Intertemporal logistics collaboration

Msc Thesis

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Abstract

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Keywords: Here, go, KEY, words

1. Introduction

During the last decades, logistics collaboration, and specially *horizontal logistics collaboration*, has gained the attention of many researchers, as it has been proofed to be an effective strategy to improve the logistics chain, for example, reducing both ecological [1] or economical (find cite) operational costs. By horizontal logistics collaboration we refer to the cooperation between several companies or agents, who playing the same role in the logistics chain, form coalitions or alliances to increase the efficiency of their logistics operations. For example, in the case of the liner hipping industry, by allowing other companies to use part of the capacity of the own ships, increasing the asset utilization ratio [2].

The literature studying the horizontal logistics collaboration between agents can be divided in two main streams depending on whether the collaboration it is centralized or not.

In the case of centralized systems, agents usually share in a pool all or part of the demands that they have to serve as well as the assets they have available. These assets can be vehicles in the case of transportation carriers, but also inventory levels, employees, etc. Then a central planner, taking into account all the demands and rources shared in the pool by the agents, solves the problem maximizing the total payoff of the coalition. Finally, the benefits of the cooperation are shared among the members of the coalition, usually using some allocation rule which ideally satisfies some desiderable conditions in terms of “fairness”, as that the resulting allocation is in the *core*, i.e., any subcoalition of the former one could obtain a higher payoff working independently [3]. A well known example of an allocation rule fulfilling this conditions is the *Shapley value* [4].

Some authors have argued in the centralized systems, the individual objectives of the agents are not considered in favour of the coalition objective, while actually the agents remain independent entities [5]. Therefore, these authors propose diferent mechanisms where both levels of objectives are considered [6] [7].

In the other hand, in the descentralized systems there is not a central planner who carries out the optimization and then allocates the benefits, but the agents remain independent decision makers during the whole collaboration process. Descentralized systems commonly operate based on auctions systems or inverse-optimization techniques [8]. In the first, agents share the part of their demands, an the other members of the coalition bid to be the ones serving that demand on exchange of a recompense from the original owner of the order. In the other hand, an example of a collaborative system based in a inverse-optimization mechanism is the proposed in [9]. On it, the authors model a multicommodity flow problem, where agents own certain fraction of the capacity of the edges of a network. Thus, the agents can collaborate sharing the capacity of the edges with the members of the coalition, who have to pay some price for using that edges. How much capacity the agents own on each edge of the and which are their demand is assumed to be public information. Using invere optimization, appropiate capacity exchange prices are found, in such a way that if the agents adopt that prices policy, when each agent selfishly optimizes his demands through the shared network, the resulting flow will be the same that if a centralized approach was used.

Some authors have argued that in the centralized systems, the individual objectives of the agents are not considered in favour of the coalition objective, while the agents actually remain independent entities [5]. Therefore, these authors propose diferent mechanisms where both levels of objectives are considered through multi-objective approaches [6] or by integrating the objectives of the agents as constraints to the coalition problem [7].

In [10] a novel framework to model descentralized systems is proposed. Based in the concept of *coopetition* [11], the authors proposed a 2-stage mechanism to model the collaboration of agents in descentralized distribution systems. In the first stage, agents individually takes strategic decisions, in their case, fixing their inventory levels. In the seconds stage an allocation of the assets is obtained through cooperation, were agents share their residual demands and inventory with the others, obtaining extra profits. They propose sufficient conditions under which a Nash equilibrium in pure strategiest exist for the first stage, and for which allocation rule in the *core* exists for the second stage.

In this paper we will compare the efficiency between a centralized system, giving to central planner different degrees of decision power, and a descentralized one, where we substite the central planner by a platform where agents can share information, and through an iterative process of optimization and information sharing, agents can achieve an equilibrium point from which any of the agents would be intested to deviate from. The problem we will use as example to implement this models is a multicommodity flow problem, where each agent have to decide which edges to active on the network at certain price, to then find an efficient flow trhough them which maximizes their payoff.

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2. Problem statement: A decision making - muldicommodity flow problem

As stated in the previous section, we will use a multicommodity flow problem with a strategic planning stage to illustrate the different cooperation mechanism we want to study in this paper. On this problem a set of agents have to first decide which edges they want to activate on a network, with certain costs associated. Then, the agents will have to route their commodities through the active edges maximizing the revenues generated by the served commodities and minimizing the costs associated with the activation of the edges. The agents might collaborate among them sharing the capacity they do not use in the active edges, allowing others to route their commodities through them at some price.

