An Application of Modified Shapley Value to Ocean Shipping Strategic Alliances

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Abstract

Over the last decade, liner shipping carriers have entered into operational relationships known as ocean shipping alliances. It allows carriers to aggregate cargoes and re-arrange vessels so that they are able to increase the revenue and reduce the cost. But it is also observed that some carriers would not join the shipping alliances for various reasons. This study aims to identify the effect when a new company tends to join an existing alliance by the use of modified Shapley Value. First, some related works and the ocean shipping alliances are reviewed. Next, the Shapley Value is briefly introduced and a modified Shapley value, mentioned as “net value” is developed. Then, the problem of entry into an existing alliance is modeled as an n-player game. At last, a case study is presented and the authors reach the conclusions that relatively small carriers tend to be accepted by the alliances while large carriers would not.

Keywords: Strategic Alliances, carriers, game theory, Shapley value

1. Introduction

Carriers create alliances in reacting to the demands of the global economy. Only global economies of scale will meet the ever-present demand to move goods at the lowest possible prices. Therefore, the ocean shipping industry has evolved to provide the wide range of services that today’s global shippers demand. To do so, the carriers have entered into constructive agreements commonly referred to as alliances. According to observed fact, alliances do help their members achieve more efficient operations and expand their service networks. But on the other hand, a number of carriers would not join the alliances or merge with other carriers.

This paper focuses on the issues of outsider companies joining strategies. The purpose of this paper is to identify the effect of outsider’s entrant action and find out if the alliance should accept this outsider or not.

2. Review of Related Works

There have been a number of researches devoted to the ocean shipping alliances. Sheppard and Seidman [1] explain the advantages and disadvantages of entering into alliances from the carriers’ point of view, but they do not conduct any theoretical analysis. Song and Panayides [2] successfully apply cooperative game theory to analyze co-operation among members of shipping alliances. They present a detailed and systematic analysis of liner shipping strategic alliances but do not consider the competition among alliance members nor do they consider the relationships between alliance and outsider companies. In contrast, Morasch [3] produces a three-stage-game where the competition between alliance members and outsiders in the product market is studied. His research is devoted to decide about forming strategic alliances and simply solve the competition problem, comparing with the former research which simply solves the cooperation problem. Rothschild [4] applies modified Shapley value to both industry-wide and dominant-firm collusive structures. The purpose of his research is to determine the optimal size of a cartel but not to analyze the entrant strategies.

Although there have been a number of researches about shipping alliances, few of them consider the outsider’s entrant strategies as well as the economical effect imposed to alliance members due to the new member’s coming.

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3. Ocean Shipping Alliances

In the ocean shipping context, alliances are defined as cooperative operational arrangements between two or more carriers that lie anywhere between a traditional arms-length relationship and an integrated strategic relationship that amounts to a virtual merger.

3.1 Advantages of alliances

As part of an alliance, carriers enter into a wide range of cooperative agreements for both ocean and land operations. Ocean borne agreements usually contain space sharing, slot charter, and sailing arrangements. Space sharing and slot charter agreements operate under the same concept — a carrier reserves a certain amount of slots on its vessels for alliance members. This type of arrangement provides two main benefits. First, it allows carriers to aggregate their cargoes to reduce the number of vessels that are needed to serve a particular port. Second, it increases the number of service options carriers can offer to their customers for little or no cost because their partners are actually operating the service.

Scheduling arrangements, another benefit of alliances, also generate greater efficiency in a different manner. By coordinating schedules, carriers reduce the total transit time because each vessel makes fewer port calls.

In addition to space sharing on vessels, alliance partners also cooperate on land operations through the joint use of ports, terminals, equipment and other facilities. The consolidation of these facilities help carriers achieve significant savings by improving their ability to load and unload, to transship or to trans-load containers in the most efficient manner.

In total, the benefits offered to carriers by alliances are:

* Provision of a seamless service that is attractive to shippers because it is functionally equivalent to service on a single carrier
* Expansion of services to more markets in the least expensive way
* More efficient operations with increased revenues and reduced costs through productivity improvements and the scale of economies
* Reduction of exposure to risk by offsetting rate reductions in one market with rate increases in another market
* Gaining of market share by stimulating new cargo, and diverting traffic from competitors
* Improving the quality of service each individual alliance member offers

At present, five major alliances — the Grand Alliance, the New World Alliance, Maersk-Sealand, Cosco/K-Line/YangMing and CMA-CGM-Norasia enjoy the vast majority of these benefits. These five alliances account for about 65% of slots deployed on the major Trans-Pacific routes.

