity. Specifically, the cargo carrying capacity supplied to the market by LNG shipping companies (the “shipping service providers”) is considered. “Capacity” depends on the number of vessels in the market, their size, and their operational characteristics. These variables actually define the “discrete”-isation of the continuous capacity (volume-distance) variable.

“Price” is another continuous strategic variable in the LNG shipping business that could be considered, i.e. the charter rates for the services provided by LNG shipping companies. The current state of the LNG industry suggests that price competition in LNG shipping cannot adequately address the interaction taking place between shipping companies. The shipping link in the LNG chain is still quite weak. LNG producers (and to a lesser degree consumers) are instead the strongest players in the market, while the shipping companies act as a weaker player for the moment, which is yet a necessary link between them. The shipping tariff is not the determinant factor of the final commodity price. As a result, modelling the LNG shipping companies as price setters in the market is rather unrealistic.

Moreover, modelling oligopolistic competition in the LNG shipping market based on price would rather apply to a short-term or spot market competitive environment. Longer-term transactions are still dominant and present little flexibility as they rely mostly on rigid contract terms. “Price” could become an increasingly important parameter with the development of a substantial spot market. The so-called Bertrand competition model could represent strategic interaction in this case. Therefore, price competition in the LNG shipping market should be revisited in the future, when market conditions will favour such an approach.

For these reasons, we focus on capacity competition. The analysis that follows is based on game theoretic concepts to be found for example in Romp (1997), Smit and Trigeorgis (2004) and Rasmusen (2001).

Capacity competition

Next, the Cournot and Stackelberg competition models are presented, that can be applied to address capacity competition in a source-destination LNG trade route. It is realistic to define such trade routes in the LNG business, as exporting facilities are often developed to meet the demand of specific consumption areas. As already explained, flexibility is an increasing phenomenon in the LNG industry that allows the diversion of cargo destination, e.g. in order to exploit arbitrage opportunities. However, such developments will not make established or expected trade routes connecting specific supply - demand points disappear. Such an example, that will be illustrated, concerns NG volumes extracted by Russia from its fields in the Arctic region and serving LNG demand in the US market.

Cournot competition

Two shipping companies are opting to capture a still available volume (i.e. not contracted and waiting to be serviced) of a trade route. The question is how much LNG shipping capacity each of these companies should devote, knowing that its competitor is ready to make a similar decision.

In a Cournot competition model, companies simultaneously compete in terms of the capacity supplied to the market. Cournot (in 1838) anticipated Nash's definition of equilibrium in the context of a particular model of duopoly. In this context, the following assumptions are made:

- two LNG shipping companies A and B compete – a duopoly (the so-called *Cournot Duopoly*)
- the two companies provide the transportation of LNG cargoes, by supplying capacity in terms of volume by distance e.g. tcm·miles p.a.[4]
- supply level decisions are taken simultaneously in an one-off game (as companies do not observe the competitor's level of supply, this is a static game)
- the market price P for the offered shipping service is market-determined, so that the aggregate supply Q is just demanded. The demand curve is $P=a-Q$, where $a>0$ and constant (an inverse demand curve)
- marginal costs are c, and no fixed costs are taken into account.

Thus, in game theoretic terms the essential elements of the Cournot competition are:

<u>Players</u>: Two companies A and B.

<u>Strategies</u>: The strategies available to the two companies are the capacities supplied by each, q_A and q_B respectively.

<u>Payoffs</u>: The payoffs are their profits, π_A and π_B, which they wish to maximise.

A solution technique to approach this game is the concept of Nash equilibrium. This involves determining, for each company, the optimal strategy dependent on the other company's move. The so-called *reaction function* shows a company's optimal supply of capacity for every capacity supplied by the other company (also known as *best response* function).

