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Sustainable Lake Basin Water Resource Governance in China: The Case of Tai Lake

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Abstract: China's water pollution is severe and has a negative impact on its residents. Establishing an emissions trading mechanism will be helpful for reducing the pollution. However, the government in China controls the emission rights market. The "GDP Only" preference blocks equitable rules to address the externalities. To modify this distortion, we develop a multi-objective primary distribution model that optimizes economic efficiency, environmental contribution, and fairness. In addition, the geographical location of a company and the industry differential are two key factors that would affect the local government's decision. According to the simulation results using data from Tai Lake in China, this model can effectively help to meet the political expectation that large-scale manufacturers with poor technology can take the initiative to reduce emissions through emission-rights distribution.

Keywords: water pollution; emission right initial allocation; China; Tai Lake

1. Introduction

In modern society, human development and the sustainable consumption of environmental resources present a paradox. This is particularly true for developing countries. The two conflicting goals generate a tug-of-war for these countries. Although developed countries have established a pattern of economic growth with an increasing awareness of global environmental protection, policy makers from developing countries face an increasingly difficult dilemma.

The primary environmental challenges faced by China relate to air pollution issues, such as carbon emissions and particle pollutants and water pollution issues, such as water recycling, excessive chemical emissions, and solid pollutant emissions. Carbon emissions and particle pollutant emissions have drawn widespread attention due to their global influence and frequent occurrence (Persson [1], Liao [2]). Meanwhile, China's water pollution is severe and has a negative impact on its residents (Zhang [3]). Therefore, it is important to study the sustainable utilization of water resources and water pollution control.

Tai Lake, located in Jiangsu Province, China, experienced an explosive growth of algae bloom in the early summer of 2007, disrupting the tap water for over 10 million residents living in the six cities near Tai Lake. This issue has raised public concern about the sustainable use and management of water resources in China. The Tai Lake problem forced the local government to improve water environmental protection policies and develop appropriate management tools.

In many developed countries, emissions trading systems have been proven to be effective for water pollution control, but adopting this tool may not exert the desired effect in developing countries due to different institutional factors. For example, in China, local governments have the ability to establish such a market. The decision to adopt strategies that control water quality in regional lakes requires further research.

Despite having huge influence over emissions trading markets, local governments in China have not been enthusiastic about using them to improve environmental quality. This is because economic growth has always been the priority of regional administrative departments and local government officers in China. Such economy-oriented regional governance policies have caused regional administrative officials to be less than enthusiastic about environmental policy. Even when a pilot environmental program was established (e.g., the pilot emission trade market system setup for Tai Lake area in 2011), it will be described by the local government as a new tool for regional economic development rather than as an environmental improvement instrument.

The establishment of an emissions trading market to combat water pollution often involves inter-regional issues. The relevant administrative bodies tend to lack interest in these issues due to the many administrative procedures involved and the cost of environmental strategies (Xia [4], Zhao [5]), which is contrary to their political objectives. Therefore, incorporating objectives and preferences of local governments is the key to optimizing the effect of the emissions trading market in China. In this paper, we developed a primary distribution model for emissions rights that could meet the local administrative department's demands regarding the region's industrial management and help control the total amount of water pollution in an area. This paper contributes to the literature through establishing a non-linear programming distribution model for water pollution emissions trading based on the local government's industrial preferences and enterprise location. We complement empirical emissions trading research through simulations using corporate data from Tai Lake basin. The combination of our theoretical model and simulation results helps fill the gap in the water pollution emissions trading literature since previous studies are more focused on carbon emissions.

Our results show that, by considering the physical characteristics of the rivers and lakes, emission rights distribution and future trading can effectively control the total pollutant amount while improving the industrial structure of the region, and potentially satisfy the local government. The application of this strategy could contribute to the sustainable utilization of water and to local economic development. The remainder of this paper is organized as follows: Section 2 reviews the previous studies; Section 3 establishes the theoretical model; and Section 4 includes a simulation. Finally, Section 5 concludes the paper.

