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2 authors:

Angela Stefania Bergantino
Università degli Studi di Bari Aldo Moro

Albert Veenstra
Eindhoven University of Technology

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Interconnection and Co-ordination: An Application of Network Theory to Liner Shipping

ANGELA S BERGANTINO[1] AND ALBERT W VEENSTRA[2]

[1]Department of Economics, University of Bari, Via C. Rosalba 53, 70124 Bari, Italy. E-mail: abergan@tin.it; [2]Center for Maritime Economics and Logistics & Department of Management and Information Systems, Erasmus University Rotterdam, PO Box 1738, 3000 Dr Rotherdam, The Netherlands

Significant changes in the world economy, mainly linked to the increased internationalisation of the economy, have induced container shipping companies to rethink their strategies to face demand. Traditional forms of co-operation, generally based on route-related agreements, have been substituted or integrated with more articulated forms of alliances, the so-called global alliances, and a wave of mergers and acquisitions have taken place in the sector. The rationale behind the new strategies of the operators is that of extending market coverage globally. Global strategic alliances, alongside with more traditional agreements and with mergers, contribute towards establishing the interconnection of individual companies' networks; however, the former respond more directly to the need to extend the geographical scope of business and to offer higher quality services. The scope of this work is to investigate, within an analytical framework based on the recent literature on network theory, the functioning and the evolution of forms of co-operation in liner shipping; in particular of global strategic alliances. It is found that, while the exploitation of network externalities is the main scope of shipping network integration and one of the most important elements in determining their optimal size, co-ordination costs are often of such strength that nullifies their effect. This appears to be the main cause of the instability of such agreements and of the permanence of business integration initiatives alongside forms of network connection. Furthermore, it is shown that the potential cost saving advantages of interconnection are, often, not fully exploited due to the frequency with which restructuring takes place within the industry.

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INTRODUCTION

Historically, the nature of liner shipping and the resulting cost structure (high fixed costs, indivisibilities, and so on) have given rise to the need for operators to co-ordinate their activities with competitors. This has led to the existence of various forms of co-operation, such as conference agreements, consortia and pools in the industry. In the last decade, more flexible and encompassing forms of co-operation have emerged — the so-called global strategic alliances.

The common element at the origin of this trend is the need to respond efficiently and effectively to the challenges posed by an ever-increasing demand for global and cheaper transportation services. To varying degrees, the different forms of co-operation, in fact, allow operators to rationalise their services, while enlarging the scope of their activities, and to achieve cost savings. In particular, global alliances have proved to be very successful on this front and have become, today, predominant in the major routes for container traffic (Thanopoulou *et al.*, 1999).

In the last few years, however, one could observe an increasing number of large-scale mergers among important shipping operators, generally already partners of alliances. The co-existence of alliances and mergers, the fact that only in some cases the companies merging are partners in the same alliances — often, they belong to different alliances operating in distinct geographical areas — and the survival of the more traditional forms of co-operative agreement raises the questions of whether these processes are linked and, given that there still is a continuous drive towards the extension of service coverage, whether an optimal level of horizontal integration in the shipping industry might be reached.

In this paper, we suggest that the investigation of the liner shipping industry from a network theory perspective can shed some light on these issues. Analysing the sector from this stance will stimulate a better understanding of the process of business integration and of its determinants. Network theory, in fact, allows a reinterpretation of the process of alliance formation, occurrence of mergers and more generally, of service integration as a process of network interconnection. Within this theoretical framework, operational co-ordination is a central theme in determining the extent of the co-operative process that takes place among the different operators.

The paper is structured as follows. In the second section, we illustrate a conceptualisation of liner shipping activities as networks and discuss the main determinants of co-operation in this sector. In the third, we define alliances and examine the driving forces behind their diffusion. The following sections contain an illustration of the different stages in alliance formation and a brief discussion of the effects of interconnection and integration at network level. Consequently, an evaluation of the available market information on co-ordination and integration in liner shipping is presented in the light of the theoretical predictions. Finally, some concluding remarks are offered.

LINER SHIPPING AND NETWORKS

Network industries are an indispensable element of our current economy in providing basic services to all other sectors. The typical features of such industries are: heavy fixed cost, substantial economies of scale and elements of non-contestability in the market in which the service is offered. However, despite these common characteristics, significant differences exist between these industries. The network sectors, in fact, cover a range of very diverse industries in terms of growth (telecommunication *versus* railways), capital intensity (air transport *versus* postal services), degree of internationalisation (parcel services *versus* water supply) and degree of competition (monopoly in most railways *versus* effective competition in non-reserved postal services).[1]

Liner shipping shares with some of the more traditional network industries, such as railways, telecommunication and water supply, three fundamental technical characteristics (David, 1992):

- its production facilities (ie ships) have significant indivisibilities;
- technical performance involves interconnectedness with other operators (both at the same level of the logistic chain and at different levels); and
- benefits of users/producers of the services are dependent on the presence of other users/producers (network externalities).