To find the reaction functions of the two companies, their profit functions are differentiated with respect to their supply level and set equal to zero (this is the first order condition for finding a maximum). The second derivative must be negative (this is the second order condition for a maximum to exist). The respective calculations are:

Company A

$$\pi_A = Pq_A - cq_A \Rightarrow \pi_A = (a - q_A - q_B)q_A - cq_A \Rightarrow \pi_A = (a - c - q_A - q_B)q_A \quad (1)$$

$$\frac{d\pi_A}{dq_A} = a - 2q_A - q_B - c = 0 \Rightarrow q_A = \frac{a - q_B - c}{2} \quad (2)$$

$$\frac{d^2\pi_A}{dq_A{}^2} = -2 < 0$$

Company B

$$\pi_B = Pq_B - cq_B \Rightarrow \pi_B = (a - q_A - q_B)q_B - cq_B \Rightarrow \pi_B = (a - c - q_A - q_B)q_B \quad (3)$$

$$\frac{d\pi_B}{dq_B} = a - 2q_B - q_A - c = 0 \Rightarrow q_B = \frac{a - q_A - c}{2} \quad (4)$$

$$\frac{d^2\pi_B}{dq_B{}^2} = -2 < 0$$

Equations (2) and (4) are the reaction functions for company A and B respectively. They represent downward sloping curves, as the optimal supply for each company is negatively related to the expected level of supply of the other one (Figure 6, left side). For this reason the two companies are called *strategic substitutes* (if the correlation was positive, they would be *strategic complements*).

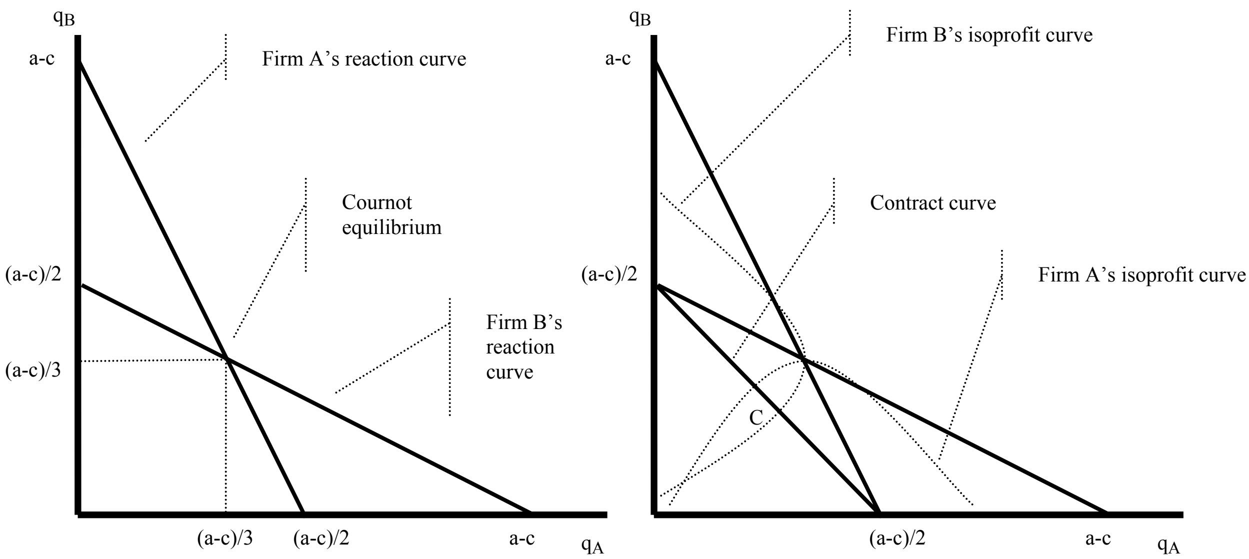

Figure 6: Cournot competition in LNG shipping

In Nash equilibrium, both companies must be maximising profits simultaneously (given the other company's capacity supply), which means that they must both be on their reaction curves. Thus, the reaction curves' intersection corresponds to the unique Nash equilibrium for this model and to a level of supply for each one equal to (a-c)/3.