2. Literature Review

Researchers (Dales [6], Brady [7], Brill [8]) have conducted systematic and in-depth theoretical studies of the primary distribution of emission rights. The work of Tientenberg [9] is regarded as the foundation for modern emission rights studies. Montgomery [10] introduced mathematical analysis into emission rights trading and proved that competitive markets achieve cost-effective pollution reductions. O'Neill [11] noted that for water environments with verification and supervision by basin regulators, optimizing emission rights trading with total amount distribution, water quality evaluation, and the simulation of sources (when a source is treated as a single pollution emission agent or a single pollution point for the estimation area), trading can effectively reduce the negative effects of emissions. Three means of primary emission rights distribution—free distribution, public auction, and sale with the bid price pre-established—are the standard emission rights distribution means under the United States Clean Air Act, as amended in 1990 for air resource governance. Rose and Stevens [12] showed that public auction and sale with bid prices are better than free distribution. However, due to the resistance encountered in the United States and other countries, free distribution is regarded as more practical.

In addition to theoretical analysis, scholars have also examined emission rights empirically, focusing mainly on carbon emissions. For example, Beckerman *et al.* [13] studied the international fairness distribution of carbon emissions. Park *et al.* [14] developed a new method for emission rights distribution with a Boltzmann distribution and guided the distribution among countries with the principle of maximum entropy. Ahn [15] adopted an MCP model to quantify the primary emission-right distribution's influence on the emission amount, emission rights price, and social welfare in Korea's electricity power market.

In China, the emission rights pilot program was first implemented in the 1980s. Since then, scholars have conducted studies on water pollution emission rights. Li *et al.* [16–19] had the most consistent ongoing involvement in all of these studies. They analyzed the importance of primary emission rights in theory and noted that, compared with paid distribution, free distribution is more practical. They also noted that the country should conduct detailed research on emission rights distribution to establish China's emission rights trading market. Later, they adopted an objective method of establishing a multi-goal decision-making model for primary emission rights distribution based on economic optimization, fairness, and production consistency. In 2005, they built a free distribution model to maximize expected social welfare in trading cost conditions with a mechanism design principle. By 2013, they had built a primary distribution model for the basin based on the economic optimization and fairness principles and conducted an empirical analysis of the Tai Lake case. The results show that the primary distribution model can help Tai Lake emission rights management institutions to better balance economic optimization and distribution fairness.

Apart from Li's group, other Chinese researchers have also performed considerable research on building models for emission rights distribution. For example, Shang [20] built a dynamic data model for primary emission rights distribution. By comparing emission standards, emission taxes, and emission rights trading, Zhou [21] stated that emission rights trading has its own advantages in terms of water pollution regulation. He developed a basin emission rights trading model to determine the advantages and disadvantages of the three types of primary distribution and the characteristics of emission rights auctions and emission rights banks. Tao [22] chose GDP, population, and water environmental volume and amount to build a multi-principle model based on an information entropy method. China's basin emission rights are distributed based on a total control objective and a maximum entropy method. Tao's [22] case study was conducted using the Chemical Oxygen Demand (COD) of China's seven basins.

To meet the requirements of local administrative departments, studies of China's emission rights have focused on solutions for severely polluted areas. Zhou [23] designed a specific method for emission rights trading in the printing and dyeing industry, explored the total amount determination and primary distribution and analyzed the corporate economic burden. Based on the status quo of emission rights distribution and its problems, Huang *et al.* [24] took the pollutants' density control and total control as the limitation and built a multi-goal economic and water quality optimal distribution model by considering fairness and the discharger's production sustainability. He also developed a better distribution method based on the Jushui River simulation. With Nanputi Qingshan as the example, Li [25] established a multi-goal distribution model to reduce pollutant costs and to optimize environmental risks. He found that water emissions trading technology provided the necessary means to measure the improvement in water environment quality based on empirical analysis. Xiao [26] simulated the carbon emissions permission distribution of three factories in the Pudong district of Shanghai with a Shapley value, benchmark, and grandfather systems. He compared these three methods with the Shapely value as the parameter and made suggestions for primary distribution in the carbon emissions trading system in Shanghai.

Until now, most research has focused on economic efficiency (which is usually measured by the total utility gain of a single firm) and fairness (removing the discrimination of firm size, industry, *etc.*) but has given little consideration to the environmental consequences of the geographic location of sources or the government's preferences for certain industries.

