Available online www.jocpr.com

Journal of Chemical and Pharmaceutical Research, 2013, 5(12):259-264

Research Article

ISSN : 0975-7384
CODEN(USA) : JCPRC5

Optimization of the grain circulation in the port cities of China using a spatial equilibrium model

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ABSTRACT

Using the spatial equilibrium model, this study estimates the flow direction and quantity in thirty-one provinces and three overseas imported strongholds, including Dalian, Ningbo and Fangchenggang, and it reveals Dalian as a representative port city plays an important role in the process of grain transshipment at home and abroad. Lastly, this paper puts forward the key to future development lies in the center position of the key port city as the grain logistics and the fixation of the function of each port city.

Keywords: Port City, Grain Circulation, Spatial Equilibrium Model

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INTRODUCTION

Since the 21th century, China's food security has always been tightly balanced. The grain circulation has become an important factor to affect people's life and production. On the one hand, China's grain production is imbalanced with the consumption, and the North-to-South Grain Diversion has become an important feature in China. On the other hand, the imported grain is increasing and the port city as a traffic hub is becoming a highlight accompanied by the strategy of grain production Going Out. Stressing the study of grain flow direction and quantity in the port city is the key to achieving food security strategy. Halbrendt & Gempseaw & Chen (1989),Hearn & Halbrendt & Gempseaw & Webb (1990) used Spatial Equilibrium Model (SEM) to investigate China's agricultural market [1,2], and Xin (2002) used GAMS (The General Algebraic Modeling System) and the railway freight over internet to investigate the circulation and price of fodder between provinces[3]. Chen (2004) simulated and predicted the spatial equilibrium of rice, wheat, soy, animal products and aquatic products [4]; Zhang (2006) used the SEM to study the changes of natural rubber in the world market [5]; Liang (2007, 2010) used the GIS (Geographic Information System) and SEM to study the comprehensive transportation costs of grain and the optimal logistics routine [6,7]. However, the above research is lack of the study of port city in the role of grain circulation. Under the condition of imbalance between the production and sales, as well as the increasing import, it is important to make full use of the advantage of port city as a traffic hub and to regulate the circulation of grain at home according to the production and the sales.

The following parts will introduce the relationship between grain circulation and the port city, and then the imitation of the grain flow orientation and quantity used by the SEM; the fourth part is about the ways to optimize grain in the port city, and then the conclusions.

Port city and grain circulation

Definitions

Grain circulation means the grain moved on the basis of the best transport routes and the cheapest means according to different needs, which is in order to achieve the best economic and social benefits.

Port, as the most important hub in the global logistics chain, plays an important role in the whole transportation system. The main port cities in charge of grain importing and exporting include Dalian, Qingdao, Lianyungang, Shanghai, Ningbo, Shenzhen, Fangchenggang. These large harbor cities are unique in geographical position and rich in deep water resources, which provide the congenital conditions for the international freight. Meanwhile, these harbor themselves with the advantage of transportation are the main places to distribute the goods and also the important inland sea channels with strong capacity to import, export and discharge goods.

Port city as the centre of grain logistics

Port city is the hub in the process of the grain circulation, and itself is a large grain logistics base to produce, store, and transport. Meanwhile, as these port cities are the forefront of China's economic reform and opening to the outside world, they have a great advantage in attracting foreign investment and are characterized by the export-oriented. Since the reform and opening policy, the local cities have established economic and industrial zones with a certain scale, which have a great demand on grain. The port cities not only play the role of grain import and export and the logistics center of grain transportation, but also the demand of grain circulation is affected by the international grain price, the supply and the demand.