An *isoprofit curve* of a company depicts the different combinations of both companies' supply that yield the same level of profit for that company (for example keeping π_B constant in equation (3) and plotting q_B against q_A provides an isoprofit curve of company B, which is in general hyperbolic). The isoprofit curve with the highest level of profit for a company is the one when the other company has an output of zero (e.g. setting $q_A= 0$ in equation (3) gives the highest level isoprofit curve for company B, which in this specific case is parabolic). In this case, the company is a monopolist and it will supply (a-c)/2, as its reaction curve suggests (see Figure 6, left side). Interestingly, the reaction curve of a company intersects all the "tops" of its isoprofit curves (as the first order condition for a maximum holds). The level of profit becomes smaller, when moving on other isoprofit curves away from the one whose "top" is the monopolist's point (the intercept of e.g. company B's reaction curve where $q_A = 0$ and $q_{B=}$(a-c)/2).

From Figure 6 (right side) it is obvious that the Nash equilibrium is not Pareto-efficient[5], as at that point the isoprofit curves of the two companies are not tangential. This means that combinations of output levels within the lens-shaped area (formed by the two isoprofit curves passing from the Nash equilibrium point) correspond to profit levels where both companies are better off. The boundary of this area is formed by the two isoprofit curves passing from the Nash equilibrium point[6]. Anywhere within this lens-shaped area, both companies have moved to isoprofit curves closer to their respective monopoly outcomes.

Isoprofit curves are tangential along the contract curve (Figure 6, right side), which shows the set of Pareto efficient outcomes. Along the contract curve, the aggregate supply level is (a-c)/2 which is equal to the capacity a monopolist would supply. Joint profits are maximised along that curve, however points outside the lens-shaped area are rejected as one of the companies would be better off on the Nash equilibrium point. Had the companies acted as a cartel, coordinating their supply levels, they could maximise profits by restricting output and increasing price along the contract curve (thus acting as a monopolist). A focal point of collusion is point C in the middle of the contract curve, where companies produce half the level of a monopolist's output.

However, C (as any other point on the contract curve) is not a Nash equilibrium as both companies are off their reaction curves. Thus, they have unilaterally the incentive to deviate from it and increase their own capacity, in order to increase their individual profit[7].

Stackelberg competition

In a similar competition setting, one of the two shipping companies may have the opportunity of capturing first a share of the volume, yet knowing that its competitor will service the rest. The question again is how much LNG shipping capacity each of these companies should be ready to devote to this market.

In Stackelberg competition, one company (the *market leader*) is able to initially pre-commit to a particular supply level, which the other company (the *market follower*) can observe and then determine its optimal output level.

The market (or Stackelberg) leader's move is observed by the market (or Stackelberg) follower and the game becomes a dynamic one. If company A is the leader and B the follower, then using backward induction B's output level is first determined. Given the leader's level of supply, B maximises profit by:

$$\pi_B = Pq_B - cq_B \Rightarrow \pi_B = (a - q_A - q_B)q_B - cq_B$$

$$\frac{d\pi_B}{dq_B} = a - 2q_B - q_A - c = 0 \Rightarrow q_B = \frac{a - q_A - c}{2} \qquad (5)$$

$$\frac{d^2\pi_B}{dq_B^{\ 2}} = -2 < 0$$

Equation (5) is the follower's reaction function and it will choose to supply a capacity q_B which is given by (5) for a given capacity q_A supplied by the leader.

Given B's reaction function, the leader will maximise its pay-off (profit) as follows:

$$\pi_A = Pq_A - cq_A \Rightarrow \pi_A = (a - q_A - q_B)q_A - cq_A \Rightarrow \pi_A = aq_A - q_A^{\ 2} - \frac{a - c - q_A}{2}q_A - cq_A \Rightarrow$$

$$\pi_A = \frac{a-c}{2}q_A - \frac{1}{2}q_A^{\ 2}$$

$$\frac{d\pi_A}{dq_A} = \frac{a-c}{2} - q_A = 0 \Rightarrow q_A = \frac{a-c}{2}$$

Thus, under the Stackelberg - Nash equilibrium, the level of supply for company A (the leader) will be q_A=(a-c)/2. From (5), the follower's optimal response will be q_B=(a-c)/4. These results are illustrated in Figure 7. The Stackelberg equilibrium point is where the isoprofit curve of A is tangential to the reaction curve of B, as A chooses to maximise its profit (i.e. to be on the isoprofit curve which is closest to its monopoly isoprofit level) under the requirement that the follower is on its reaction curve[8].

