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Game models of US-China waste paper transportation under the background of empty container allocation

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China is the largest destination country of US mixed waste paper exports, with exports accounting for about three quarters of its total exports. It is interesting that the transportation price of US-China waste paper is much lower than that of conventional goods. In order to find out the generation mechanism in the price of waste paper transportation and study the impact of the latest waste paper import policy in China on US-China waste paper transportation, this study uses cooperative game theory as tool to study the price of waste paper transportation. Firstly, this study puts the United States empty container transportation issues and US waste paper transportation problem in a unified framework. Secondly, this study takes the concept of core and Shapley value in cooperative game as the two fundamental tools and gives the price range of waste paper transportation. Thirdly, this paper predicts the development trend of US-China waste paper transportation price through studying the effect of the import policy of waste paper in China on the upper bound of the price range of waste paper transportation. Finally, this study verifies the effectiveness of the novel models by taking the "Los Angeles - Shanghai" paper transportation of a plant in Changshu, China as an example.

Keywords: Waste paper transportation, container empty allocation, Nash equilibrium, Shapley value, core.

1 Introduction

Since 21st century, China government has paid high attention to imported waste paper management and has issued a series of new policies and regulations with the concept of resource conservation and emission reduction. Nowadays, under the background of waste paper industry, how to distribute the values created from waste paper transportation to the interest-related parties has become an interesting problem currently. Therefore, it has been deserving to carry out researches on the transportation price decision-making model, which mainly centers on the two aspects of empty container transportation and transportation benefit distribution.

The US-China trade has been existing with the phenomenon of trade gap over the years, wherein, the annual export volume of China to America is far more than its annual import volume from America to China. Therefore, the solutions to the empty container allocation problem of the transport companies have attracted large attention from many scholars. For

example, Liu (2002) puts forward a concept that the empty container transportation level of the container liners has direct relationship with the container transportation cost. In order to make full use of the empty containers, Wang (2002) finds out the quantitative method for reasonable transportation of an empty container. From the perspective of the transportation benefit distribution method, the previous researches could be composed of the game theory method and optimization method. As for game theory, the main research results regarding this issue are based on the Shapley value method including the solutions proposed by Ma and Wang (2006) to the benefit distribution among the supply chain partners. Besides, Zhang and Luo (2008) also conducts similar researches on the benefit distribution process based on Shapley value method. Wei and Tang (2005) analyses the influence index for the cooperation among different interested parties based on the Shapley value method, and then analyses the benefit distribution problem of different interested parties. Meanwhile, the transportation price of US-China waste paper is also an important problem. On this point, Feng (2013) makes comparisons and analysis on the current situation and future development of the imported waste paper and domestic waste paper from the perspectives of consumption quantity, price tendency and quality criterion; Li (2009) puts forward an idea that the future development of the domestic waste paper recovery industry would impact the waste paper trade mainly engaging in waste paper import. Besides, game theory is one of the fashionable analysis tools in economics, which has also been applied on shipping industry, wherein, Peleg (1992) proposes a stablest solution in the cooperative game theory by core method. Ji (2010) provides an analysis on development strategies of shipping industries by using game theories. Kong and Han (2010) puts forward a novel transportation distribution method based on Shapley value in conventional logistics system. Thereafter, the researches mainly focus on Shapley value concept application under the background of cost distribution (Winter, 2002; Petrosjan and Zaccour, 2003). Meanwhile, Chander and Tulkens (2006) conducts a research on the core and free rider problems in the cooperative game.

All the aforementioned research results provide a foundation to study the pricing determination of waste paper transportation and to study the influence of the latest transportation policy on waste paper transportation. In this paper, the "US - China" waster paper transportation is studied. The research gap is as follows. Firstly, there are many empty containers which are arranged to be transformed from America to China. Secondly, the "China - US" transportation route is in peak season, and the transshipment of the liner shipping companies between ports in P. R. China with the containers of waste paper will bear a certain opportunity cost. In the following, by aid of core method and Shapley value method, a price decision-making model is established to analyses the distribution of the benefits created from transportation between the shipping company and Paper-making Plants (shippers) under the background of empty transportation, and the influence of the latest transportation policy on US-China waste paper transportation is also studied.