Three grain circulation belts

From the distribution, the overall grain logistics patterns come into being around the Bohai Sea, the Yangtze River Delta, and the Pearl River Delta. From the transportation maritime channels at home, the grain in northeast of China are transported by railway and highway to Liaoning, Dalian, and other ports, and then transported by water to Tianjin, Shandong, Shanghai, Jiangsu, Zhejiang, Fujian, Guangdong, Guangxi, Hainan and other places. The main grain logistics nodes include Harbor Beiliang, Dalian, Yingkou, Qinhuangdao, Jinzhou, Dandong, Tianjin, Qingdao, Lianyungang, Shanghai, Ningbo, Xiamen, Huangpu, Shekou, Zhanjiang, Shantou, Fangchenggang, which connect with the railway channels and the water channels of Yangtze and Pearl River. These passages stretch across the major producing and sales areas, covering northeast, the areas around Bohai Sea, Yangtze River Delta, Pearl River Delta, and other economic zones. The amount of annual grain circulation is nearly to 50 million tons, accounting for 26.5% of the total grain logistics [8]. From the transportation channels of grain import and export, it can be seen that they are mainly composed of soybean import channels and corn export channels. The soybean import channels refer to the imported soybean flowing into the southeast coast of China, Shandong, Beijing and Liaoning from America, Brazil, and Argentina. The exported corn channels refer to the corn exported to South Korea, Japan, Malaysia, Canada and other countries from Harbor Beiliang, Dalian, Yingkou, Jinzhou, and Dandong. Therefore, the port cities not only bear the task of international grain import and export, but also responsible for the domestic grain transportation from the main producing areas to the main sales areas.

The analysis of grain circulation in the port city simulated by SEM

Spatial Equilibrium Model considering price

The objective function:

Constraint conditions:

（1） $C_{ijt} = F \times d_{ijt}$

（2） $\sum_{i=1}^{N} X_{ikjt} \le MIQ_{it}$

（3） $\sum_{j=1}^{30-N} X_{ijt} \ge MOQ_{ijt}$

（4） $(MIQ_{it}, MOQk_{jt}, P_{it}, P_{jt}, x_{ijt}, c_{ijt}) \ge 0$

Solve: x_{ijt}

MIQ represents the net imported quantity of grain in each province; MOQ is the net exported quantity of grain in each province; i refers to the grain imported province; j refers to the grain exported province; t is the year; x is the traffic volume; c is per transportation cost per unit grain between two regions; F is the grain transportation cost; d is the distance between regions.

Constraints:

(1) is the formula to calculate the transportation cost per unit grain between regions.

(2) means the in-flowed restrictions that the quantity of inflow grain from other provinces is less than or equal to the amount lacking of in the local.

(3) refers to out-flowed restrictions that the rest quantity at the local is more than or equal to the amount out-flowing.

(4) is the restriction for each variable symbol.

Data

The objects in this paper involves with China's thirty-one provinces, including the autonomous regions and municipalities (except Hong Kong, Taiwan, and Macau). The data comes from China Statistical Yearbook and China Agriculture Statistical Yearbook, among which involve with the quantity of imported and exported grain, namely the total quantity of cereal and cereal powder.

The grain surplus in each province

Grain supply is decided by the long-term production and net import, which is affected by the grain stocks in a short term. Grain consumption is determined by the total number of population and per capita consumption. As the data of grain stocks is unavailable, this paper adopted the mean in the five years from year 2006 to 2010 to eliminate the influence of grain stocks to the supply. In this paper, the total grain supply is the quantity of grain annual production plus the net quantity of the imported grain; the grain annual consumption per capita is the ratio of overall grain supply divided by the total number of China's population. The grain annual consumption per capita is as a benchmark, which multiplies with the total population number in each region respectively to calculate the grain annual consumption in every province. The difference between the grain annual production and annual consumption is the overage or the shortage.

According to the above method and the calculation results of the data from year 2006 to 2010, eleven provinces among the thirty-one provinces are the surplus areas, including Heilongjiang, Jilin, Henan, Inner Mongolia, Anhui, Shandong, Hunan, Jiangxi, Liaoning, Ningxia, Xinjiang, and Jiangsu, and the other provinces belong to the grain imported areas. (Seen in Table-1)

Table-1. The grain production, consumption in each province (Mean Year2006-2010)