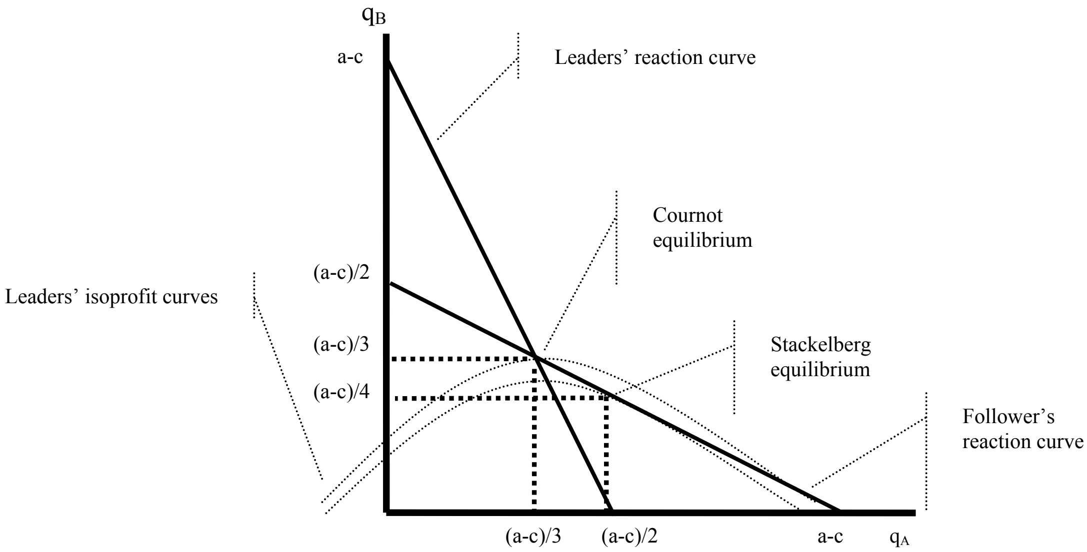

Figure 7: Stackelberg competition in LNG shipping

Compared to the Nash-Cournot equilibrium, the Stackelberg equilibrium corresponds to a higher total capacity supply and lower total profits. However, it suggests a higher profit for the leader and a smaller profit for the follower or, in other words, the first mover gets a larger share of the smaller pie. The leader is able to pre-commit to a higher level of supply and gain a *first-mover advantage*.

Illustration

As an illustration of the above models, a future trade route is considered connecting NG liquefaction facilities in the Russian Arctic region (supply point) with regasification terminals in the US (demand point). The distance is 4,000 miles. The production capacity of the liquefaction facilities at the supply point is 13 bcm of natural gas p.a. Thus, the trade route's annual volume can be served by a transportation capacity of Q = 52 tcm·miles (we consider only the laden leg of a round voyage in the calculation of transport capacity).

Two LNG shipping companies are competing over the service of the above trade route and need to decide on the transportation capacities to be supplied by each, q_A and q_B respectively.

Case 1: Decisions are taken simultaneously (Cournot competition).

Assuming the case where both companies would serve the total trade volume on an annual basis, i.e. Q= $q_A + q_B$, then under Cournot competition (see Figure 6):

$$q_A = q_B = \frac{a-c}{3} \qquad (i)$$

$$\Rightarrow \quad \frac{Q}{2} = \frac{a-c}{3} \Rightarrow \quad a-c = \frac{3Q}{2} \qquad (ii)$$

$$and \quad (i),(ii) \Rightarrow q_A = q_B = \frac{Q}{2}$$

which translates into the supply to the specific trade route of a transportation capacity of 26 tcm·miles annually by each. Assuming an average size LNG vessel of 145,000 cu.m., with an operational speed of 19.5 knots, operating 355 days per year and spending on average one day at each port, the above transportation capacity to be devoted by each company corresponds to a fleet of 4 LNG vessels.

If only one company served the trade route, then acting as a monopolist, and under the above assumptions, it would supply a transportation capacity of (a-c)/2 = 3Q/4 = 39 tcm·miles annually, which corresponds to a fleet of 6 LNG vessels. This fleet does not serve the total annual trade volume, but increases the price of the service and achieves maximum profits for the monopolist.