The liner shipping industry can, thus, be defined as a network industry by analogy with other network industries. In particular, as the latter, this industry is formed by a system of nodes and links, which can be identified with ports and sea-lanes, respectively.

While this conceptualisation of the liner industry is widely acknowledged,[2] less evident is the relationship between the single firm part of the industry and the whole shipping network (Bergantino and Veenstra, 2000). However, in order to understand the workings of the system, it is necessary to identify the role played by the individual companies. The nodes and the links forming the liner shipping network, in fact, become effectively connected the moment a liner shipping operator decides to serve a certain port: prior to this decision the network exists only potentially. A shipping company, therefore, can be identified with the sub-network it represents and the set of shipping companies operating their ships can be considered as the various components of the global liner shipping network. Their presence transforms the network from virtual (Figure 1A) to real (Figure 1B).

By associating, shipping companies 'connect' their individual sub-networks forming a larger and integrated network, part of the potential liner shipping network (Figure 2A). The beneficiaries of this 'new' network are both the companies (producers) and the shippers (consumers): the latter because they are able to take advantage of the increased connections available, the former because they can offer a better service in terms of accessibility and geographical coverage (higher quality of service). Additionally, by co-operating, operators can rationalise their activities and routes achieving significant cost savings (Figure 2B).

The issue of network externalities

For some goods or services, consumers' utility increases with the number of subjects consuming the same good or service: they are said to exhibit positive reciprocal externalities in consumption (Katz and Shapiro, 1985). In a network context, the above can be rephrased as: there are goods or services for which the utility of the single user depends on the number of the other users that are in the same network. Capello and Nijkamp (1995) further point out that a good or

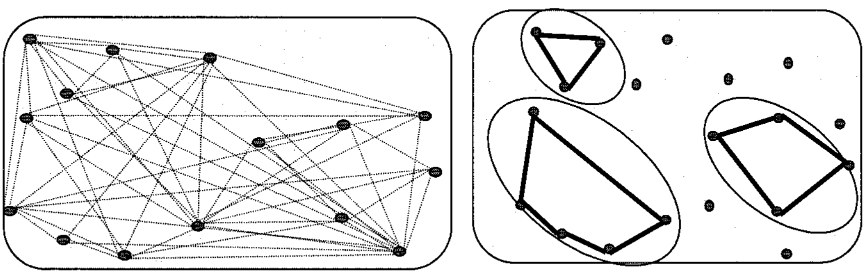

Figure 1: Potential shipping network *vs* companies' sub-networks (A-B)

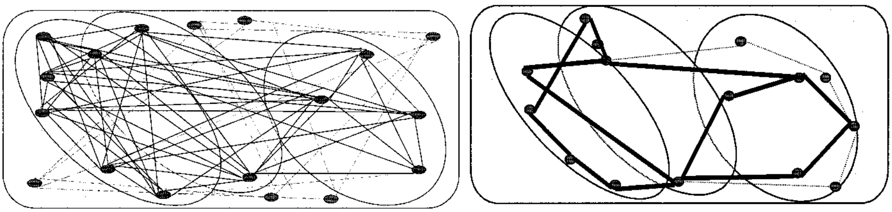

Figure 2: Co-operation and rationalisation (A-B)

service is characterised by network externality if the utility to users increases with usage and if, at the same time, this does not imply an increased 'cost of access'. In fact, it can be said that a good or service would be characterised by network externality if the utility the user receives from its consumption (usage value for the network) increases with the use of the good or service by other agents and if to those increased benefit corresponds no compensation.

Thus, with respect to networks, the term externality might refer to:

- the interdependence of consumers' utility when the behaviour of other persons enters the utility function of each agent;
- the direct interdependence between producers when unpaid factors generated by third party enter the production function of each firm; or
- the interdependence between producers when the profit function of each firm depends on the activities of other producers that affect the market.

While generally, in most network industries (telecommunications, hardware/software, etc), it is *consumers* whose preferences exhibit network externalities, in transportation industries — and in particular in the liner shipping sector — it is 'the production technologies' of *producers* which 'exhibit economies of network' (Shy, 2000; p.215). In other words, in our specific context, network externalities can be interpreted as the increased utility that the additional member of the alliance achieves by connecting to it which is not accompanied by an increase in the costs of accessing the service (ie administrative, organisational, operational costs).