Province	Production (en thousand ton)	Consumption (en thousand ton)	Overage and Shortage (ten thousand ton）	Province	Production (ten thousand ton)	Consumption (ten thousand ton)	Overage and Shortage (ten thousand ton)
Heilongjiang	3425.47	1519.12	1906.35	Hubei	2180.06	2291.79	-111.73
Jilin	2621.00	1082.10	1538.90	Qinghai	95.60	217.52	-121.92
Henan	4892.54	3758.41	1134.13	Hainan	177.94	332.37	-154.43
Inner Mongolia	1762.88	952.82	810.06	Sichuan	3083.64	3288.83	-205.19
Anhui	2826.73	2459.92	366.81	Gansu	832.65	1038.55	205.90
Shandong	3978.42	3698.25	280.17	Yunnan	1509.19	1781.11	271.92
Hunan	2704.40	2551.90	152.50	Tianjin	139.97	431.90	291.93
Jiangxi	1827.32	1725.23	102.09	Shanxi	1029.68	1340.99	311.31
Liaoning	1777.22	1692.99	82.23	Guizhou	1136.66	1506.12	369.47
Ningxia	310.80	239.74	71.06	Shaanxi	1069.78	1484.19	-414.41
Xinjiang	874.57	814.74	59.83	Guangzhou	1428.06	1896.14	-468.08
Jiangsu	3002.56	3001.79	0.77	Beijing	100.36	631.20	-530.84
Tibet	94.13	111.53	-17.40	Shanghai	109.56	721.94	-612.38
Hebei	2705.76	2741.80	-36.04	Fujian	688.11	1414.15	-726.04
Chongqing	1092.88	1143.39	-50.51	Zhejiang	807.56	1969.75	-1162.20
				Guangdong	1340.14	3640.52	-2300.38

Estimating the flow orientation and quantity based on the SEM

The study of grain circulation optimization in the port city is under the background of China's grain circulation, which estimates the grain flow orientation and quantity when the route of grain circulation is the most optimal. The grain circulation in this paper focuses on the grain transfer in space and time. In terms of space, the most optimal route is chosen to ensure the grain transported smoothly between regions; In terms of time, the length of grain transporting between different regions is the shortest; In terms of expenses, the total expenses of grain circulation is minimized. Ideally, the optimal grain route should be optimal in space, time, and expenses. However, it is difficult to make the above three factors be optimal at the same time as a result of the limitation of objective conditions. The fastest transportation route means higher cost, and the least cost is likely to be long in time and path. Therefore, this paper chooses the railway and water as the main transportation ways.

As the grain price is unavailable and basically flat in the long term though there is narrow gap between the purchased grain, and the grain transportation restricted by the capacity and volume, so the differences of price estimating are eliminated. Therefore, it becomes the calculation of the optimal producing quantity in each place and the optimal number of transportation between regions, namely the allocation, to minimize the transportation cost according to the demand, production potential and transportation cost. The transportation cost here refers to the transportation over railway ￥0.0616/ ton per kilo[6] and water ￥0.035/ ton per kilo, and the distance between provinces is the railway distance between the capitals in each province.

If take the grain surplus provinces as a benchmark, and do not take imported grain into account, it can be seen from the simulation of SEM that it is impossible to meet the grain demand in the main sales districts located in the remote areas. For example, Tibet, Chongqing, Hainan, Sichuan, Yunnan, Guizhou and Guangxi are lack of grain, and Guangdong is partly lack of grain. From the distribution, most of regions which are lack of grain lie in the southwest of China, and followed by the coastal areas in the south of China.

On the basis of the above situation, this paper takes the net grain gap 18.5718 million as the imported grain quantity. Considering the current grain logistics situation in the coastal port cities and the results of the above simulation, this paper will analyze thirty-one provinces, besides the three ports, namely Dalian, Ningbo, Fangchenggang, which are the important hub in the North-to-South Grain Diversion, a representative city in the Yangtze River Delta, and a port city in the Pear River Delta correspondingly.

Assume the average 18.5718 million tons of grain imported to China from port Dalian, Ningbo, and Fangchenggang, and each port accounts for one-third of the total quantity respectively. The goods is transported over water from Dalian, Ningbo, and Fangchenggang to other capitals as ports, and transported over railway to other places, and the distance is calculated to the capital of each province. The results can be seen in Table 2 imitated by LP (Linear Programming).