3.2 Disadvantages of alliances

It is important to note that alliances deliver these benefits even though their members remain competitors. Because the carriers — not the alliances — work directly with their customers to handle unique transportation needs, so individual carrier’s strategic goals are separate from those of the alliance although alliance members work together on a variety of issues.

To make the alliance work, the partners must truly commit to making their relationship smooth, or else, the alliance will fail. Failure may be caused by any reasons. First of all, there is often a lack of trust between partner companies. It is often difficult for each partner to believe that it is benefiting from the alliance and no other partner is receiving greater benefits. If a partner believes its needs are not being met, it may abandon the alliance since the carriers are usually not formally bounded to the alliance. Similarly, members may leave one alliance to join another if another alliance promises greater benefits.

Additionally examples might include cases
where alliance members obtain space on their partners' vessels at severely discounted rates and then re-sell the space at prices high enough to generate a profit for the reseller, but well below the market rate for such services. When this reselling happens, the carrier who is actually operating the vessel loses a substantial amount of money. To regain the money, the carrier does the same thing back to its partner, causing both parties to lose both money and trust in one another.

Nonetheless, carriers have decided that the benefits of alliances outweigh the drawbacks. Alliances generate operational efficiencies and expand services in ways that could be reproduced only by merging, buying or building-options that are unavailable to most carriers. Conversely, failure to enter into an alliance could transform a major carrier into a niche one because it cannot offer the services as wide as those who have entered into global alliances.

4. The Modified Shapley Value

As has been introduced above, this paper deals with the problem which is raised among alliance members and outsider, i.e., the problem in which situation the outsider should join and when should not (See figure 1). This problem is modeled as an n-player cooperative game.

Existing Alliance

<table>
<thead>
<tr>
<th></th>
<th>A</th>
<th>B</th>
<th>YES</th>
</tr>
</thead>
<tbody>
<tr>
<td>C</td>
<td>D</td>
<td>NO</td>
<td></td>
</tr>
</tbody>
</table>

Figure 1 Problem description

4.1 Shapley Value

For cooperative game, there exist a number of solution concepts, the best well-known of which are the values, the core, bargaining set and stable set. Shapley value – the concept adopted in this paper – has been widely employed and is probably the most powerful of those solutions for cooperative games. Let $I$ be the grand coalition, $n$ the number of firms, and $k$ the cardinality of a given coalition $K$, $K \subseteq I$. Then the Shapley value for each firm $i$ is the unique payoff

$$\theta_i = \frac{1}{n!} \sum_{i=0}^{k-1} \left( \frac{(n-k)(k-1)}{n!} \right) \left[ v(K) - v(K/-i) \right]$$ (1)

In this expression, the term $v(K) - v(K/-i)$ is the increment in the total worth of the coalition $K$ due to the entry of firm $i$. The term $\frac{(n-k)(k-1)}{n!}$ represents the probability that, in a random build-up of the grand coalition $I$, firm $i$ will be the next firm to join a coalition containing the first $(k-1)$ members. The Shapley value thus identifies for each $i$ its expected marginal contribution to each of the coalitions which can be formed to contain $i$.

4.2 Modified Shapley Value

As it stands, the Shapley value simply reflects the increment in the total worth of the coalition due to the entry of $i$. Hence, a difficulty of using Shapley value lies in the fact that it does not reflect any losses which the entry of firm $i$ may impose upon firm $j$, $j \in K$, $j \neq i$. In order to solve this problem, a modified version of the Shapley value, called net value was introduced. As a first step towards the identification of the net value, let:

$$\theta_i^t = \frac{1}{n!} \left[ \sum_{K \subseteq N, i \in K} \left( \frac{(n-k)(k-1)}{n!} \right) \sum_{j=1}^{k-1} \left[ \Delta P_j \right] \right]$$ (2)

be a measure of the impact of the entry of firm $i$ on existing individual members of all coalitions which can be formed to contain $i$. In this expression, the first term has the same interpretation as its counterpart in (1). By contrast, the second term represents the sum over all $j$ of the changes in the payoffs caused by the entry of $i$.

The net value for a member $i$ is $\theta_i - \theta_i^t$.

A coalition is optimal if it is made up of all members for whom the net value is non-negative. In other words, a coalition is optimal if it comprises all of those members whose entry generates an increase.
in the worth of the coalition to compensate all those who are made worse off.

5. The Model

Here the net value of a given firm \( i \) is considered and the effect of \( i \)'s entry to an existing alliance is identified.