When joining the alliance, the utility of the participating companies depends positively on the number of other participating shipping operators (producers), since an increase in the number of members augments the utility (profits) of each individual member who will be able to be part of a wider network. The companies therefore enjoy the positive effects generated by the interdependence of their utility functions, which are not offset by increased costs associated with their participation (no-compensation criteria). The concept of network externality is, thus, closely linked with network size (dimension) and cost related aspects.

The issue of dimension and cost savings

Two main driving forces can be identified behind the attempt of liner shipping operators to interconnect services: (1) increase the network dimension and, thus, the service coverage and market power; and (2) rationalise costs. Both these factors have special relevance in liner shipping.

The issue of dimension is strictly connected with the fact that, like in many other network industries, the components of the network are subject to physical capacity constraint. While in the shipping industry, network links are virtual (since they do not have a 'physical' structure) — and thus, saturation is less likely to occur and adaptation to volume increases is relatively easy to achieve[3] — ship size and ultimately fleet size cannot be instantaneously adjusted to face changes in demand. The same holds for the nodes (ie ports). Ports, in fact, might actually reach congestion, either on the sea side or on the land side. Capacity adjustment in liner network cannot be continuous: it is determined, instead, by stepwise increments through the addition of new ships or new infrastructure and by taking into account capacity of other links in the logistics chain.

Co-operation among operators might lead to reducing the need to introduce additional physical capacity by:

- rationalising and jointly owning vessels;
- a common organisation of activities and service schedules;
- jointly controlling container repositioning;
- implementing own hub and spoke systems;[4] and/or
- linking up with networks of different types, such as intermodal operators or operators of different modes of transport, forming an extended network involving a greater set of possible origins-destinations and a wider spectrum of services.

In their operations and as a result of increased co-operation, however, companies have to co-ordinate their activities continuously, both internally and externally; in the latter case either with other shipping companies or with other parties in the logistic chain.

While standardisation has, partly, solved the problem (see Carlton and Klamer, 1983), the complexity of the transport activity continues to require additional co-ordination efforts, which generally lead to further co-operative agreements or horizontal integration. Co-ordination costs in the liner shipping business are related to:

- changing, adding or deleting routes and ports of call on existing routes;
- re-routing ships;
- reconsidering slot-charter agreements;
- changing the ship mix of the (joint) fleet (resulting in S&P, ordering, scrapping), reorganising, adding, selling port terminals and inland transport networks; and/or
- forming or breaking up co-operative arrangements, such as conferences, alliances and mergers and acquisitions (setting up or splitting secretariats, agency activities, restructuring organisational activities, changing IT systems, and so on).

From a network theory perspective, the integration of liner services, through co-operative agreements among shipping companies, can be analysed in the light of the concept of interconnectivity:[5] the newly formed network would consist of multiple sub-networks linked to one another and capable of offering a better co-ordinated and rationalised service. The mechanics of this process are analysed below.

Interconnecting service networks through co-ordinating and rescheduling sailings on common or partly common trades and sharing facilities and equipment could result in significant cost savings.[6] Thus, when rationalising activities internally and dealing with direct competitors becomes excessively costly, the options available to the individual companies range from signing some form of co-operative agreement with other companies to deciding a full-scale merger. As Carlton and Klamer (1983) point out, it is the level of co-ordination costs that makes the difference: if this is moderately high, firms will integrate networks through co-operative agreements, if it is extremely high, or become excessively high on account of the difficulties in co-ordinating activities, companies may consider merging.

It might be for this reason that the liner shipping sector has been, traditionally, highly concentrated[7] and characterised by the coexistence of interlocking operating areas, long term contracts, joint-ventures, mergers and other forms of co-ordinating agreements, such as global alliances.[8] The measurement of co-ordination costs would, thus, contribute to identify the boundaries between forms of co-operative agreements and mergers and to shed some light on the important policy question whether or not alliances might represent a pre-stage of mergers.

GLOBAL ALLIANCES AND NETWORKS

Global alliances have been considered as a substantial breakthrough in the industry's co-operative practice. Unlike previous partnerships, they are not limited in scope, but aim to cover greater geographical areas and to extend their influence over the global market well beyond vessel operations towards shared use of terminals, joint equipment management, inland transport and logistics, joint purchasing and procurement (Clarke, 1997).