2 Research problem

In order to study the influence of various external environments on the "US-China" transportation of waste paper , this study takes core and Shapley value as two basic tools to research the pricing rule of waste paper transportation and defines the upper and lower bounds of the waste paper transportation price. Besides, the study also researches the influence of the latest transportation policy of Chinese mainland to "US-China" transportation price of waste paper. In order to establish the "US-China" waste paper transportation pricing model, this study takes the waste paper transportation of "Los Angeles port- Changshu port" as sample, and signifies the problem as follows. The paper-making plant in Changshu city is denoted as L; the US-China liner shipping companies are

denoted as $C_1, C_2, \ldots, C_n$, respectively; the full container loading expense and the empty container encasement expense in the Port of Los Angeles are denoted as H_{lf} and H_{le}, respectively; the full container unloading expense and the empty container loading expense in the Port of Shanghai are denoted as H_{sf} and H_{se}, respectively. It is also noteworthy that waste paper is usually transported by Forty-foot Equivalent Unit container (FEU). The price of each Forty-foot Equivalent Unit container (FEU) for domestic waste paper is denoted as P_c, the FOB of each FEU for American waste paper is denoted as P_a, and the benefit brought from each FEU is denoted as U. At present, L company relies on liner shipping companies to transport American waste paper to Changshu while after 2018, in accordance with the latest transportation policy of Chinese mainland, L company relies on shipping companies to transport the American waste paper to Shanghai port, then, Zhangjiagang, then, Changshu. Usually, L and the liner shipping companies need to make negotiations on the price every half a year. Next, the features of Los Angeles port- Changshu port waste paper transportation are summarized, and the transportation pricing problem is introduced.

(i) The Los Angeles port - Changshu port waste paper transportation has low requirement in timeliness, which needs the liner shipping companies to transport the waste paper to China within a period of time. When the US-China transportation business is busy, the liner shipping companies can retain all containers of the conventional commodities without considering the waste paper transportation; while when the Los Angeles port-Changshu port transportation business is not very busy, the liner shipping companies can transport the waste paper using the empty containers. After the containers are transported to Shanghai, when the liner shipping companies have no urgent need on containers, the paper transportation brings no opportunity cost for the liner shipping companies; while the liner shipping companies have demands on containers when the China - US ship route is busy, the opportunity cost to transport waste paper for liner shipping companies is denoted as P_t.

(ii) The waste paper transportation increases the actual transportation cost of the liner shipping companies less. Compared with the empty container transportation, each FEU will increase the expense by $(H_{lf} - H_{le})+(H_{sf} - H_{se})$, for the liner shipping transportation. While the fuel usage amount and management expense increase a little, which will be neglected.

(iii) The liner shipping companies which transport waste paper from Los Angeles port to China, have no right to operate coastal incidental business according to China's laws. Therefore, they have to transport the waste paper to Shanghai port, and employ barge company to transport the waste paper from Shanghai port to Changshu port. Denote the freight of transportation from Shanghai port to Changshu port as P_b. Besides, it is noteworthy that the freight P_b paid by the carrier to the barge company at present.

To conclude, the benefits brought from one FEU of waste paper transportation from Los Angeles port and Shanghai port can be obtained, which is denoted as

$$P_r = P_c - P_a - P_b - \left(H_{lf} - H_{le}\right) - \left(H_{sf} - H_{se}\right) - P_t. \tag{1}$$

The following section will conduct systematic analysis on the benefit distribution problem and solve the problems by using core and Shapley value methods (Tarashev et al. 2015) .