First, it is assumed that there is alliance \( K^0 \), which contains \( k \) firms, indexed \( i = 1, 2, \cdots k \). It is supposed that each firm \( i \) has the output of \( q_i \), subject to a marginal cost function of the form

\[
mc_i(q_i) = \frac{\alpha_i}{q_i}, \alpha_i > 0, q_i > 0
\]

here \( \alpha_i \) is a parameter which can differ from firm to firm. For the calculation simplicity, it is assumed that the fixed cost for each \( i \) is 0. Let the demand curve in inverse form be

\[
P = a - b \cdot Q, \quad Q = \sum_{i=1}^{k} q_i \quad \text{and} \quad a, b > 0.
\]

Suppose the alliance's marginal cost is the aggregated sum up of each firm. Then the alliance's total marginal cost \( MC \) is

\[
MC = \frac{S}{Q} \quad \text{where}
\]

\[
S = \sum_{i=1}^{k} \alpha_i.
\]

The total revenue of the alliance is:

\[
TR = P \cdot Q = -bQ^2 + aQ, \quad \text{and the alliance's cost is:}
\]

\[
TC = \int \frac{S}{Q} dQ = S \cdot \log Q. \quad \text{Hence, the alliance profit:}
\]

\[
V = TR - TC = -bQ^2 + aQ - S \cdot \log Q
\]

(3)

Suppose inside the alliance, each member's profit is in proportion to the share of its throughput out of the alliance's total throughput. Hence the corresponding profit for each member is:

\[
p_i = \frac{q_i}{Q} \cdot V = \frac{q_i}{Q} \cdot \left(-bQ^2 + aQ - S \cdot \log Q\right)
\]

(4)

Consider the impact of outsider's entry, say the new member is mentioned as \( j \) and the new member's throughput is \( q_j \) and the parameter is \( \alpha_j \). Let \( Q' = Q + q_j, Q' > 0 \). \( S' = S + \alpha_j, S' > 0 \). The change of the profit of the whole alliance is given by:

\[
\Delta V = V(K^0) - V(K^0 / i)
\]

\[
= -bQ^2 + aQ' - S' \cdot \log Q' - \left(-bQ^2 + aQ - S \cdot \log Q\right)
\]

\[
= -bq_j(2Q + q_j) + aq_j - (S' \cdot \log Q' - S \cdot \log Q)
\]

(5)

Secondly the authors consider each existing member's change of profit caused by the outsider's entry. It is important to note that the change of each member's share in the alliance should be given enough attention. In the new “alliance” where member \( j \) is also contained, each member's new share is described as \( \frac{q_j}{Q} \), and the corresponding profit of each existed member in the new alliance is:

\[
p_i' = \frac{q_j}{Q} \cdot V = \frac{q_j}{Q} \cdot \left(-bQ^2 + aQ - S \cdot \log Q\right)
\]

(6)

The change of profit of each member is:

\[
\Delta p_i = p_i' - p_i = q_j \cdot \left(-bq_j - \frac{S' \cdot \log Q'}{Q'} + \frac{S \cdot \log Q}{Q}\right)
\]

(7)

The net value of the new member's entry to the alliance can be written as:

\[
\Delta V + \sum_{i=1}^{k} \Delta p_i
\]

\[
= (a - 3bQ)q_j - bq_j^2 - (1 + \frac{Q}{Q'}) \cdot S' \cdot \log Q' + 2S \cdot \log Q
\]

(8)

Expression (8) is not necessarily non-negative because it is very likely that the entry by \( i \) would lower the profits of the existing members. On the other hand, the new member could be admitted if its contribution is at least as large as the costs its entry imposes on the other members, i.e. if the new member's contribution can cover the compensation, the new member could be admitted by the existing members.

After compensation has been paid, this expression (8) may be positive, negative or zero, depending upon the magnitude of parameters of the members involved and the cost function parameters \( a \) and \( b \). The net value of member \( i \) is \( \theta_i - \theta_i^L \).

It is easy to know that the new entrant will be accepted when the net contribution of the \( k \)th entry to the alliance is positive, i.e.

\[
(a - 3bQ)q_j - bq_j^2 - (1 + \frac{Q}{Q'}) \cdot S' \cdot \log Q' + 2S \cdot \log Q > 0
\]
6. Case Study

6.1 Problem description

In this sector, the model to shipping alliance is applied. It is assumed that there is an existing alliance between Asia and North America.

According to observed data, it is assumed that the total throughput of this alliance is 240,000 TEU per month. It contains three companies sharing 50%, 25% and 25% of the total business, respectively (See figure 2) and each company employs 4,500 TEU’s container vessels.