On the rest of this section we will introduce the specific characteristics of these problem as well as the notation we will use. We will finish the section modeling the problem that each agent would face in case he does not take part of the collaboration.

Let $N = \{1, ..., n\}$ be a set of agents. Let $G = (V, E)$ be a directed graph with V and E the sets of nodes and edges respectively. Each edge $e \in E$ will be noted by a tuple, $e = (v, w, i)$, indicating that it connects the node $v \in V$ with the node $w \in V$ and that his owner is the agent $i \in N$. Note that could exist as many edges between a pair of nodes as agents exists. Each edge $e \in E$ has certain units of capacity associated, q_e, and a a fixed activation cost c_e, that the owner of the edge have to pay if the edge is used to route any commodity. We will note by $OE(v) \subset E$ the subset of edges whose origin is the node $v \in V$. Similarly, $IE(w) \subset E$ is the subset of edges whose terminal node is $w \in V$.

Let Θ be the set of commodities. Each commodity is noted by a tuple, (o, t, i), where $o \in V$ is its origin node, $t \in V$ its destiny node and i is the agent who owns it. A commodity (o, t, i) ocupies $d_{(o,t,i)}$ units of capacity of the edges it pass throu, and has an associated revenue $r_{(o,t,i)}$. The owner of that commodity earns $d_(o, t, i) \cdot r_(o, t, i)$ if the commodity is succesfully delivered from its origin to its terminal node. The commodities are unsplitable, i.e., can not be divided between different edges.

We will note by $E^i \subset E$ and $\Theta^i \subset \Theta$ the subsets of edges and commodities owned by agent i.

2.1. Single agent model

The objective of an agent $i \in N$ is to maximize her payoff, by routing her commodities from their origin nodes to their terminal nodes through the edges she has activated. If the agent does not take part of the collaboration, she will not have any acces to other agents edges, neither the other agents will have acces to her edges. Thus, the problem which agent $i \in N$ has to solve can be modeled as the following ILP, that we call P_i,

$$P_i: \quad \max \sum_{(o,t,i)\in\Theta^i} \sum_{e\in IE^i(t)} f_e^{(o,t,i)} \cdot d_{(o,t,i)} \cdot r_{(o,t,i)} - \sum_{e'\in E^i} u_{e'} \cdot c_{e'} \tag{1a}$$

$$\text{subject to} \sum_{e\in IE^i(z)} f_e^{(o,t,i)} - \sum_{e'\in OE^i(z)} f_{e'}^{(o,t,i)} = 0, \qquad \forall\ z \in V \setminus \{o,t\},\ \forall\ (o,t,i) \in \Theta^i, \tag{1b}$$

$$\sum_{e\in OE^i(o)} f_e^{(o,t,i)} \leq 1, \qquad \forall\ (o,t,i) \in \Theta^i, \tag{1c}$$

$$\sum_{e\in OE^i(t)} f_e^{(o,t,i)} = 0, \qquad \forall\ (o,t,i) \in \Theta^i, \tag{1d}$$

$$\sum_{(o,t,i)\in\Theta^i} f_e^{(o,t,i)} \cdot d_{(o,t,i)} \leq u_e \cdot q_{(o,t,i)}, \quad \forall\ e \in E^i, \tag{1e}$$

$$\sum_{v\in S} \sum_{w\in S} f_{(v,w)}^{(o,t,i)} \leq |S| - 1, \qquad \forall\ S \subset V,\ \forall\ (o,t,i) \in \Theta^i, \tag{1f}$$

$$f_e^{(o,t,i)} \in \{0,1\}, \qquad \forall\ e \in E^i,\ \forall\ (o,t,i) \in \Theta^i, \tag{1g}$$

$$u_e \in \{0,1\}, \qquad \forall\ e \in E^i \tag{1h}$$

where, $\forall\ (o,t,i) \in \Theta^i,\ \forall\ e \in E$

$$f_e^{(o,t,i)} = \begin{cases} 1 & \text{if } (o,t,i) \text{is routed through } e, \\ 0 & \text{otherwise} \end{cases}$$

$$u_e = \begin{cases} 1 & \text{if } e \text{ is activated,} \\ 0 & \text{otherwise} \end{cases}$$

The objective of agent i, equation (1a), is to maximize the profit generated by the commodities which arrive to their destination nodes while minimizing the cost associated to the activation of the edges. Constraint (1b) ensures that, for any commodity, the flow that enters and leaves every transit nodes (neither the origin, neither the terminal node of that commodity) is equal. Constraints (1c), together with (1g), guarantee that each commodity is send at most only once from its origin node. Constraint (1d) ensures that none commodity is send from its terminal node. Constraint (1e) ensures that the capacity of edges is not exceed. Finally, constraint (1f) are subtour elimination constraints.

