A game theoretical analysis of vertical and horizontal co-operation among freight forwarders

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INTRODUCTION

This paper[1] compares vertical and horizontal cooperation among freight forwarders and analyses three freight forwarders ('players') with two different means of transportation. The first two players are truck-operating freight forwarders, one large and one small. The third player is a freight forwarder with its own ship. Freight forwarders have long played an important role in commerce and the international carriage of goods. Traditionally, the freight forwarder has been the link between the owner of the goods and the carrier, and provided forwarding or clearing services. The forwarder acted as the agent for the owner of the cargo or the carrier.

Some of the functions included in the freight forwarders' activities are:

- Acting on the customers' behalf to procure the most suitable mode/combination of transport modes, be it road, rail, sea or air. However, road, sea and air transport is most commonly used, while very few freight forwarding companies deal with railway transport, even casually (Kokkinis *et al*. 2006).
- Undertaking the arrangement of the routing and choice of mode for the customer, together with any ancillary service such as customs clearance or packing. This level of involvement introduces a higher level of expertise, which the shipper may not always be able to provide.
- Offering stand-alone ancillary services, such as warehousing, customs clearance, packing and port agency.
- Moreover, freight forwarders must work closely with shippers as they must adapt and provide more value-added logistics activities in order to respond effectively to the ever-changing needs of customers' logistics requirement. This has led freight forwarders to effectively become third-party logistics service providers (3PLs), particularly with regard to international freight logistics services. In order to compete, many 3PLs have utilised price competition and sales-influenced strategies. As a result, only arms-length

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relationships between 3PLs and trading firms are developed (Banomyong and Supatn, 2011).

In this paper following three players are defined:

1. A freight forwarder with its own means of land transport (trucks). This is assumed to be a large truck-operating company.
2. The second player is a small truck-operating company that also works as a freight forwarder.
3. The third player is a freight forwarder with its ship. This type of player is known in the literature (see UNCTAD, 1995) as a vessel-operating multimodal transport operator (VO-MTO). VO-MTOs are ship owners that have extended their services beyond carrying the cargo from port to port to include carriage over land and even by air. They may or may not own the other means of transport, in which case they arrange for these types of transport by subcontracting with such carriers.

Various combinations of coalitions are possible in this situation.

- For instance, if player 1 or player 2 cooperated with player 3, this would result in an *intermodal freight transportation* situation*.* This type of cooperation is considered vertical cooperation because it involves two different means of transportation; that is, trucks and ships.
- Similarly, players 1 and 2 could cooperate with each other. This is considered horizontal cooperation because it involves two players with the same means of transportation; that is, trucks.

The objective of this paper is to compare vertical and horizontal cooperation among freight forwarders. A two-stage game is applied for the purpose of analysis. In the first stage, the three players have to decide on whether to act singleton or to enter into a coalition with any other player. The decision at this stage should presumably be based on the predicted outcome for the second stage. The second stage is here modelled as a Bertrand game with one outside competitor and the coalition. Since the first stage decision (when players have to decide whether to join the coalition or not) depends on the predicted outcome for the second stage, the problem will be studied by backward induction. Furthermore, the stability of these suggested coalitions will be checked with the help of concepts of ‘‘coalitional rationality” of the cooperative game.

The rest of the paper is organised as follows: Section 2 presents a number of research works related to the application of cooperative game theory to the freight forwarders' sector. In Section 3, a model for a Bertrand game for the second stage and its parameters are presented. Section 4 constitutes a numerical analysis and is followed by a conclusion and policy implications in Section 5.

LITERATURE REVIEW

Krajewska and Kopfer (2009) presented a model for collaboration among independent freight forwarding entities. They argued that, in today's highly competitive transportation branch, freight forwarders reduce their fulfilment costs by exploiting different execution modes (self-fulfilment and subcontracting). The freight forwarders use their own vehicles to execute self-fulfilment requests and forward subcontracting orders to external freight carriers. Competitiveness can be further enhanced if the freight forwarders cooperate in the form of coalitions in order to balance their request portfolios. Participation in such a coalition provides additional profit for the entire coalition and for each participant, which reinforces the market position of the partners. Their paper introduces the integrated operational transport problem, as well as existing collaboration approaches.