It can be seen that the grain flows from the main producing areas into the main sales places unidirectional. The surplus of grain in Anhui and Jiangsu are all transported to Zhejiang; the surplus in Shandong can supply the overall shortage in Hebei and Tianjin; the surplus of grain in Henan can meet the shortage in Chongqing, Hubei, Sichuan and part shortage in Yunnan and Guizhou; the surplus of grain in Inner Mongolia can meet the shortage in Qinghai, Shanxi, and part shortage in Yunnan and Guizhou; the surplus of grain in Guizhou just meet the part shortage in Guizhou; the surplus of grain in Jiangxi just meet the part shortage in Guizhou; the surplus in Ningxia can meet the overall shortage in Tibet and part shortage in Gansu; the surplus of grain in Xinjiang can meet the part shortage in Gansu.

Port Dalian, Ningbo, Fangchenggang, as an important node, plays an important role in domestic grain transportation and import. Most grain in the main grain producing areas in the northeast of China is transported to the south of China through Dalian. Except the 2.4642 million tons of grain in Heilongjiang are transported to Beijing directly, and the rest 16.5993 million tons of grain are transported through Dalian to other places, and the 15.389 million tons of grain in Jilin are all transported through Dalian. Except the 488,000 tons of grain in Liaoning are transported to Tianjin, the rest 344,300 tons are transported through Dalian. The grain transported though Dalian and the imported grain can meet the overall demands in Shanghai and Fujian, and also meet most grain shortage and small part grain shortage in Zhejiang and Guangdong respectively. The imported grain through Ningbo can satisfy the most demands in Guangdong and small demands in Guangxi, and the imported grain to Fangchenggang can meet the overall demands in Hainan, the most demands in Guangxi, and part demands in Yunnan. What should be paid attention to is the assumption in this paper that there is no strict distinction between the varieties of grain, treating the grain as a whole.

Therefore, it can be seen that the flow orientation and quantity of grain is different from the reality, but is roughly similar. If every variety of grain is estimated, the flow orientation and quantity of each variety using the same method can be achieved too.

The ways to optimize the grain circulation in port cities

To strengthen the construction logistics facilities of port cities and optimize the logistics channels

At present, the distribution of grain logistics facilities in south and north of China is greatly imbalanced. In the main sales areas, the south-east coast is short in loading and capacity, especially lacking in the capacity of the transshipment depot. The amount of raw grain flowing into seven southeast coastal cities, namely Shanghai, Jiangsu, Zhejiang, Fujian, Guangdong, Guangxi, and Hainan, accounts for half of the total inflow in China. However, the capacity in these cities is only 10%, and short in highly mechanized silo and squat silo. Though the south is rich in water, the transport efficiency is not high as lack of bulk grain barge and supporting discharged equipments. The primary task is to fulfill the center position as a grain logistics. Speeding up the construction of supporting hardware facilities in the port city, especially loading and unloading equipment, construction of transport corridors, is to make the railway, highway and waterway joint seamlessly. Meanwhile, pay attention to the construction of soft environment in key port cities. To optimize the transportation routes in the whole society is to reduce the transportation cost and to stimulate the development of grain logistics over water.

Table-2.The grain flow orientation and quantity in each province and port city

Province	Hei long jiang	Ji lin	He nan	Inner Mongo -lia	An hui	Shan dong	Hu nan	Jiang xi	Liao ning	Ning xia	Xin jiang	Jiang su	Da lian	Ning bo	Fang cheng gang	Demands
Dalian	1659.93	1538.9							34.43							0
Tibet										17.4						17.4
Hebei						36.04										36.04
Chongqing			50.51													50.51
Hubei			111.73													111.73
Qinghai				121.92												121.92
Hainan															154.43	154.43
Sichuan			205.19													205.19
Gansu				92.41						53.66	59.83					205.9
Yunnan			237.41												34.51	271.92
Tianjin						244.13			48.8							291.93
Shanxi				311.31												311.31
Guizhou			114.88				152.5	102.09								369.47
Shaanxi			414.41													414.41
Guangxi														37.96	430.12	468.08
Beijing	246.42			284.42												530.84
Shanghai													612.38			612.38
Fujian													726.04			726.04
Zhejiang					366.81							0.77	794.62			1162.2
Guangdong													1719.28	581.1		2300.38
Supply	1906.35	1538.9	1134.13	810.06	366.81	280.17	152.5	102.09	82.23	71.06	59.83	0.77	619.06	619.06	619.06	8362.08