Oum *et al.* (2000) point out that there is no generally accepted definition of global strategic alliances in the literature. Nevertheless, in the context of liner shipping, a strategic alliance may be defined as an agreement of two or more firms who attempt to enhance their competitive advantages collectively *vis-a-vis* competitors on a global marketplace. This is done, generally, by sharing risks and scarce resources including brand assets and market access capability, enhancing product quality, customer services and market accessibility, and thereby, improving profitability. Global alliances, however, in contrast to other types of alliances, do not include joint management and executive functions, joint multi-modal pricing, common tariff agreements and revenue pools.

In practical terms, a global alliance is one involving strategic commitment by top management to link up a substantial part of their respective route networks as well as collaborating on some key areas of the business. This type of alliances allow users to perform vessel planning and co-ordination on a global scale (whereas separate tie-ups on individual routes can lead to unproductive conflicts of interest and sub-optimal fleet deployment), to share risks and investments, to obtain economies of scale (as larger alliances allow a line to enter a trade even without the deployment of additional tonnage, simply by using slots on its partners' existing services), to increase frequency of services (as global partnerships offer great potential for enhancing overall frequency and allow multiple fixed-day-of-the week sailing) and to combine purchasing power and volumes. Thus, they can drive down the cost per unit of container handling, intermodal and feeder services (Midoro and Pitto, 2000; see also Gardiner,1997 and Brooks, 2000).

Global strategic alliances seem to highlight, more than the previous forms of organisations typical of the liner shipping sector, the network character of the industry, taking greater advantage of the potentials offered by the interconnection with other networks. On the one hand, their structure allows them to easily expand by either connecting with other operators (of the shipping business or of related activities), or with other existing co-operative agreements: they could be seen as intermediate stages between the myriad of sub-networks of the individual companies and the global liner network. On the other hand, their members can take advantage of the so-called network externalities more readily than the participants of more traditional forms of co-operation agreements (Bergantino and Veenstra, 2000).

In the remainder of this work, recalling that within transport industries networks externalities are exhibited by the producers, we identify alliances as the 'infrastructure' providing organisations and shipping operators as their 'clients' or 'users'. In other words, they can 'connect' to the alliance by becoming members. By so doing, the shipping operators will add a partial or complete set of new relations (increase geographic coverage or scope), thus benefiting other participants. They will integrate their network with the existing one.

By taking shippers as the users, this extension of the network would not occur since they will simply 'use' the existing (network) service. In transport networks, in fact, it is possible to identify two different levels of relationships: one concerns the physical network directly, the other concerns the service network directly and the physical network only indirectly. In the former the transport company is the actual user of the physical structure it constitutes by co-operating, in the latter the shipper is the user of the services provided by the transport services supplier. The shipper does not 'connect' to the infrastructure directly.[9]

In the following sections, we present a possible formalisation of the advantages of alliance formation and an illustration of the effect of interconnection on the co-operation process. In particular, we show the benefit that individual companies might have in participating in the agreements and identify the possible evolution these arrangements might have. Since, among the various types of alliances, strategic global alliances are the ones that place more emphasis of the geographical coverage of the market — and, thus, on the overall dimension of the network — the following analysis is particularly suited to explain their evolution.

Stages in alliance formation and evolution

Adapting the approach used by Noam (1992) for the telecommunication industry, we propose a model of alliance formation and evolution. Let the total cost of the alliance serving (composed of) n homogeneous participants[10] be given by:

$$TC(n) = F + c(n), \tag{1}$$

where F is the fixed costs ($F > 0$) and c is its variable cost. The marginal costs would be:

$$mc(n) = \partial c(n)/\partial n \geq 0 \tag{2}$$

An operator's net utility (profits) from joining the network would be given by $u_i(-r, v, n)$ where r is the 'fee' that the operator has to sustain to access the services offered by the alliance, in particular, the share of the administrative costs connected with running the network plus the cost that each operator has to sustain in order to reorganise its service to fit in the network (co-ordination costs) and v is the gross benefit (revenues). The latter can be interpreted as the advantages from partnership (greater diversification, increased geographical coverage, higher overall quality level, and so on).