If the two companies acted as a cartel and coordinated their capacity supply levels, then they would maximise profits by restricting their total transportation capacity to 39 tcm·miles (imitating a monopolist) along the contract curve as in Figure 6. The focal point of collusion would be point C, where companies supply a fleet of 3 LNG vessels each.

Case 2: Company A has a first mover advantage (Stackelberg competition).

Assuming again that at the Cournot equilibrium $q_A + q_B = Q$, then at the Stackelberg equilibrium (see Figure 7), company A, which has the first mover advantage by deciding first on capacity supply level, will devote in the service of the considered trade route a transportation capacity of (a-c)/2 = 3Q/4 = 39 tcm·miles annually, which corresponds to a fleet of 6 LNG vessels. The market follower company B will supply (a-c)/4 = 3Q/8 = 19.5 tcm·miles annually, which corresponds to a fleet of 3 LNG vessels.

Overall, under Stackelberg competition the two companies will provide 9 LNG vessels, i.e. 1 more than under Cournot competition, and will achieve lower combined profits. However, the leader will gain a higher profit, while the follower a lower one compared to Cournot competition.

Comments

The Cournot and Stackelberg models provide some useful intuition regarding capacity competition in LNG shipping. An LNG trade route was considered as an example, where a demand point in the US market is supplied with gas from a supply point in Russia. Two shipping companies are willing to service an available volume of this trade. Their decisions resemble to a Cournot or Stackelberg interaction, depending on whether a leader exists or not.

The first main suggestion is that they must take into account the shipping capacity supplied to the market by the competitor. The respective model can provide an aggregate indication of the optimal supply of capacity. In capacity competition, competitive reactions are strategic substitutes (downward-sloping reaction curves) and they can be called *contrarian* (Smit and Trigeorgis, 2004). The best response to a competitor's move is to do the opposite. When a rival increases its supply of cargo carrying capacity, a company's profits fall. They can be improved, if the company reduces its own supply.

A second remark concerns the definition of capacity. As already mentioned, capacity can be expressed in terms of volume by distance (e.g. tcm·miles). However in practice, the volume is determined by both the number of vessels launched in the market and their size. The capacity variable is not actually continuous, but discrete in steps.

The same capacity can be supplied by a number of small ships or fewer bigger ships. Although bigger ships enjoy economies of scale and are the current trend in the market, smaller ships can achieve a better approximation of the optimum supply level of a shipowner in a given market.

In the discussed Illustration, if the natural gas production level at the supply point is reduced to 11 bcm p.a., then under Cournot competition each company should devote 3.4 LNG vessels of 145,000 cu.m., i.e. one vessel should operate with a loading factor of 40%. Instead, if the companies employed a fleet of 3 vessels of 145,000 cu.m. and 2 vessels of 70,000 cu.m., then when the trade volume reduced to 11 bcm p.a., they would employ all 3 large LNG vessels at their full capacity and one of the small ones with a loading factor of about 80%. The other small vessel could be disengaged from the considered trade route. So the existence of smaller LNG vessels in a shipowner's portfolio may give him greater versatility and adaptability compared to a portfolio consisting only of large scale vessels.

The possibility of non-cooperative collusion

The equilibria suggested in the previous models are Pareto inefficient. With effective collusion, the companies could achieve higher profits. As it was explained, the problem is that without binding contracts, the players that participate in a collusion state have an incentive to deviate from it. However, the possibility of non-cooperative collusion is theoretically supported under certain conditions (see also Gkonis & Psaraftis, 2007).

What game theory suggests in the case of infinitely repeated oligopoly interaction

In infinitely repeated oligopoly interaction, non-cooperative collusion can be maintained if players adopt credible punishment strategies. These punishment strategies induce companies to maintain the non-cooperative collusion outcome and avoid deviating to Pareto inefficient outcomes. One such strategy is the so-called *trigger strategy*. A certain action by one player makes other players permanently change the way they act and so the prospect of an infinite punishment period exists, if deviation from the collusive outcome occurs.