3 Pricing Model

Against the background of unbalanced shipping routes between China and US, there are a large number of empty containers dispatched from the west coast of the United States to

China. As a base cargo, the *L* company's transportation demands are very popular in the market. In order to carry out US-China waste paper transportation, *L* company first needs to apply for a permit from China government. After obtaining the permit, the company can negotiate separately with the companies $C_1, C_2, \ldots, C_n$, which mainly operate the Los Angeles-Shanghai shipping business, to determine the carrier and the freight. The above negotiations are affected by many factors, such as cooperation history, seasonal changes and so on. Under regular circumstances, there are a large number of empty containers in the "Western US-China" shipping route with empty container rate of about 40%, while the empty container rate of "China- Western US" routes varies with the seasons. Next, Three situations are discussed, respectively.

(*i*) During "China - Western US" shipping off-season, liner shipping companies will lose no opportunity cost of using containers after the containers arrived in Shanghai. The benefit *U* of waste paper transportation will be divided among *L* company and companies $C_1, C_2, \ldots, C_n$. For a specific container, owing to the fact that $C_1, C_2, \ldots, C_n$, can replace each other and causally choose a shipping company from $C_i (1 \le i \le n)$ that the combination (L, C_i) can bring benefit *Pr*. Therefore, the problem can be solved with a feasible configuration.

(*ii*) When the "China - US" route is in peak season, the liner shipping companies which transport the container with waste paper by waterway from Shanghai port to Changshu port, will bear a certain opportunity cost as P_t. At this time, $C_1, C_2, \ldots, C_n$ are still possible to replace each other. Causally choosing a shipping company from C_i $(1 \le i \le n)$, the combination (L, C_i) will bring a benefit *Pr* by Eq. (1).

(*iii*) As the transportation business of "China - US" route is further busy, when the containers loaded with waste paper arrived in Shanghai port, the liner shipping companies have urgent need of using containers. At this time, how to share the profits between liner shipping companies and paper-making plants can be solved by Rubinstein bargaining model.

As parts (*i*) and (*iii*) are relatively classical, only part (*ii*) is studied in this study. For convenience, "Los Angeles - Shanghai" transportation route is selected as a research sample. In recent years, all the liner shipping companies in "Los Angeles - Shanghai" route basically have the same empty container rate. Therefore, the opportunity costs of liner shipping companies are almost the same. For convenience, denote the actual distribution results between paper-making plants and all the liner shipping companies as

$$\vec{n}_0 = \left(i_L, i_1, i_2, i_3, \cdots, i_n\right). \tag{2}$$

By core method, the distribution between paper-making plant and all liner shipping companies is obtained, which is denoted as

$$\vec{n}_1 = \left(P_r, 0, 0, 0, \cdots, 0\right). \tag{3}$$

In this situation, once a carrier transports a FEU of waste paper from Los Angeles to Changshu, the freight that the paper-making company should pay the carrier is obtained as

$$P_l = P_b + \left(H_{lf} - H_{le}\right) - \left(H_{sf} - H_{se}\right) + P_t. \tag{4}$$

Meanwhile, by Shapley value method, the distribution between paper-making plant and all liner shipping companies is obtained, which is denoted as

$$\vec{n}_2 = \left(i'_L, i'_1, i'_2, i'_3, \cdots, i'_n\right). \tag{5}$$

Since there is only one chance that the shipper gets no marginal revenue, i.e., when he ranks at the head of the rank. Therefore, the shipper can get a proportion of profit as

$$i'_L = \left[(n+1)! - n!\right] \cdot \left[(n+1)!\right]^{-1},$$

which reduces to $i_L' = n*(n+1)^{-1}$, meanwhile, the carrier can a proportion of profit as $P_r - i_L'$. In this situation, once a carrier transports a FEU of waste paper from Los Angeles to Changshu, the carrier should be paid as

$$P_u = \left(P_r - i_L'\right) + P_b + \left(H_{lf} - H_{le}\right) - \left(H_{sf} - H_{se}\right) + P_t. \tag{6}$$

Denote the actual price of waste paper as P. Because the Shapley value method considers the actual contributions of all parties in a game, the share of benefits calculated based on the Shapley value will be higher than the actual share rate for a route shipping company. Therefore, it gets that $P \in [P_l, P_u]$. When China introduced a new waste paper transportation policy (China's General Administration of Customs, 2017), P_u will become an important index for analyzing the allocation of interests among liner shipping companies.