However, the government's preferences are a kind of discrimination due to the "GDP Only" philosophy. When regulating the initial allocation of emission allowances, in order to maintain high economic growth, the government often gives large enterprises more pollution emission permits. Many of these companies have serious negative environmental impacts. In addition, some technologically advanced firms do not get sufficient emission permits due to the small volume of their economic contributions. The policy that aimed to let backward enterprises pay more has led the advanced firms to purchase emission rights from the laggards in the process of actual execution. This arrangement on one hand leads to an inactive emission trading market; on the other hand, it is in breach of the fair principle that might hurt the firms' enthusiasm to develop new technologies and eventually hinder development sustainability. The government in China controls the emission rights market. It has the responsibility to build fair and equitable discriminatory rules to reflect the externalities and conserve the sustainability.

The existing research does not capture such initial pollution right distribution discrimination against small companies. Therefore, we try to solve this unfair treatment and build a primary distribution model for pollution emission rights that balances three goals: economic efficiency, environmental contribution (positive or negative), and fairness optimization. This model also considers the geographical location and different types of industries. We then conduct a simulation using the corporate data for the Wujin District of Lake Tai in China.

3. Theoretical Model for Water Pollution Right Distribution

For water pollution, extensive research (Sun [27], Cui [28], Zhang [29]) has focused on the lake itself. Little work has been performed on the tributaries surrounding the lake, despite their role as the sources of lake water pollution. Therefore, for seriously polluted tributaries, there has been a continuous effort to prevent and control industrial-sourced pollution and to pilot an emission trading system. Meanwhile, many problems remain in the theoretical study of lake basin emission rights distribution and in actual practice. There is much room for improvement, especially in water resource governance using tools such as emission rights distribution and trading.

For China's local government officers, there are two main aspects of water pollution management. First, current emission rights distribution often aims to control the pollutant density instead of considering the strong impact of the physical features of a self-cleaning pollutant, such as the flow rate, on water pollution control. Second, for emission rights distribution model design (Shang [20], Li [16], and Li [25]), production sustainability is taken into consideration, but the anti-discrimination of initial pollution rights distribution has not yet been used. The primary emission rights distribution design in practice encourages the development of high-pollution and low-effect sources. This research tries to introduce the source's location and anti-discrimination of initial pollution right distribution into the traditional emission rights model. The new river emission rights model is essentially a multi-goal distribution model that focuses on the economy, the environment, and fairness. We believe that this research can complement the current distribution method.

3.1. Non-Linear Model for the Initial Allocation of Pollution Permits

3.1.1. Economic Optimization

In the process of primary emission rights distribution, the environmental regulator prioritizes economic development, which enables drain manufacturers with the biggest economic contribution in the region to obtain emission rights sufficient for their needs. Under the condition that the environment in the region is protected, economic efficiency can be maximized. However, in reality, the source of lake water pollution is often industrial pollution or diffused agricultural pollution in tributaries. If the industrial source pollution is severe, the different geographic locations of the polluters affect the environment to various degrees. For example, due to the self-cleaning ability of flowing water, the pollution of a large-scale polluter upstream is sometimes smaller than that of a middle-scale or small-scale polluter downstream in the same river. In other words, the location of the polluter matters as much as the scale of the polluter.

As a result, from the viewpoint of total volume control, this study adopts the following assumptions in terms of the establishment of a primary distribution model for emission rights.

Assumption I

There are n major polluters (drain manufacturers) in the area supervised by the environmental regulator, which specifies an upper limit E^* for the total pollution amount according to the environmental capacity. Each drain manufacturer i has a full right of use of the primary emission right distributed to itself and thereby earns utilities. The utility function between the pollution x that firm i emitted could be denoted as $f_i(x_i), i = 1, 2, ..., n$, and meets the following conditions:

(1) $f_i(x_i)$ has a sequential second derivative, and when $x_i > 0$, $f_i'(x_i) > 0$;
(2) $f_i(x_i)$ is a strictly concave function that equals $f_i''(x_i) < 0$.