Assuming that the participation to the alliance is priced at average cost (ie operators share costs equally), we have:

$$r(n) = TC(n)/n \tag{3}$$

While the network is in its cost-sharing phase, $r(n)$ will be declining. We also assume that, *ceteris paribus*,[11] the more members are on the network[12] the better off a user is (ie network externalities exist), but that utility increases at a declining rate:[13]

$$\partial u_i/\partial n > 0 \tag{4}$$

$$\partial^2 u_i/\partial n^2 < 0. \tag{5}$$

For simplicity, utility can be expressed in monetary terms:

$$u_i(-r, v, n) = v(n) - r(n) \tag{6}$$

As specified earlier, a necessary condition for the users of the network to take advantage of the network effect is that this has reached a 'critical mass' or, in other words a 'minimum dimension'. In this case, critical mass can be defined as the smallest number of operators that allow *v(n)* to be equal to *r(n)*. If the alliance does not have such a minimum size, the advantages are not large enough to induce potential participants to enter ($v(n) < r(n)$). To reach n_1 requires a subsidy either by government or by the company's willingness to accept losses in the early phases of operation (this is a condition in which liner companies would often find themselves when starting up services, for instance, on a new route). Beyond the critical mass the alliance has, instead, sufficient size to potentially attract new participants and increase by itself, without the need of external inputs ($v(n) > r(n)$).

The above is illustrated graphically in Figure 3, where *AC* is the average cost curve of the alliance, which, according to (3), indicates also the participation fee ($r(n) = AC$), and $u(n) = \Sigma_i u_i(-r,v,n)$ is the utility function of the users of the network. As it will be seen, the figure illustrates also other useful concepts related to network sustainability.

A second issue which is of great relevance in the study of alliances is that of its private optimal dimension once the critical mass has been achieved. In Figure 3, this point is indicated by n_2. While this point is beyond that of minimal cost, n_0 (where average cost is equal to marginal cost), the alliance is likely to expand up to n_2 because additional participants will continue to add utility. As it can be seen from the figure, in fact, the net utility of joining the network continues to rise after the n_0 point and reaches a maximum value at the n_2 point, after which, the

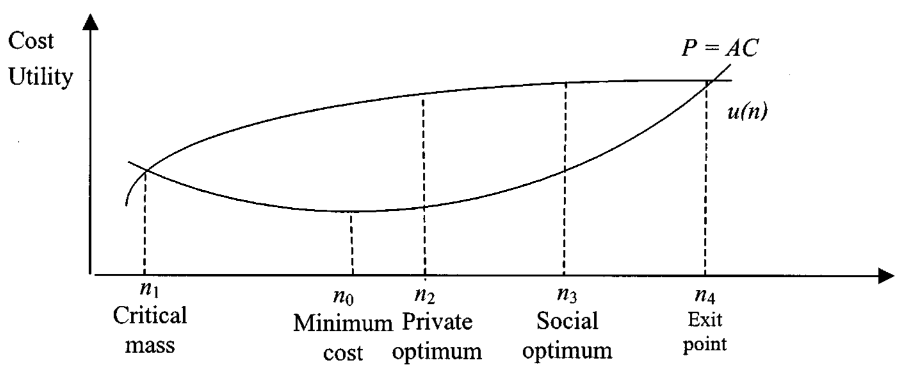

Figure 3: Stages in alliance formation and expansion (adapted from Noam, 1992)

alliance members would not accept any additional participants.[14] The increase of costs after n_0, instead, indicates that economies of scale or scope have been fully exploited in the first phase of the alliance expansion. Growth beyond the cost minimisation point is thus induced solely by network effects.

From Figure 1, one can see that the cost function and the utility function share a second intersection point, n_4. This represents the exit point: ie the largest number of participants such that the last potential subscriber is indifferent between dropping off or sharing in the cost of supporting the expanded network $(u(n)=u(p))$. From this point onwards, given increasing marginal costs, the operator is better off not participating. This point represents, therefore, the largest possible size of the network if there is no subsidy mechanism or price discrimination. Furthermore, if $n_4<N$, the total population of potential participants, then a truly universal service is not possible.

The social optimal size of the network is the point where total welfare is optimised. Social welfare is defined by the sum of the net utilities of all the participants:

$$SW = n[u(-r(n)) - v(n)] = n[AC + v(n)] \tag{7}$$

This is still increasing at the private optimal size of the network. At the exit point, welfare is zero.

$$\partial SW/\partial n = mc(n) + n\ \partial v(n)/\partial n + v(n) = 0 \tag{8}$$

Hence, the social optimum lies somewhere between these two points.

While the network will reach the private optimum on its own, the social optimum can be reached only through government intervention, differentiated pricing schemes or internal politics of expansion (such as striving for larger market share). Private interest consideration, thus, would lead the network to expand only to the point of private optimum.