4 The influence of National Control Policy on the Transportation of Waste paper

According to the General Administration of Customs Announcement No. 48, notice on regulating transit services, China has increased its restrictions on the permitted import of waste paper ports (China's General Administration of Customs, 2017). One of them is that "Customs requires the import ports of waste paper to be equipped with a large container inspection system". Owing to this announcement, there is a risk for paper-making plant L of increasing the transportation costs of waste paper between the United States and China since Changshu Port does not meet this requirement. Therefore, the waster paper has to be transported from other ports, such as Zhangjiagang Port. Formally, assume that the additional transportation costs regarding this issue as P_a. In accordance with the requirements of the General Administration of customs, assume that the collection of ports meeting the new qualifications of imported waste paper as S. When $L \notin S$, assuming that the transportation price of every container between S and L as P_L.

When $L \in S$, the overall benefits brought by liner shipping companies and paper-making plant through transporting the waste paper in the route of Los Angeles-Shanghai remains the same. When $L \notin S$, the carrier has to find a non-local port to discharge cargo, therefore, the entire profits brought by consignment paper through the Los Angeles-Shanghai route decreases. The decline in efficiency will pressure the carrier to benefit from the upper limit of compressed carrier and shipping paper business negotiating space between the tariffs and thus reduce the price of transporting of waste paper with containers.

On the other hand, the announcement of Circular 48 will raise the overall cost of transporting waste paper in the "US-China" route. To a certain extent, the announcement will reduce the power of paper-making plant in China to import waste paper from the "US - China" route waste paper traffic. Due to the decline of traffic volume, the carrier's position of negotiating with the paper-making plant in China will continue to decline and the downward trend of freight rates will be further strengthened.

5 Illustrative example

This study mainly takes the waste paper transportation of "Los Angeles - Shanghai" in a paper-making plant in Changshu City, Jiangsu Province as an example to testify the theory put forward. In the US waste paper market, most of waste paper is divided into the following categories: 3#, 8#, 9#, 10#, 11#, 13#, 37#. In China market, the purchases concentrate on 3# paper where its FOB price index is the highest one. Therefore, this type of waste paper is

studied here. At present, the liner transportation between Los Angeles and Shanghai are mainly operated by nine liner shipping companies, including Maersk Line, Mediterranean shipping, APL, CMA-CGM, COSCO Shipping, Evergreen, Hapag-Lloyd, NYK Line and K-line, which are indicated as n=9 in Eq. (2).

At present, the studied plant imports waste paper mainly from Los Angeles port, and the existing water transportation route is "Los Angeles - Shanghai - Changshu" . The loading or unloading cost of full container in Los Angeles Port is 202.44 $, while the cost is 127.6$ in Shanghai Port. Meanwhile, the loading or unloading cost of empty container in Los Angeles Port is 142$, while the corresponding cost in Shanghai Port is 88.2$. When a liner shipping company decides to transport the given container of waster paper, it may lose a chance to transport other ordinary goods due to market factors. In this study, the opportunity cost is set at 5$. To transport the waste paper from Los Angeles Port to Changshu port, another fee that the paper-making plant should pay is the freight from Shanghai to Changshu, which is about 180$/FEU. The prices of 3# waster paper in Los Angeles, US and Changshu, China are varying every day. In this paper, the price of 3# waste paper is adopted the ones happened in February, 2017, i.e., the price of 3# waste paper in Los Angeles is adopted as 213$/ton, while the price in Shanghai is adopted as 275$/ton. Besides, a FEU can contain 25 tons of waste paper. To identify the aforementioned data more clearly, Table 1 is given as follows.