Ting (2009) described the logistics service (even freight forwarders with no independent means of transport) as a type of oligopoly market because a small number of logistics service providers (LSPs) always compete to win a shipping contract. They are interdependent in the sense that the profit that each provider earns also depends on the others' actions. Ting (2009) use a game theoretic approach including the Cournot, Collusion and Stackelberg models to study the cooperative and competitive behaviour among the oligopolistic competitors.

Cantos-Sanchez et al. (2010) developed a theoretical model for freight transport that is characterised by competition between means of transport (the road and maritime sectors), where modes are perceived as differentiated products. Competitive behaviour is assumed in the road freight sector, and there are constant returns to scale. In contrast, the freight maritime sector is characterised by oligopolistic behaviour, whereby shipping lines enjoy economies of scale. The market equilibrium in which the shipping lines behave as profit maximisers provides a first approximation to the determinants of market shares, profits and user welfare. Moreover, the results show that maritime freight increases after the merger, in cases where the merger entails further economies of scale. When prices for maritime services increase, which occurs when the merger only has a strategic effect, road freight transport also increases. Furthermore, horizontal integration has been found to be beneficial in private and social terms under certain conditions. In empirical applications, Cantos-Sanchez et al. (2010) employed data for two freight routes between the hinterland of Valencia and the hinterlands of Genoa and Antwerp. Their results show that, in all of the examined cases, the shipping lines have strong incentives to merge. Additionally, a merger (horizontal integration) between two shipping lines in which economies of scale are exploited further generally leads to an increase in social welfare. In most cases, the merger produces a significant increase in road traffic that is greater than the reduction in traffic transported by the shipping lines, which leads to an increase in user surplus. Their study has found that the social gains depend mainly on the characteristics of the market. Then, the social gains obtained with the merger are higher in those markets where the road and shipping services are less differentiated. If the services are clearly differentiated, then the social gains are significantly lower.

Krajewska et al. (2008) analysed the profit margins that resulted from horizontal cooperation among freight carriers. The work presented in their paper combines features of routing and scheduling problems and of cooperative game theory. The authors assumed that the structure of customer requests corresponds to that of a pick-up and delivery problem with time windows for each freight carrier. The paper then discusses the possibility of sharing these profit margins fairly among the partners. The paper also presents numerical results for real-life and artificial instances. The paper shows that collaboration can yield a considerable cost decrease and that efficient profit allocation is possible using cooperative game theory.

Theys et al. (2008) illustrated the potential of cooperative game theory as a methodological tool with which to analyse intermodal networks. More specifically, they have used the many solution concepts proposed in the game-theoretic literature to evaluate whether cooperation in an intermodal project is *feasible* and *efficient*, as well as what would be a *fair* cost division among the participants.

According to Theys et al. (2008), an important assumption that is often made in applications of cooperative game theory is the subadditivity of the characteristic function, which implies that no player is worse off as a result of cooperating and that the grand coalition is the most efficient cooperation structure. This assumption of subadditivity will hold for most economic applications. However, as Theys et al. (2008) illustrated, this is not necessarily the case for more realistic intermodal cooperation projects. Hence, they concludes that, for real-life applications in intermodal transportation, one must rely on far more advanced game-theoretic solution concepts, which results in a significant increase in computational complexity. Hence, practical limitations to the computations in intermodal cost-allocation games seem to exist and should be explored further.

This research is different from the previously mentioned research done in the same field in the following aspects. First, in none of the research is the multinomial logit model used to analyse the game outcome by solving a numerical example with the help of data. Second, to author's knowledge, no one has analysed the possibilities of coalitions between freight forwarders (vertical and horizontal cooperation) as presented in this paper. Third, in this paper the Bertrand game in terms of prices is solved but we also analyse the outcome from the perspective of users' benefits when coalitions are formed.

MODEL

This paper applies the model developed by the author in previous work (Saeed and Larsen, 2010) in order to illustrate the competition and cooperation among freight forwarders. However, some additional characteristics related to the freight forwarding sector (such as schedule delay, frequency) have also been incorporated into the model.