It should be noted that the assimilative capacity of the river (represented by E^*) is closely related to the water features, water quality goals, and pollutant characteristics. Therefore, when calculating the assimilative capacity, we adopt the water transport function from environmental science to calculate and control the pollutant density of a cross-section of the river. The dilution and mixture function of the river water and polluted water is as follows:

$$C = \frac{C_p Q_p + C_e Q_e}{Q_p + Q_e} \tag{1}$$

where C is the density of the completely mixed water quality(mg/L); Q_p and C_p stand for the upstream designated water amount (m^3/s) and the designed water density (mg/L), respectively; and Q and C_e are the designed flow rate of the polluted water and the designed emission density (mg/L), respectively. Because the influence of the pollution source can be superimposed linearly, the impact of several polluted source emissions on the controlling point or cross-section equals the sum of each polluted point, which conforms to linear superimposition. The calculation of each source can be superimposed to measure the source point conditions. The restrictions of a single section or single point can recur in multi-section or multi-point restrictions based on node balance.

The emission can be summarized as the full mixture; the equation for calculating the acceptable assimilative capacity in the water area between the drain outlet and the controlling section is as follows:

Single-source emission:

$$E^* = S(Q_p + Q_E) - Q_p C_p \tag{2}$$

Multi-source emission:

$$E^* = S(Q_p + \sum_{i=1}^{n} Q_{Ei}) - Q_p \cdot C_p, i = 1, 2, ..., n \tag{3}$$

In Equations (2) and (3), S represents the water quality standard of the controlling section (mg/L), Q_{Ei} is the emission flow rate of the i^{th} drain outlet, and n represents the number of drain outlets.

Meanwhile, to maximize the economic efficiency of the pollution control area, a second assumption is adopted for this study.

Assumption II

To maximize the total economic effectiveness of the pollution control area α_i, α_i stands for the environment regulator's preference for the emission drain manufacturer with a large marginal contribution. $\alpha_i \geqslant 0, i = 1, 2, ..., n$, and α_i is a standard unit in the current regional pollution industry.

According to Assumptions I and II, a free emission rights distribution decision-making model based on economic optimization in the control area could be established as follows:

$$\max \sum_{i=1}^{n} \alpha_i f_i(x_i)$$
$$s.t. \begin{cases} \sum_{i=1}^{n} x_i \leqslant E^* \\ x_i \geqslant 0, i = 1, 2, ..., n \end{cases} \quad (4)$$

3.1.2. Environmental Optimization and Fairness

Apart from economic considerations, there is no doubt that the implementation of an environmental policy improves an area's total utility, especially when the given area had been through rapid economic growth and local citizens require environment improvement. This improvement is called environmental optimization. In this research, environmental optimization refers to the smallest total amount of pollution emission in the entire area, especially the smallest pollution amount that flows to the control section of the lake. Moreover, in actual emission rights distribution situations, the fair distribution of emission rights among drain manufacturers cannot be neglected; this fair distribution is often referred to as fairness optimization.

With regard to fairness, Li [16] defined it as the need for each drain manufacturer to have an equal right in the primary emission rights distribution. The distribution result is a good way to motivate drain manufacturers to cleanly produce and to be active in preventing pollution. Therefore, with the condition that the environment regulator ensures that each drain manufacturer enjoys an equal right, the distribution should also take into consideration factors such as development, production technology, pollution control, and future planning. It should not protect a backward manufacturer nor limit its development. To achieve these two goals, we make assumptions III and IV, respectively.

We hold that the contribution of manufacturers can be reflected in the amount of polluted water disposed of. In this regard, assumption III is as follows:

Assumption III

The contribution of drain manufacturer *i* to the environment of the control area is an important reference index that determines whether the regulator will allow the manufacturer to continue to exist, and the environment contribution index λ_i conforms to the following function:

$$\lambda_i = \frac{wt_i}{WT} \quad (5)$$

where wt_i refers to the amount of wastewater disposed of by manufacturer i in the control area, and WT refers to the total amount of water disposed of by manufacturers in the control area.