INTER-NETWORK CO-OPERATION

The model in the previous section can also be used to illustrate the rationale for network integration in the liner shipping industry. Within the context of networks, this process is called 'interconnection'. As it can be seen from the graphical representation in Figure 4, increasing the connectivity of the network implies an upwards rotation of the utility curve of the entrants. The latter, in fact, can benefit not only from participating to the network of which they are direct members, but also from all other interconnected networks. They can directly

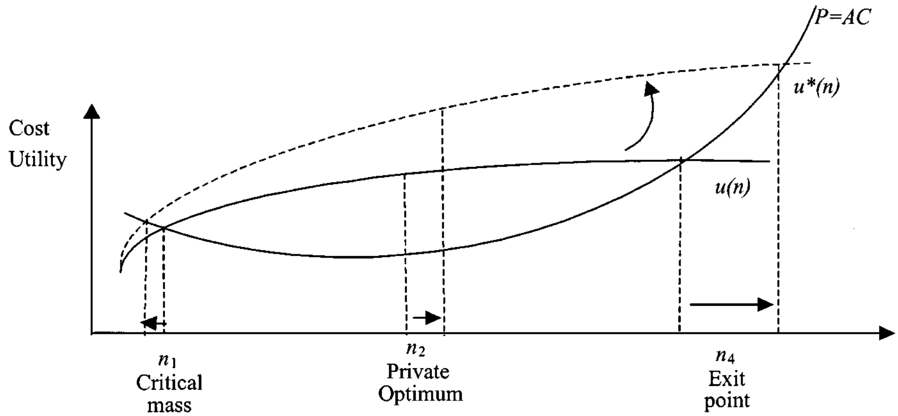

Figure 4: Interconnectivity effect

profit from the positive network externalities associated with membership to all the related networks.[15]

In his new position, the entrant can establish relations with other users in all interconnected networks, which were previously only potentially available but are now economically feasible. Under the assumption that the cost curve does not shift, the critical mass would be reached with a smaller number of users, the exit point with a larger number of users and private optimal size would increase. In other words, assuming that co-ordination required by interconnecting does not generate changes in costs, alliances might become self-sustainable with only a limited number of partners, given their dimension is sufficiently large and they will be attractive for a larger number of companies before the congestion comes into play. This is very much in line with liner shipping practice.

At this point, some considerations on cost issues are due. On the one hand, the higher the density of the network, the lower the cost of service,[16] on the other hand, the increased effort in co-ordination and restructuring will undoubtedly exert upward pressures on costs. The final outcome of the evolutionary process of alliances and of co-operative practices will thus depend on the balance between the cost savings and the additional costs that alliances generate. Cost factors will, thus, influence their degree of stability or, in other words, the pace at which the exit point is reached.

In the next section we present a short overview of the data available on reorganisation processes, which have taken place in the liner shipping industry. From the information available, we attempt to draw a picture of the advantages and disadvantages of co-operation for individual companies and of the factors influencing the expected stability of these agreements.

SOME EVIDENCE FROM THE INDUSTRY

The analysis presented in the previous sections shows that the structure and the economics of the liner shipping business yield an inherent drive for operators towards the extension of their individual network. This enlargement process materialises through the interconnection with other networks in the form of either co-operative practices (global alliances, consortia, conferences and so on) or mergers. The decision as to which strategy to pursue and the stability of such strategies depends, as it has been shown, on the extent and evolution of the related co-ordination costs.

A first evaluation of the available data, obtained from the analysis of a large number of reports,[17] which describe restructuring, mergers and alliance formation over the last five years or so, has allowed us to gain some insights on the extent of co-ordination expenses in liner shipping. It was mentioned above that companies re-co-ordinate their activities regularly – often due to changes in their co-operative or corporate arrangements – , while, due to the very nature of liner shipping, day-to-day co-ordination, in terms of adapting operating speed, route changes and flexible departure, can only be limited. This implies that the co-ordination effort, and thus its cost, is rather incidental and not continuous. An overview of available information is presented in Table 1.

From Table 1 the strong positive correlation between the investments in restructuring activities and cost savings is immediately apparent: the latter are achieved only by spending large amounts on restructuring companies' activities. This is especially obvious comparing, for instance, the annual restructuring charges of Sealand, and the consequent, generally only slightly higher cost savings achieved.

The almost continuous process of restructuring and co-ordinating makes it questionable if the expected cost savings from network integration are actually achieved in the period between subsequent restructuring operations.[18] Also, it appears unclear if the positive network externalities which should be generated by the aggregation of single companies' sub-networks into integrated networks can fully manifest themselves given the seemingly continuous reorganisational activities taking place.