Schedule delay

Another important concept, introduced by Small (1982), is the schedule delay costs for trips. Consumers (users) who want to undertake certain activities during a day will schedule them according to their preferences, taking into consideration external constraints. Deviating from these scheduling preferences will result in disutility; that is, schedule delay costs. Schedule delay costs focus on alleviating congested transport networks because they indicate the costs that travellers attribute to changing their travel behaviour (Bakens et al. 2010).

Schedule delays become much more important for users' decisions when any mode of transportation has low frequencies and timetable information is used to select that mode of transportation. In our case, trucks have a high frequency and low waiting time compared to ships. The model considers this feature by assigning high negative value of alternative specific constants in the utility functions of player 3 (ship-operating company).

In our numerical implementation of the Bertrand model, the market share of each freight forwarder is determined by an aggregate multinomial logit model, and the demand for all freight forwarders combined is a function of the logsum from the logit model.

The use of a logit model presupposes that a 'utility function' can be assigned to each freight forwarder. The utility functions in an aggregate logit model can be interpreted as a measure of the attractiveness of a freight forwarder as perceived by the 'average' user.

The utility functions of freight forwarders are given as follows:

$$U_i = a_i + b(p_i) \tag{1}$$

Where U_i is the 'utility' of freight forwarder i

P_i is price charged per unit by freight forwarder i

b is the co-efficient of price charged by freight forwarders and;

a_i is the alternative specific constant for freight forwarder i;

$a_1, a_2 > a_3$ due to low waiting time and high frequency of trucks;

The market share of freight forwarder '*i*' is given by the logit expression:

$$Q_i = \frac{e^{U_i}}{\sum_j e^{U_j}} \qquad \text{i= freight forwarders} \tag{2}$$

The logsum is defined by:

$$LS = \ln\left(\sum_j e^{U_j}\right) \tag{3}$$

Thus, the total aggregate demand (in TEUs) for all the players is given by:

$$X = Ae^{\theta LS} \tag{4}$$

where A and θ are constants and 0 < θ <1,

Individual demand for player 'i' is given by the equation:

$$X_i = X . Q_i$$ i= freight forwarder
(5)

Therefore, the demand faced by a freight forwarder i will depend on handling prices and schedule delay (which is reflected in alternative specific constant) for all players. Individual demand is elastic because changes in the price and other attributes of one freight forwarder will shift the cargo between that freight forwarder and other freight forwarders. There will also be a slight effect on the total demand via the logsum.

Revenue/profit for freight forwarders

The operating surplus of the freight forwarder 'i' is:

$$\Pi_i = (p_i - c_i) \cdot X_i \tag{6}$$

Where p_i is the price per cargo unit paid by the users, c_i is the marginal cost per cargo unit.

Whatever the price that other freight forwarders are charging, the freight forwarder i's profit is maximised when the incremental profit from a very small increase in its own price is only zero. Thus, in order to find the best reply for player i, its profit function is differentiated with respect to p_i and the derivative is set equal to zero. Thus, the Bertrand Nash equilibrium is characterised by the first-order conditions:

$$\frac{\partial \Pi_i}{\partial p_i} = 0 , \quad \text{i= freight forwarders} \tag{7}$$

The profit function, say for freight forwarder 1, is given by:

$$\Pi_1 = (p_1 - c_1) \cdot X_1 \tag{8}$$

Since $X_1 = Ae^{\theta LS} Q_1$ (9)

By substituting the value of X_1 in equation (8):

$$\Pi_1 = (p_1 - c_1) \cdot Ae^{\theta LS} Q_1 \tag{10}$$

$$\Pi_1 = p_1 . Ae^{\theta LS} Q_1 - c_1 . Ae^{\theta LS} Q_1 \tag{11}$$

By taking the derivative of equation (11) and setting it equal to zero:

$$\frac{\partial \Pi_1}{\partial p_1} = Ae^{\theta LS} Q_1 + p_1 \frac{\partial (Ae^{\theta LS} Q_1)}{\partial p_1} - c_1 \frac{\partial (Ae^{\theta LS} Q_1)}{\partial p_1} = 0 \tag{12}$$

$$\frac{\partial \Pi_1}{\partial p_1} = Ae^{\theta LS} Q_1 + (p_1 - c_1) \frac{\partial (Ae^{\theta LS} Q_1)}{\partial p_1} = 0 \tag{13}$$

Solving the above equation for p_1 results in:

$$p_1 = c_1 - \frac{1}{b(\theta Q_1 + 1 - Q_1)} \quad (14)$$

This is the implicit reaction curve (pricing rule) for player 1. The reaction function cannot be given on a closed form in this model. The prices of the other players enter via Q_1, see (1) and (2). Similarly, the reaction curves for the other two players can be derived. Solving these reaction functions yields the Nash equilibrium in prices.