In the illustration considered above and assuming that the companies are able to alter their capacity supply periodically, e.g. on an annual basis, a trigger strategy is for both companies to supply half the monopoly capacity level in the first year as a collusion point (as it was so identified) and continue to do so until one of them deviates (this action is the trigger). Then the response is to supply the Cournot – Nash capacity for ever (the punishment).

The threat to switch to the Nash equilibrium point is credible as a rational response to deviation from collusion. The promise to supply the collusion capacity is also credible[9]. The threat of a more severe punishment is not supported in the discussed model, as it would not be credible (the only credible punishment strategy is the supply of a Nash equilibrium capacity that corresponds to the intersection of the two reaction curves[10]).

An infinitely repeated interaction is not a realistic assumption for a real-world interaction such as the one concerning the two LNG shipping companies of our illustration. However, this assumption can be replaced by total uncertainty of companies about when their interaction might actually end, which sustains the non-cooperative collusion. This and other conditions under which such collusion can be sustained are discussed next.

Finitely repeated oligopoly interaction

The so-called "chain-store paradox" (Selten, 1978) says that non-cooperative collusion cannot be supported in finitely repeated games. Specifically, using backward induction, the last period is first examined where the Nash equilibrium is played in a one-off game. Moving backwards, the first time period is reached and in all stages the unique Nash equilibrium will have been played. The reason is that a finitely repeated game is qualitatively different from an infinite game (Romp, 1997). The structure of a finite game changes as the final period is approached, which does not happen in an infinite game. Several ways can be suggested to overcome the paradox of backward induction in finitely repeated Cournot interaction.

The existence of multiple Nash equilibria (A, B, C in Figure 8) means that the outcome in the final game is not uniquely determined (there is no unique prediction about the last period of play). In this case, companies need to coordinate on focal points. This term was used by Schelling (1960) to describe strategy combinations, which for some reason are more compelling and give a more likely prediction of the actual outcome among numerous Nash equilibria. The focal points may be provided by past history or some special characteristics of the specific combination.

If the outcome in the final period is not uniquely determined and the equilibria correspond to different levels of profit for the companies, a collusive outcome is more easily sustained in the early periods of the game. The existence of multiple Nash equilibria moreover allows companies to be punished more efficiently, if they deviate from the collusive outcome. As the final period is approached the non-cooperative collusion collapses, as the outcome in the final period must be a Nash equilibrium (Romp, 1997).

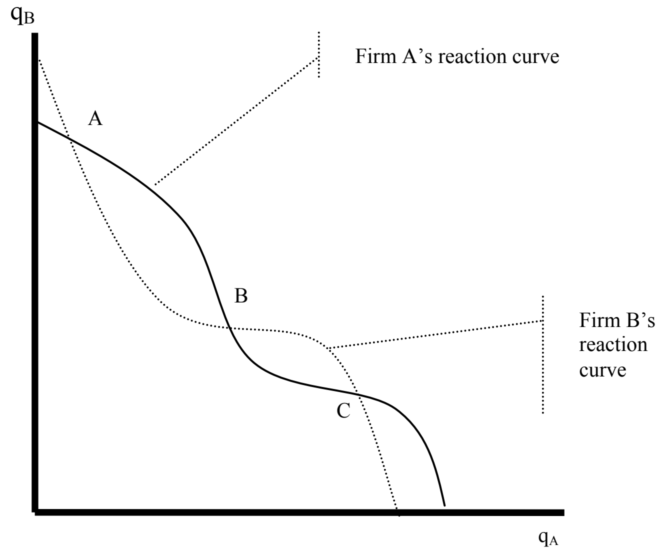

Figure 8: Multiple Nash Equilibria in Cournot competition

Uncertainty about the future, such as uncertainty about when the game will actually end, can also overcome the paradox, as already mentioned. In this case, players can place credible threats and promises because there is only a possibility and not a certainty that the game will end in the next period.

Uncertainty about other players in the game is another way to overcome the paradox. Such uncertainty may have to do with the parameters of the competitors' profit functions. Incomplete information leads to the need for the introduction to the analysis of concepts such as the Bayesian Subgame Perfect Nash Equilibrium, which is beyond the scope of this paper.