Tab. 1 Key prices

Port	Loading (unloading) cost of full container	Loading (unloading) cost of empty container	*3#* waste paper price
Los Angeles port	*202.44 $*/FEU	*142$*/FEU	*213$/ton*
Shanghai Port	*127.6$*/FEU	*88.2$*/FEU	*275$/ton*

Then, the overall benefit by transporting a single FEU of *3#* waste paper is obtained as

$$P_s = (275\text{-}213) * 25 - (202.44\text{-}142) - (127.6\text{-}88.2) - 180 - 5 = 1265.16\$.$$

Next, the benefit distribution problem is settled by core and Shapley methods, respectively.

(*i*) By core theory, the given benefit distribution problem is solved. Specifically, by Eq. (3), the profits obtained by the paper-making plant and liner shipping companies are $\vec{n}_1 = (1265.16,0,0,0,0,0,0,0,0,0)$. All profits obtained belong to the paper-making plant, and liner company gets no profit. Concretely, by Eq. (4), when the shipping company transport a single FEU of 3# waste paper from Los Angeles, US to Changshu, China. the paper-making plant needs to pay the liner shipping company

$$P_l = (202.44\text{-}142) + (127.6\text{-}88.2) + 180 + 5 = 284.84\$.$$

(*ii*) According to Shapley value method, the given benefit distribution problem can be solved too. Specifically, according to Eqs. (11) and (12), the total benefits obtained by paper-making plant and liner shipping companies is obtained as

$$\vec{n}_2 = (1138.64,14.06,14.06,14.06,14.06,14.06,14.06,14.06,14.06,14.06).$$

By Eq. (6), once a liner shipping company transports a single FEU of *3#* waste paper from Los Angeles, US to Changshu, China, the expected freight of the transportation is obtained as

$$P_u = 14.06 * 9 + (202.44\text{-}142) + (127.6\text{-}88.2) + 180 + 5 = 411.38\$,$$

By Eqs. (4) and (6), the freight interval of a single FEU of *3#* waste paper is obtained as *[284.84, 411.38]*. In fact, the actual freight from Los Angeles to Changshu of a single FEU of *3#* waste paper is 380$, which locates in the interval *[284.84, 411.38]*. The calculation results show that the freight interval is reasonable and satisfactory. It is noteworthy that the cost of empty container transportation from Los Angeles to Changshu is 480$/*FEU*. Therefore, this

study has proved one interesting thing, the freight that the paper-making plant pays to the liner shipping company is lower than the cost of it when the liner shipping company transports waste paper for the paper-making plant.

In the following, the impact of the newly transportation policy of P. R. China on the waster paper transportation price range is introduced. It is well known that the Announcement No. 48 of the Notice on Regulating the Transit Transport Business issued by the General Administration of Customs has been effective since 2018. When the announcement comes into effect, Changshu Port will not be eligible for imported waste paper. Therefore, the existing "Los Angeles - Shanghai - Changshu" water transportation will be changed to "Los Angeles - Shanghai - Zhangjiagang - Changshu" water transportation, where domestic freight from Shanghai to Changshu will increase by *50$/FEU*. As the freight rate increases, through the game model, it can be settled that the total profit of paper companies and liner shipping companies through the "West Coast-China" transport of waste paper will be reduced to *1215.16$/FEU*. Specifically, the Shapley value model shows that each FEU of *3#* waste paper will bring Changshu Paper-making *1093.64$*, while the liner shipping company would earn *221.36$*. Then, it gets a new freight interval. Since the upper bound of the freight interval is reduced, the actual freight value would be pulled down in the future.

6 Conclusions

In this study, cooperative game theory, especially the models of core and Shapley values are used as two main tools to study the Western US - China shipping price of waste paper. The study reveals the influence of the US - China empty container allocation on waste paper transportation pricing. In theory, this study takes the core concept and Shapley value concept in cooperative game as the two basic tools, giving the price range of waste paper transportation, and studying the policy of waste paper in China impact on the true value of transport prices. In practice, this study takes the waste paper transportation of a paper-making plant in Changshu, Jiangsu Province as an example to verify the new theory. The verified results show that the price range of waste paper transportation calculated by game theory is highly consistent with the actual price of waste paper transportation.

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