Cooperative game with external competitors

As suggested above, the three freight forwarders can establish different combinations of coalitions. In this situation, the profit function for each player will be different from equation (6). For instance, if all the freight forwarders decided to work under one decision unit, then the profit function of the coalition (player 1, for example) would be as follows:

$$\Pi_1 = [X_1(p_1 - c_1) + X_2(p_2 - c_2) + X_3(p_3 - c_3)] \quad (15)$$

This will give three conditions, one for each price.

Again, the Bertrand Nash equilibrium is characterised by the first-order conditions. Therefore, by taking the derivative of equation (15) and setting it equal to zero, we get the condition:

$$\begin{aligned} \frac{\partial \Pi_1}{\partial p_1} &= \frac{\partial\left(Ae^{\theta LS} Q_1\right)}{\partial p_1}(p_1 - c_1) + Ae^{\theta LS} Q_1 + \frac{\partial\left(Ae^{\theta LS} Q_2\right)}{\partial p_1}(p_2 - c_2) \\ &+ \frac{\partial\left(Ae^{\theta LS} Q_3\right)}{\partial p_1}(p_3 - c_3) = 0 \end{aligned} \quad (16)$$

$$[b(\theta Q_1 + 1 - Q_1)](p_1 - c_1) + 1 + Q_2[b(\theta - 1)](p_2 - c_2) + Q_3[b(\theta - 1)](p_3 - c_3) = 0 \quad (17)$$

This is the reaction curve for player 1 when all three players have formed a coalition. Similarly, reaction curves for other two players can be derived.

NUMERICAL ANALYSIS

Route: From Oslo to Rotterdam

By sea: For example, the Unifeeder service line offers a container feeder service from Oslo to Rotterdam, twice a week. The Unifeeder vessel departs Oslo on Thursday and reaches Rotterdam on Monday. It departs Rotterdam on Friday and reaches Oslo on Monday.[2] Therefore, it takes three or four days to reach from Oslo to Rotterdam via sea. The capacity of feeder vessels is between 700 and 750 TEUs.

By road: Travel distance between Oslo and Rotterdam is approximately 960 kilometres.[3] A road vehicle maintaining an average speed of 50 km/h would take approximately 19 hours to travel from Oslo to Rotterdam.

A model consisting of equations 1, 2, 6, 14, 15, 17 (for each player) and 4 is solved using an equation solver. In other words, solving the equilibrium of the Bertrand game provides the pricing rule set by the players, which will yield the Nash equilibrium

Table 1: General parameters of demand

Level of Demand (A)	*Logsum parameter (θ)*	*Price parameter (λ)*
200,000	0.010	-0.050

Table 2: Freight forwarders' specific parameters

	Player 1 (Big truck-operating company)	Player 2 (Small truck-operating company)	Player 3 (Ship operator)
Alt.spec. constant (α_i)	0.9	0	-16
Marginal cost in $ (c_i)	$400	$400	$80
Capacity (CAP_i)	3000 TEU	1000 TEU	73000 TEU

Bertrand solutions

In the first case, when all players are working independently, Nash equilibrium prices are higher for players 1 and 2 than for player 3. These are reasonable results because player 3 (the ship) is a cheap means of transportation. However, despite the high price, player 1 captures the largest market share. This reflects users' preference to trucks over ship to carry their cargo, even though ships are cheaper. This could be due to the fact that trucks offer a flexible, door-to-door service with low waiting time. For example, as information about the case study shows, travel time

[2] See http://www.unifeeder.com/C125702600609F2D/0/DD65A320D08D0680C125708300548F1C?opendocument.