Overall, game theory supports the possibility of non-cooperative collusion even in finitely repeated interactions, as in an LNG shipping capacity competition. However, for the punishment strategies to be effective, there should be a way for companies to detect deviation when it occurs. Otherwise they may cheat without fear of being punished. A mechanism for sharing information on supplied capacities may therefore be required for the collusive outcomes to be sustainable.

CONCLUSIONS

In this paper, an introduction to and an overview of the LNG market was provided and, more specifically, the developments in its shipping segment were discussed. LNG shipping is a specialized bulk trade in energy shipping. Compared to its parent markets, the oil trade and the onshore gas markets, it differentiates substantially, because of its limited fluidity and because it is not expected to reach in the near future similar levels of mature competition.

However, its growth rate and the opening up to new players with the adoption of more flexible terms of operation, makes it a most promising field in the shipping industry.

The focus was placed on oligopolistic capacity competition taking place in LNG shipping and the Cournot and Stackelberg game theoretic models were used for this purpose. The competing companies are strategic substitutes and the first main suggestion is that they must take into account the capacity each one supplies to the market. The respective model can provide an aggregate indication of the optimal supply of capacity, depending on whether a leader exists or not. As a second remark, it was noted that in practice the supplied capacity is determined by both the number of vessels launched in the market and their size. The advantages by the existence of smaller vessels in a shipowner's portfolio that give him greater versatility and adaptability should be compared to the economies of scale advantages that a portfolio consisting only of large scale vessels enjoys.

Finally the possibility of non-cooperative collusion in oligopolistic competition in the LNG shipping business was examined, as the equilibria suggested in the previous models are Pareto inefficient. If companies face one-off competition, collusion seems unlikely. However, under continuous interaction, non-cooperative collusion can be sustained. A remark of potential commercial value has to do with the need to detect deviation from collusion when it occurs. Otherwise companies may cheat without fear of being punished. A market mechanism (service) for sharing information on capacities supplied in the LNG shipping markets may therefore be required for the collusive outcomes to be sustainable.

In the changing environment of the LNG market, new entrants, such as the independent oil tanker companies, are opting to capture a share in its trade routes. Strategic decision-making is crucial and this paper proposes game theory as a support tool. The considered models (as any model) present limitations and rely on imposed assumptions, e.g. regarding the relation of the market price to total capacity supply. However, the main purpose has not been to provide readily usable results for real world applications, but to introduce a new analysis rationale and demonstrate the potential usefulness of game theory as a supplement to the intuition of market players, as it helps in identifying right strategies given certain conditions.

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ENDNOTES

[1] Although ships of up to 270,000 cu.m. are under way.
[2] bcm: billion cubic metres.
[3] The players are unable to enter into binding and enforceable agreements. In *cooperative* game theory such agreements are possible.
[4] tcm p.a.: trillion cubic metres per annum
[5] An outcome or equilibrium is Pareto-efficient when, by choosing another strategy, no player gains without another player loosing. In other words, when a player is made better-off, someone else is always made worse-off
[6] On the boundary of the lens-shaped area, except from the intersection points of the isoprofit curves, one firm is better off and the other indifferent compared to the Nash equilibrium profit level.
[7] This situation corresponds to a prisoner's dilemma game and is a classic argument for why a cartel might be unstable.
[8] The leader knows that the rival will react to its choice, so it picks the point on the rival's reaction curve that maximizes its profit.
[9] This is true, if the present value of maintaining collusion exceeds the present value of deviating from it. It can be easily proved that this will happen if the discount rate is small enough, that is if future profits are not discounted a lot (in this latter case the current profit matters more).
[10] Romp (1997), referring to the game theory literature, mentions that a more severe punishment strategy that lasts only for a temporary period is sustainable (a carrot-and-stick strategy). This is an application of the Folk Theorem, which shows that any capacity combinations that Pareto-dominate the minimax strategy are part of a subgame perfect Nash equilibrium provided that companies do not discount the future too much and that they adopt appropriate punishment strategies.