The recent upsurge in inter-alliances mergers (and to a lesser extent, in intra-alliance mergers) could be interpreted as the shipping companies' reaction to the difficulties to achieve cost rationalisation within the alliances. One conclusion could be that alliances are used, primarily, to achieve sufficient levels of quality and service coverage and not as cost saving means. The optimal dimension of these agreements and their stability would then be determined on the basis of the trade-off between the costs of 'access' — defined as the costs of required re-co-ordination — and the benefits that undoubtedly derive from offering a global coverage of the relevant market. In some instances, thus, it might be the case that

Table 1: Companies' restructuring costs and resulting savings

Carrier	*Date*	*Savings (a)*	*Restructuring effort (b)*	*Comment*
APL	1995		$48.4 m	
APL	1998	$130 m/yr	$80 m	Takeover APL/NOL; additional write off of goodwill $200 m announced savings for 1999:$162.7 m
CGM	1995	$8.9 m/yr		Replacing 4 ro-ro's by cellular ship
AP Moller	1997	> 15 ships	$154 m	Maersk-Sealand takeover restructuring provision
OOCL		$5-8 m/yr		Grand Alliance interchange of equipment
Nedlloyd	1995	$30/TEU		Formation of global alliance merger
P&O Nedlloyd	1997	$200 m/yr	$104 m	P&O and Nedlloyd
Sealand	1991		$67 m	
Sealand	1992		£17 m	
Sealand	1993	$124 m	$93m	
Sealand	1994	$100 m		
Sealand	1995	$120 m	$61 m	
Sealand	1996	$136 m		
Sealand	1997	$217 m	$78 m	
Maersk/Sealand	1998	$100m/carr.	Repos. 82 ships	
Maersk/Sealand	1999	6 ships		one less transpacific crossing
CSX Corporation	1995		$250 m	new communication systems, restructuring of Sealand, reflagging 5 ships
CYE consortium		11 ships		Replacing services with ESA consortium
VSA consortium		1 ship		Replacing previously separate services
H-S/Alliance/ Transr/CMG-cons		4 ships		Changing frequency from 7 days to 5.3 days
Grand Alliance	1997	$40 m		Savings since its start in 1997
New World All.	1998		repos. 176 ships	re-alignment of alliances due to P&O – Nedlloyd merger

(a) *Savings are reported in terms of either money or ships*
(b) *Restructuring efforts are quantified either in money terms, or, if no amounts were mentioned, in terms of the repositioning of ships*

Sources: Containerisation International – various issues, Lloyd's Shipping Economist – various issues, Sealand: annual reports 1990 – 1997

the optimal dimension of a network in liner shipping might be equal to the dimension of the company itself, if the geographical and organisational extent of its own network allows it to respond to its clients' needs and if by joining an alliance the network benefits (potential externalities) it would enjoy would be fully counterbalanced by the 'cost of access' in terms of re-organisational investments. This would be in line with the presence of operators (Maersk-Sealand, Evergreen), which sustain an operational strategy of independence. In this case, their own dimension is 'sufficient' to create critical mass and to achieve a 'private optimal dimension'.

Existing market conditions will continue to exert pressure to reduce costs and increase geographical scope. It can therefore be expected that efforts to further integrate liner operations might continue for some time. However, the optimal dimension of the network (point n_2) appears to be only a temporary outcome: any private equilibrium in liner shipping networks is currently unstable due to the continuous co-ordination effort (and related costs) resulting from co-operation. Since costs related to the integration processes increase with the complexity of separating and joining the route networks of the individual companies, it can be forecasted that, at some point, these costs will overrun the benefit and this will hinder further integration. Whether this will happen before a truly global dimension — a completely interconnected network — will be reached, remains to be seen.

Finally, with the available empirical evidence, it is difficult to say on a case-by-case basis if the integrated network formed by allied companies will be sustainable or if companies will opt for a merger (whether inter-alliance or intra-alliance). What can be stated is that, generally, it is the shape of the cost function that determines the process of network growth while the dimension of the potential cost gains (savings) determines the level of integration.