[3] http://www.distance-calculator.co.uk/distances-for-oslo-to-rotterdam.htm

from Oslo to Rotterdam by road is approximately one day, while travel by ship takes three to four days.

Table 3: Case A: Bertrand equilibrium (when all players are independent)

	Player 1	*Player 2*	*Player3*
Equilibrium Price US$/TEU	440	430	110
Market share%	44	28	28
Profit (in millions of US$)	2.6	1.2	1.2
Total demand in 1000s TEUs	163.5		
Logsum	20		

Table 4: Case B: Bertrand equilibrium (when players 1 & 3 are cooperating)

	Player 1	*Player 2*	*Player 3*
Equilibrium Price US$/TEU	450	430	130
Market share	30	37	33
Profit (in millions of US$)	2.6	1.9	2.9
Total demand in 1000s of TEUs	162.8		
Logsum	20.6		

In case B, players 1 and 3 established a coalition that resulted in a duopoly situation. As expected, the Nash equilibrium prices of players who have joined a coalition are higher than in case A. As a result of these higher prices, the market shares of players 1 have declined. Although the Nash equilibrium price of player 3 is also higher compared to the previous case, it still offers a cheaper and better service after cooperating with player 1. As a result, its market share has increased. Moreover, player 2, which is an outsider in this situation, is able to capture a higher market share due to the comparatively low price offered by this player.

Table 5: Case C: Bertrand equilibrium (when players 1 & 2 are cooperating)

	Player 1	*Player 2*	*Player 3*
Equilibrium Price US$/TEU	450	450	112
Market share	46	15	39

Profit (in millions of US$)	3.8	1.2	2.0
Total demand in 1000s of TEUs	162.6		
Logsum	20.6		

Similarly, in this case, the Nash equilibrium prices of all players are high compared to a situation in which all players are working independently. However, there is a drastic decrease in the market share of player 2 (small-truck operating company) due to new higher price after forming a coalition with player 1. Player 1's market share has increased slightly despite charging a higher price; this is due to the provision of better service after collaborating with player 2. Finally, player 3 managed to capture a significantly higher market share due to its lower price.

Table 6: Case D: Bertrand equilibrium (when players 2 & 3 are cooperating)

	Player 1	*Player 2*	*Player 3*
Equilibrium Price US$/TEU	435	440	120
Market share	46	14	39
Profit (in millions of US$)	2.8	1.0	2.7
Total demand in 1000s of TEUs	163.4		
Logsum	20.18		

In this case, when players 2 and 3 are cooperating, the overall results are similar to the previous case. That is, player 2's market share decreases and those of players 1 and 3 increase.

Users' surplus

In addition to profit, which is the payoff for freight forwarders, the situation can be analysed from the users' perspective. The 'rule of the half' is used to estimate the users' benefits.

$$US = \frac{1}{2}(X_i + X_0).\frac{1}{b}(LS_i - LS_0) \qquad (18)$$

where LS_0 = logsum of the logit model before formation of a coalition *i*. *i*= B, C, D, E.

LS_1 = logsum after formation of a coalition *i*. *i*= B, C, D, E.

b = the model parameter for user's cost.

Table 7 presents the calculated users' surplus in all three coalitions. In all coalitions, the users' surplus is negative. Therefore, the formation of any kind of coalition among freight forwarders is not beneficial for users.

Table 7: Users' surplus for all the coalitions (in thousands of US$)

Coalitions	*Users' surplus*
Case B: (1+3) and Player 2 is independent	- 1958
Case C: (1+2) and Player 3 is independent	- 1957
Case D: (2+3) and Player 1 is independent	- 588

CONCLUSION AND POLICY IMPLICATIONS

This paper addresses four cases for three freight forwarders with two different means of transportation. In the first case, all players work independently and the numerical analysis obtained by solving the Bertrand model reveals that the Nash equilibrium prices are higher for players 1 and 2 – freight forwarders with their own trucks. However, despite the high price, player 1 captures the largest market share. This reflects users' preference to trucks over ship to carry their cargo, even though ships are cheaper. The frequency of ships is lower and waiting time is high, which is why this player, despite its low price, could not capture as much market share as captured the large truck operating company. Moreover, although player 2 is also a freight forwarding company with its own truck, it is a small company that simply cannot offer services with the same high frequency as a large truck-operating company.