![Diagram of Member companies in the case study](image)

Consider the problem where an outsider tends to join the alliance. Note that in order to enrich the case study, different cases are figured out in terms of the outsiders’ scales, i.e. by setting the outsiders’ throughput as percentage of the alliance’s total throughput.

6.2 Numerical experiment

Due to the limited space, it is hard to list all the details in this paper. To sum up, the authors first calculate the profit change of the alliance due to the entry of the outsider (as is shown in eq.(5)) and then figure out each existing member’s profit change (as is shown in eq.(6)). At last, sum up the total changes (as is shown in eq.(8)) and observe the result.

If the total change is positive, the outsider’s entry will be accepted. In contrast, if the result is negative, it is implied that the outsider’s entrant strategy will not be accepted since the profit it brings into the alliance could not cover each member’s losses. To be exact, existing member is losing its share due to the outsider’s coming.

Ten different cases are calculated to obtain the “net values” of various outsiders. Table 1 and Figure 3 show the results. It is found that when a relatively small company joins the alliance, the benefit it brings into the alliance can cover each member’s loss, where the entering action is assumed to be acceptable by all the other members, theoretically. While on the other hand, it is also very interesting to find that pretty large carriers are not going to be accepted by the alliance because this new entering “giant” makes too much losses to the others.

<table>
<thead>
<tr>
<th>share</th>
<th>10%</th>
<th>20%</th>
<th>30%</th>
<th>40%</th>
<th>50%</th>
<th>60%</th>
<th>70%</th>
<th>80%</th>
<th>90%</th>
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<tr>
<td>(q_1)</td>
<td>23,833</td>
<td>47,666</td>
<td>71,499</td>
<td>95,332</td>
<td>119,165</td>
<td>142,998</td>
<td>166,831</td>
<td>190,497</td>
<td>214,497</td>
<td>238,330</td>
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<tr>
<td>(Q')</td>
<td>262,166</td>
<td>286,000</td>
<td>309,833</td>
<td>333,667</td>
<td>357,500</td>
<td>381,334</td>
<td>405,167</td>
<td>429,001</td>
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<tr>
<td>(Q'Q')</td>
<td>0.91</td>
<td>0.83</td>
<td>0.77</td>
<td>0.71</td>
<td>0.67</td>
<td>0.62</td>
<td>0.59</td>
<td>0.56</td>
<td>0.53</td>
<td>0.50</td>
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<tr>
<td>(q)</td>
<td>171,600</td>
<td>343,195</td>
<td>514,790</td>
<td>686,385</td>
<td>857,980</td>
<td>1,029,575</td>
<td>1,201,170</td>
<td>1,372,765</td>
<td>1,544,360</td>
<td>1,715,955</td>
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<tr>
<td>(S')</td>
<td>1,887,600</td>
<td>2,059,195</td>
<td>2,230,790</td>
<td>2,402,385</td>
<td>2,573,980</td>
<td>2,745,575</td>
<td>2,917,170</td>
<td>3,088,765</td>
<td>3,260,360</td>
<td>3,431,955</td>
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<td>in million</td>
<td>37.63</td>
<td>34.65</td>
<td>28.14</td>
<td>17.88</td>
<td>4.15</td>
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<td>-34.43</td>
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7. Conclusions

Alliances are rational responses to both the historical problems faced by the ocean shipping industry and the new issues presented by today’s global market. With all of the benefits flowing from the alliance system, the success of alliances may depend, in large measure, on the likelihood that they will lead to mergers, i.e. the ultimate form of alliance where smaller carriers are acquired by larger ones.

At the same time, the instability of many alliances prevents carriers from making long-term investments in shared facilities or marketing strategies. This is reflected by the fact that there are some competitions remaining within an alliance.

Large carriers are confident on their service and they would operate independently without cooperating with the other carriers of the same sizes. By modeling the problem and its application to shipping alliance, this paper also draws the conclusions that large carriers tend not to share an alliance or merge with one another. While on the other hand, relatively small carriers are more likely to join existing alliances to expand their businesses.

References

Questions and Answers
林 美鶴 (神戸大学)
新規参入があった場合、その規模によるトータルの利益変化を示されましたが、トータルでマイナスになる場合でも、個別の企業によっては利益が増加する場合もあるのでしょうか？
劉 森佳 (神戸大学 大学院)
はい、新規参入者の規模により海運同盟全体の利益がマイナスになるときは、個別の企業は自分自身の規模や特性によって利益が増加する場合もあります。ただし、この企業は同盟の一員として同盟全体の利益を考えなければならないので、新規者の参入行動は認められないと考えられます。