To pinpoint the status of each port city
Avoid the repetitive construction and vicious competition in the grain logistics in port cities and fix the function of each port city according to different functions of each port city in transporting grain. Dalian can not be replaced by other ports, which is not only the main producing and sales areas, but also the hub in the national and international market. Meanwhile, Dalian owns the national grain futures trading center, namely Dalian Futures Exchange. Therefore, Dalian is the joint of grain cash and grain futures, the joint of water and land, and the joint of grain trading, storage, and processing, which can radiate most areas of China. Ningbo is an important port city in the Yangtze River Delta. On the one hand, it is an important channel to undertake the grain transportation from the northeast of China and foreign countries. On the other hand, it is also an important entrance to enter the Chinese hinterland through the Yangtze River. Logistics base has been built in Ningbo, which plays an important role in food processing, storage and transportation and radiating the areas around Yangtze River Delta. Fangchenggang in Guangxi province is an important exit in transporting grain in southwest of China. Because of the excellent port natures, it shoulders an important role in regulating food import and export, and particularly undertakes the transportation of a large quantity of grain for South Asia.

Furthermore, Qingdao in Shandong province, Lianyungang in Jiangsu province, Shenzhen in Guangdong province, and Shanghai are important nodes in transporting grain, and are also important channels for the inflow of grain from northeast of China and the outflow to the other parts of the world. Lianyungang and Ningbo, as Two Wings of Shanghai, belong to the Yangtze River Delta, which radiate strongly to the areas in the Yangtze River Delta. Shenzhen and Fangchenggang, as Pearl River Grain Corridors, play an important role in importing and exporting. Qingdao, as an important port in Jiaodong Peninsular, and together with other port cities meets the supply and demand in the local areas.

CONCLUSION

The key port cities in China mainly include Dalian in Liaoning province, Qingdao in Shandong province, Lianyungang in Jiangsu province, Shanghai, Ningbo in Zhejiang province, Shenzhen in Guangdong province, Fangchenggang in Guangxi province, etc. They are important channels to transport grain at home and import and export overseas, and they are also important to ensure food security strategy. This paper used the SEM to estimate the flow direction and quantity of grain in China, and found that Dalian, Ningbo, and Fangchenggang play an important role in grain transportation in China and grain import and export overseas. The important problem to be solved in the future is the full use of the center grain logistics and the fixation the status of each port city.

Acknowledgement
This research was financially supported by the University Philosophy and Social Science Fund of Jiangsu Provincial Department of Education (Grant NO. 2010SJB790017), the National Natural Science Foundation of China (Grant NO. 71203087), the National Natural Science Foundation of China (Grant NO. 71373116), the Ministry of Education Research of Social Sciences Youth funded projects(Grant NO. 09YJC790138),the Jiangsu Provincial Key Research Base of University Philosophy and Social Sciences Program(Grant NO.2012JDXM002),Governmental Public Industry Research Special Funds for Projects(Grant NO. HY13133075), the National Soft Science Research Program(Grant NO. 2013GXS2B014), the Key Research Bases of the Center for Food Security and Strategic Studies of Nanjing University of Finance and Economics(Grant NO. JD2013004),and the Center for Food Security and Strategic Studies of Nanjing University of Finance and Economics (Grant NO. CFSSS2011-08, CFSSS2012-05). It was a Priority Academic Program for Development of Jiangsu Higher Education Institutions (PAPD) and a Major Project of Jiangsu Provincial Key Research Base of University Philosophy and Social Sciences.

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