We will note by P_i^* the optimal solution of P_i and it is the maximal payoff agent i can obtain by his own, without cooperating with the other agents.

3. The centralized cooperation models

In the previous subsection, we have presented ILP that models the problem of an agent $i \in N$ who works independently. In this section, we present different centralized cooperative mechanisms that the agents in N could make use of, in order to find synergies among them and increase their payoffs.

In all our centralized models, we will allocate the benefits of the cooperation in the following way:

1. The revenues generated by every succesfully supplied commodity will be allocate to its owner.
2. The activation cost of every active edge will be payed by its owner.

3. If a commodity (o,t,i) is routed through an edge $e=(v,w,j)$ and $j \neq i$, agent i will make a side payment equal to $d_{(o,t,i)} \cdot \frac{c_e}{q_e}$ to the agent j. In words, for each commodity sent through an edge owned by other agent, the owner of the commodity will pay to the owner edge the fraction of the activation cost of that edge equivalent to the fraction of the total capacity of the edge that his commodity occupies.

Therefore, for any solution resulting from the cooperation, α, we can express the payoff corresponding to an agent $i \in N$ as

Furthermore, similarly to what is done [7], we will integrate the payoff of each agent as contraints of the central planner's problem, ensuring that the final payoff of each agent is not smaller than what they could achieve by their own without cooperation. Doing this, we ensure that the final payoff allocation is *individually rational* [3], i.e., no single agent is interested in leaving the coalition. [1]

In the rest of the section we introduce the three different centralized cooperative scenarios we propose in this work, that as stated before, differ in the degree of decision power given to the central planner.

3.1. Full cooperation scenario

We start introducing the model where more power is given to the central planner. In this model, all the commodities and edges of all the agents are given to the central planner, who has to solve the following ILP,

$$\Gamma_F : \max \qquad \sum_{(o,t,i)\in\Theta} \sum_{e\in IE(t)} f_e^{(o,t,i)} \cdot d_{(o,t,i)} \cdot r - \sum_{e\in E} u_e \cdot c_e \tag{2a}$$

[1] We can extend this idea by forcing the solution resulting from the cooperation to be in the *core*, by adding constraints ensuring that any the sum of the payoffs of the members of any subcoalition is equal or greater than what that agents could obtain by leaving the grand coalition and cooperating only among them. Nevertheless, doing it will increase the complexity of the models and we consider that it does not add value to the paper.

$$\text{subject to} \sum_{e \in IE(z)} f_e^{(o,t,i)} - \sum_{e' \in OE(z)} f_{e'}^{(o,t,i)} = 0, \qquad \forall\, z \in V \setminus \{o,t\}, \quad \forall\, (o,t,i) \in \Theta, \tag{2b}$$

$$\sum_{e \in OE(o)} f_e^{(o,t,i)} \leq 1, \qquad \forall\, (o,t,i) \in \Theta, \tag{2c}$$

$$\sum_{e \in OE(t)} f_e^{(o,t,i)} = 0, \qquad \forall\, (o,t,i) \in \Theta, \tag{2d}$$

$$\sum_{(o,t,i) \in \Theta} f_e^{(o,t,i)} \cdot d_{(o,t,i)} \leq u_e \cdot q_{(o,t,i)}, \quad \forall\, e \in E, \tag{2e}$$

$$\sum_{v \in S} \sum_{w \in S} f_{(v,w)}^{(o,t,i)} \leq |S| - 1, \qquad \forall\, S \subset V, \quad \forall\, (o,t,i) \in \Theta, \tag{2f}$$

$$f_e^{(o,t,i)} \in \{0,1\}, \qquad \forall\, e \in E, \quad \forall\, (o,t,i) \in \Theta, \tag{2g}$$