The next three cases analyzed different combination of coalitions among these players. The numerical results reveal that all three kinds of coalitions generate higher profits for the members of the coalitions, as well as for the competitors in each case. Although all combination of coalitions result in higher profit for the players involved, the combined profit of the members of coalition, as well as competitors, is highest in a situation in which players 1 and 3 cooperate and offer intermodal services to their users. Due to market power and improved quality of service, these players are able to charge higher prices. The quality of service would improve in different aspects in this case. Firstly, having cooperated with the large truck operating company, player 3 can increase the frequency of its services and, as a result, provide flexible services to its customer. Secondly, these two big players can jointly offer different value-added services to their customers. In other words, the first and second points reveal that both players can utilise the benefits of economies of scale and economies of scope. Thirdly, trucks can be used to cover short-distance delivery of services. This would help decrease congestion in the road sector. Longer distance can be covered by cheap and environmentally friendly modes of transport; that is, ships with higher frequency.

Therefore, according to these findings, it is more beneficial to establish a vertical cooperation between a large truck operator and a ship operator to offer intermodal services than to establish a horizontal cooperation between two players. Moreover, establishing vertical cooperation among a small trucking company and a ship operator is also not as beneficial as the previously mentioned vertical cooperation. This is mainly due to the fact that cooperation between a vessel operating company and a small truck operating company would not increase the volume of cargo to a great degree, which can be utilised to increase the frequency of a vessel. However, this cooperation would be beneficial for a vessel-operating company to decrease its road access cost to and from port.

Finally, calculations of users' surplus show that these kinds of coalitions are not beneficial for users because they generate a negative payoff for them, which reflects the high prices they will have to pay to the service providers. However, there is a possibility that users will ignore the increase in price when they receive improved and good quality services after the formation of a coalition among players.

REFERENCES

Bakens, J. Knockaert, J. and Verhoef, E.T. (2010). Rewarding off-peak railway commuting: A choice experiment, *Proceedings of theWorld Conference on Transport Research,* 2010 Lisbon.

Banomyong, R. and Supatn, N. (2011). Selecting logistics providers in Thailand: a shippers' perspective, *European Journal of Marketing,* 45(3): 419–437.

Cantos-Sanchez, P., Moner-Colonques, R., Sempere-Monerris, J. and Alvarez, O. (2010). Competition and horizontal integration in maritime freight transport. Working paper, available to download at http://www.fedea.es/eng/033_Publicaciones_VerMas.asp?id=893.

Kokkinis, G. Mihiotis, A. and Pappis, C.P. (2006). Freight Forwarding in Greece: Services Provided and Choice Criteria. *EuroMed Journal of Business,* 1(2): 64–81.

Krajewska, M. and Kopfer, H., Laporte, G., Ropke, S. and Zaccour, G. (2008). Horizontal cooperation of freight carriers: request allocation and profit sharing. *Journal of the Operational Research Society,* 59, 1483–1491.

Krajewska, M. and Kopfer, H. (2009). Transportation planning in freight forwarding companies – Tabu Search algorithm for the integrated operational transportation planning problem. *European Journal of Operational Research (EJOR),* 197(2): 741–751.

Saeed, N. and Larsen, O.I. (2010) An application of cooperative game among container terminals of one port. *European Journal of Operational Research*, 203, 393–403.

Small, K. (1982). The Scheduling of Consumer Activities: Work Trips. *The American Economic Review*, 72(3): 467–479.

Theys, C., Dullaert, W., Notteboom, T. (2008). Analyzing cooperative networks in intermodal transportation: a game-theoretic approach. In: Nectar Logistics and Freight Cluster Meeting, Delft, The Netherlands.

Ting, T.U. (2009). Development of Competitive Pricing Game for Logistics Service. MPhil Thesis, City University of Hong Kong.

UNCTAD (United Nations Conference on Trade and Development) (1995). *Multimodal Transport Handbook.* SDD/MT/8. Geneva: UNCTAD.