CONCLUDING REMARKS

In this paper, we have presented an examination of the structure of the liner shipping market using an analytical framework based upon network theory concepts. As it has been shown, the liner shipping industry can be identified as a network industry on the account of its technical and economic characteristics. Furthermore, individual liner companies can be identified with the sub-network they form through operational choices on trade lanes and ports of call. In this context, the existence of co-operative agreements — in particular of global strategic alliances — and the occurrence of mergers have been interpreted as the strive to achieve a greater degree of interconnectedness among individual liner networks. Alliances have been compared to providers of a new integrated service infrastructure composed of companies' sub-networks. It has been demonstrated that the trade off between the benefits (positive network externalities) which are generated by network integration on account of the interdependence of the utility functions of companies 'connected' to the same alliance might, in reality, be offset by the increasing costs that companies partners of alliances have to bear. These costs are not directly related to the participation in the alliance, but stem from the necessity of reaching the required level of intra-network co-ordination. Co-ordination costs, thus, in the absence of direct access costs associated to joining the alliance, can be considered as the main drive of the observed alliances' instability. They would pose an obstacle to the attainment — or to the preservation — of the optimal network size, and, thus, to the natural growth process of these agreements.

Relating the findings of the theoretical analysis to some empirical evidence, it can be suggested that the key variable in determining (i) whether forms of co-operation will take place and (ii) the extent and degree of stability of such agreements (which might vary from loose alliances to full scale mergers) is, specifically, the difference between co-ordination costs and realised co-ordination savings. The current information is not sufficient to show which type of integration process will prevail. However, a preliminary evaluation of market data on business strategies and related costs seems to suggest that liner companies may be taking decisions on the basis of potential cost savings which might never be achieved in practice (as a consequence, mainly, of the frequency of the restructuring initiatives). Furthermore, the analysis of available data indicates that a careful study of industry cost information, and especially of the extent cost savings are offset by restructuring charges, can offer a lead to assess how far business concentration in the liner shipping will continue into the future.

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ENDNOTES

1 For greater details of the main characteristics of network industry and their role in the economy, the reader is referred to the report by the European Commission (1999) on the economic implications and policy issues related to liberalising network industries.

2 See for instance: Brooks (2000), Midoro and Pitto (2000), Bergantino and Veenstra (2000), Button (1999), Ryoo and Thanopoulou (1999).

3 This latter characteristic differentiates liner shipping from a standard network application, like, for instance, railways.

4 Organised in such a way that participating companies specialise in the two different types of trade: mainline transport and feeder services.

5 For instance, for railroad companies, interconnection means that trains belonging to one company use the tracks owned by different companies, within or outside, the country (Shy, 2001; p. 117); in the airline sector, code-sharing agreements are forms of interconnection.

6 The co-operation of SeaLand and Maersk, for instance, is reported to have saved ten ships in all of the included routes (LSE, April 1998, p. 18). Such savings can hardly be achieved by rationalisation on a route by route basis.

[7] For instance, in 1997, the top twenty liner shipping companies sold to more than 50% of the market. Brooks (2000) contains a detailed investigation of the concentration levels in this industry for the past decades.

[8] As Brooks (2000) points out, although the various types of agreements that have characterised the organisation of the liner trade have had different purposes, a continua of alliances can be identified in this sector, since, most of the previous types of agreements can, somehow, enter in the definition of alliance (p. 77).

[9] This is not the case, for instance, for the telecommunication industry where the link between the client and the infrastructure is generally direct.

[10] Although, generally, network participants might have differing sizes, as Noam (1992) points out, this assumption is not very restrictive since it is always possible to define larger organisations 'to consist of multiple members of type *n*' (p. 11).

[11] Including network performance and price.

[12] For convexity, we assume that the first user has positive benefits even if he is the sole user of the network: $u(-r,1) > \mathrm{u}(-r,0)$.

[13] This hypothesis reflects the possibility of congestion and consumption of economies of scale/scope as the maximum productivity level is reached.

[14] At n_2, the marginal utility for the alliance of an additional participant would be equal to zero. This will happen in the range of increasing *AC* (Noam, 1992).

[15] On this specific issue see also Hayashi (1992).

[16] Brueckner and Spiller (1991, 1994) report, in fact, that the marginal cost of carrying an extra passenger in a high-density network is 13% – 25% below the cost in a medium or low-density network, thereby giving the high density carrier a distinct cost advantage. The above seems to imply that the average cost curve of a liner shipping network would move downward as a result of the interconnection with different networks.

[17] Most of the information contained in this section is taken from Lloyd's Shipping Economist, Containerisation International and the Containerisation International Yearbook. Additional information was obtained through research into annual reports of liner shipping companies and company websites.

[18] See, for instance the P&ONedlloyd merger and the resulting reshuffling of alliances. Actually, before merging in 1998, Maersk and Sealand used to be partners in an alliance. They had thus reached, between themselves, the critical mass needed to the functioning of the extended network: they formed a self-sustaining network in their own right. The subsequent decision to merge was taken once the benefits obtainable with the degree of co-operation proper of an alliance had been exploited.

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