$$u_e \in \{0,1\}, \qquad \forall\, e \in E \tag{2h}$$

$$\varphi_i(\Gamma_F) \geq P_i^*, \qquad \forall\, i \in N \tag{2i}$$

where

$$\begin{aligned}
&\varphi_i(\Gamma_F) = \\
&= \sum_{(o,t,i) \in \Theta^i} \left[\sum_{e \in IE^i(o)} f_e^{(o,t,i)} \cdot d_{(o,t,i)} \cdot r_{(o,t,i)} - \sum_{e \in \Theta^j \,:\, j \neq i} f_e^{(o,t,i)} \cdot d_{(o,t,i)} \cdot \frac{c_e}{q_e} \right] + \\
&+ \sum_{\substack{(o,t,k) \in \Theta: \\ k \neq i}} \left[\sum_{e \in E^i} f_e^{(o,t,k)} \cdot d_{(o,t,k)} \cdot \frac{c_e}{q_e} \right] - \sum_{e \in E^i} u_e \cdot c_e,
\end{aligned} \tag{3}$$

is the payoff allocate to the agent $i \in N$ for any feasible solution of Γ_F.

Note that the linear programm that the central planner has to solve in the *full cooperation* scenario is almost identical to P_i, the ILP that an agent $i \in N$ has to solve when no cooperating. Both problems only differ in two aspects. First, the central planner manages the commodities and edges of all the agents,

Θ and E, while an agent i only has access to his own assets, Θ^i and E^i. Second, the constraint (2i) is exclusive to the cooperation scenario. This constraint guarantees that the vector of payoffs associated with the optimal solution found by the central planner, Γ_F^*, is individually rational. This means, as already introduced before, that the payoff of every agent $i \in N$, $\varphi_i(\Gamma_F^*)$, has to be equal or greater than the best payoff that the agent would obtain by his own without cooperating, P_i^*.

3.2. Partial cooperation scenario

In the partial cooperation scenario, the central planner has to optimize once again the flow of all the commodities of all the agents through the network maximizing the total generated revenue. Nevertheless, the decision of which edges activate remains as an individual decision of each agent.

In our model, each agent $i \in N$ solves his own P_i problem. Precisely the edges that are active in the optimal solutions, P_i^*, of each agent are the agents that the central planner can use to route the commodities throught the network.

Let $E_A \subset E$ be the subset of edges such that $\forall e = (v, w, i) \in E_A$, e is active in P_i. Then

the ILP, Γ_P, that the central planner has to solve in the partial cooperation scenario is

$$\Gamma_P : \max \sum_{(o,t,i)\in\Theta} \left[\sum_{e\in OE_A(o)} f_e^{(o,t,i)} \cdot d_{(o,t,i)} \cdot r_{(o,t,i)} - \sum_{\substack{e\in E_A^j: \\ j\neq i}} f_e^{(o,t,i)} \cdot \frac{c_e}{q_e} \right] \tag{4a}$$

$$\text{subject to} \sum_{e\in IE_A(z)} f_e^{(o,t,i)} - \sum_{e'\in OE_A(z)} f_{e'}^{(o,t,i)} = 0, \qquad \forall\, z \in V \setminus \{o,t\}, \quad \forall\, (o,t,i) \in \Theta, \tag{4b}$$

$$\sum_{e\in OE_A(o)} f_e^{(o,t,i)} \leq 1, \qquad \forall\, (o,t,i) \in \Theta, \tag{4c}$$

$$\sum_{e\in OE_A(t)} f_e^{(o,t,i)} = 0, \qquad \forall\, (o,t,i) \in \Theta, \tag{4d}$$

$$\sum_{(o,t,i)\in\Theta} f_e^{(o,t,i)} \cdot d_{(o,t,i)} q_{(o,t,i)} \qquad \forall\ e \in E_A, \tag{4e}$$

$$\sum_{v\in S}\sum_{w\in S} f_{(v,w)}^{(o,t,i)} \leq |S| - 1, \forall\ S \subset V, \quad \forall\ (o,t,i) \in \Theta, \tag{4f}$$

$$f_e^{(o,t,i)} \in \{0,1\}, \ \forall\ e \in E_A, \quad \forall\ (o,t,i) \in \Theta, \tag{4g}$$

$$\varphi_i(\Gamma_P) \geq P_i^*, \qquad \forall\ i \in N \tag{4h}$$

3.3. Residual cooperation

This is the model among the three in which less decision are left to the central planner, and it is inspired in the already mentioned framework presented in [10].

In the first place, every agent $i \in N$ will indivually solve his corresponding P_i problem by his own, deciding which edges to activate and how to route his commodities through that edges. Secondly, each agent will inform the central planner about which commodities they have not been able to route in an efficient way, as well as which active edges still have some free capacity. With all this information, the central planner routes in a efficient way the commodities

		Level cooperation		
		Partial-1	Partial-2	Full
AGENT	Activate edges	Yes	Yes	No
”	Route flow	Yes	No	No
Central planner	Activate edges	No	No	Yes
”	Route flow	Yes	Yes	Yes

Partial-1 cooperation

In the first type of cooperation, what we will call “Partial-1 cooperation”, each agent $i \in N$ will solve its own (P^i) problem and then pass to the central planner the demands he was not able to serve and the not used capacity of the edges he has activated. Will the information from all the agents, the central planner will try to maximize the profits of the grand coalition, routing the unserved commodities through the not used capacity of the edges. If a commodity is route through an edge ow by a different agent, the owner of the commodity will pay to the owner of the edge the proportional cost of the fraction of the capacity of th edge he is using.

Therefore, the central planner would be solving the following model:

$$\Gamma_1 : \max \sum_{(o,t,i)\in\Theta} \left[\sum_{e\in OE(o)} f_e^{(o,t,i)} \cdot d_{(o,t,i)} \cdot r_{(o,t,i)} - \sum_{\substack{e\in E^j :\\ j\neq i}} f_e^{(o,t,i)} \cdot \frac{c_e}{q_e} \right] \tag{5a}$$

$$\text{subject to} \sum_{e\in IE(z)} f_e^{(o,t,i)} - \sum_{e'\in OE(z)} f_{e'}^{(o,t,i)} = 0, \qquad \forall\, z \in V \setminus \{o,t\}, \quad \forall\, (o,t,i) \in \Theta, \tag{5b}$$

$$\sum_{e\in OE(o)} f_e^{(o,t,i)} \leq 1, \qquad \forall\, (o,t,i) \in \Theta, \tag{5c}$$

$$\sum_{e\in OE(t)} f_e^{(o,t,i)} = 0, \qquad \forall\, (o,t,i) \in \Theta, \tag{5d}$$

$$\sum_{(o,t,i)\in\Theta} f_e^{(o,t,i)} \cdot d_{(o,t,i)} q_{(o,t,i)} \qquad \forall\, e \in E, \tag{5e}$$

$$\sum_{v\in S} \sum_{w\in S} f_{(v,w)}^{(o,t,i)} \leq |S| - 1, \forall\, S \subset V, \quad \forall\, (o,t,i) \in \Theta, \tag{5f}$$

$$f_e^{(o,t,i)} \in \{0,1\}, \;\; \forall\, e \in E, \quad \forall\, (o,t,i) \in \Theta, \tag{5g}$$

where E is the set of all the edges, e, activated by an agent and with some not used capacity, q_e; and Θ is the set of all the demands that the agent left unserved.

We will note by Γ_1^* the optimal solution of Γ_1, and by $\varphi_i(\Gamma_1^*)$ the payoff corresponding to agent i, with

$$
\begin{aligned}
\varphi_i(\Gamma_1) = \sum_{(o,t,i)\in\Theta^i} \Bigg[& \sum_{e\in IE^i(o)} f_e^{(o,t,i)} \cdot d_{(o,t,i)} \cdot r_{(o,t,i)} - \\
& - \sum_{e'\in\Theta^j:\, j\neq i} f_e^{(o,t,i)} \cdot d_{(o,t,i)} \cdot \frac{c_{e'}}{q_{e'}} \Bigg] + \\
& + \sum_{(o,t,k)\in\Theta:\, k\neq i} \sum_{e''\in E^i} f_{e''}^{(o,t,k)} \cdot d_{(o,t,k)} \cdot \frac{c_{e''}}{q_{e''}},
\end{aligned} \tag{6}
$$

for every $i \in N$. Note that the first sum equals the payoff that agent i obtains from each of her demands, i.e., the revenue she obtains from subcessfully serving it minus the cost of the commodity being route through edges of another agents. The second sum equals the "side payments" that agent i obtains from other agents whose commodities are route through her edges. Thus, the final payoff of each agent $i \in N$ when the Partial-1 cooperation is used would be $\varphi_i(\Gamma_1^*) + P_i^*$

Partial-2 cooperation

In the second type of cooperation that we study, "Partial-2 cooperation", all the agent will also start by solving their P^i problems. Once they have done it, they do not route any commodity, but they pass all the commodities to the central planner, as well as all the edges they activate following their optimal solution for (P^i). Then, as in "Partial-1 cooperation", the central planner will try to maximize the profits of the Grand Coalition, but also ensuring that any agent will get a final payoff smaller than what he will optain without cooperation. Therefore, to the model of "Partial-1 cooperation" is added the following constraint:

Constraint (4g) ensures that the flow is routed in such a way that every agent ends up with a payoff equal or greater than what (s)he could optain without cooperation.

Full cooperation

The final type of cooperation we study, “Full cooperation”, is the case where all the agent pass to the central planner all their commodities, and let the central planner to decide which edges to activate and how to route the commodities. As in “Partial-2 cooperation”, the central planner must ensure that any agent end up with a payoff smaller than what (s)he would have obtained without cooperation.

with

$$\begin{aligned}\varphi_i(\Gamma_F) = \sum_{(o,t,i)\in\Theta^i} \Bigg[& \sum_{e\in IE^i(o)} f_e^{(o,t,i)} \cdot d_{(o,t,i)} \cdot r_{(o,t,i)} - \\ & - \sum_{e'\in\Theta^j:\, j\neq i} f_e^{(o,t,i)} \cdot d_{(o,t,i)} \cdot \frac{c_{e'}}{q_{e'}} \Bigg] + \\ & + \sum_{(o,t,k)\in\Theta:\, k\neq i} \sum_{e''\in E^i} f_{e''}^{(o,t,k)} \cdot d_{(o,t,k)} \cdot \frac{c_{e''}}{q_{e''}} - \\ & - \sum_{e\in E^i} u_e \cdot c_e,\end{aligned} \tag{7}$$

4. An iterative optimization mechanism

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5. Results

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6. Conclusion

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References

[1] E. Ballot, F. Fontane, Reducing transportation co2 emissions through pooling of supply networks: perspectives from a case study in french

retail chains, Production Planning & Control 21 (6) (2010) 640–650. doi:10.1080/09537287.2010.489276.

[2] R. Agarwal, O. Ergun, Ship scheduling and network design for cargo routing in liner shipping, Transportation Science 42 (2) (2008) 175–196. doi:10.1287/trsc.1070.0205.

[3] J. González-Díaz, I. García-Jurado, M. G. Fiestras-Janeiro, An Introductory Course on Mathematical Game Theory, American Mathematical Society, 2010. doi:10.1090/gsm/115.

[4] L. S. Shapley, A Value for N-Person Games, RAND Corporation, Santa Monica, CA, 1952. doi:10.7249/P0295.

[5] C. Defryn, K. Sörensen, Multi-objective optimisation models for the travelling salesman problem with horizontal cooperation, European Journal of Operational Research 267 (3) (2018) 891–903. doi:10.1016/j.ejor.2017.12.028.

[6] C. Defryn, K. Sörensen, W. Dullaert, Integrating partner objectives in horizontal logistics optimisation models, Omega 82 (2019) 1–12. doi:10.1016/j.omega.2017.11.008.

[7] C. Vanovermeire, K. Sörensen, Integration of the cost allocation in the optimization of collaborative bundling, Transportation Research Part E: Logistics and Transportation Review 72 (2014) 125–143. doi:10.1016/j.tre.2014.09.009.

[8] X. Xu, Collaboration mechanism in the horizontal logistics collaboration, Ph.D. thesis, Business administration. Ecole Nationale Supérieure des Mines de Paris (2013).

[9] R. Agarwal, Özlem Ergun, Mechanism design for a multicommodity flow game in service network alliances, Operations Research Letters 36 (5) (2008) 520–524. doi:10.1016/j.orl.2008.04.007.

[10] R. Anupindi, Y. Bassok, E. Zemel, A general framework for the study of decentralized distribution systems, Manufacturing & Service Operations Management 3 (2001) 349–368. doi:10.1287/msom.3.4.349.9973.

[11] A. M. Brandenburger, B. J. Nalebuff, Co-opetition, Crown Business, 1996.