By referring to Li's idea that the contribution of a manufacturer to the regional economy is determined by the output value (count as GDP) of one company, the job opportunity that one company created, and the profit and tax in equal proportions, the economic contribution can be regarded as an important index for the local government when evaluating fairness for companies that need a pollution rights allocation. Therefore, we adopt the following assumption:

Assumption IV

The economic contribution index γ_i by the drain manufacturer in the pollution control area is as follows:

$$\gamma_i = \frac{1}{3}\left(\frac{g_i}{G} + \frac{p_i}{P} + \frac{z_i}{Z}\right) \quad (6)$$

In this index, g_i represents the total output value calculated under GDP achieved by drain manufacturer *i* in normal conditions in the pollution control area; p_i refers to the job opportunities created by drain manufacturer i in normal conditions in the pollution control area; z_i is the sum of the profit and tax realized by drain manufacturer i in normal conditions in the pollution control area; G is the total output value of all of the drain manufacturers in the pollution control area; P refers to all of the job opportunities created by drain manufacturers; and Z refers to the total profit and tax realized by drain manufacturers.

According to the above assumption, we can build a primary free emission-rights distribution decision-making model based on water quality optimization in the control area as follows:

$$\begin{gathered} \min \sum \frac{2}{(\gamma_i+\lambda_i)} \beta_i x_i \quad (i=1,2,3\ldots,n) \\ s.t. \begin{cases} C_i \leqslant C_{i\max}, i=1,2,3\ldots,n \\ x_i' \geqslant 0, i=1,2,3\ldots,n \end{cases} \end{gathered} \tag{7}$$

where C_i stands for the actual pollution amount in point C_i, which can be gained from Equations (1) and (5). $C_{i\max}$ represents the assimilative capability in C_i, which can be derived based on Equations (2) and (3). Moreover, β_i is the geographic preference (which depends on whether the company is at the upstream or downstream of a river) of manufacturers in the same industry. When the drain discharger has the same level of technology, due to the attention given to the final emission into the lake cross-section, the regulator will give a smaller geographical preferred coefficient to manufacturers that are further from the final section to encourage them to move further away from the final lake emission section.

3.2. Simulation Agent Category

Based on the distribution model and the current realities of China's lake basin industry, we classify enterprises in the same key pollution industry in one pollution basin into four categories according to their corporate scale and their wastewater treatment technology. Type A are highly polluting large-scale enterprises with low levels of technology. In China, these are mainly traditional state-owned enterprises (SOEs) and local large-scale collectively owned enterprises. These companies are major players for China's economy, and have been protected by the local administrators because of their current economic growth ability. Type B are leading large-scale enterprises with high pollution treatment technology. In China's regional economy, these agents are mainly represented by foreign enterprises and large-scale SOEs with relative advanced technology (compared with Type A agent). They were welcomed by the local government, but usually could provide less economic contribution compared with Type A agents in the meantime. Type C agents are developing small-scale companies with high levels of technology. These are mainly innovative companies with new industrial technologies. They are interactive and full of future possibility but contribute least to the local economy at the current moment. Finally, Type D agents are small-scale companies with low technology, mainly small local private companies. In modern China's economy, these companies usually provide the most job opportunities in one region, which leads to some special protection by the local governments. The typical classification of enterprises is shown in Table 1.

Table 1. Type classification of enterprises.

Agent Type	Size	Technology
A	Large	Low
B	Large	High
C	Small	High
D	Small	Low

For one polluted lake basin area, the objective function of economic optimization is as follows:

$$\min \sum_{i=1}^{n} \alpha_i \times f(x_i)$$
$$s.t. \begin{cases} \sum_{i=1}^{n} x_i = E \\ x_i \geqslant 0, i = 1, 2, 3, \ldots, \mathrm{n} \end{cases} \tag{8}$$

For the same area, when economic optimization is determined and the water quality requirements of the lake section are considered, the objective function of the local environment and fairness is as follows:

$$\min \sum_{i=1}^{n} \frac{2}{\lambda_i + \gamma_i} \beta_i x_i$$
$$s.t. \begin{cases} \sum_{i=1}^{n} x_i = E \\ x_i \geqslant 0, i = 1, 2, 3, \ldots, \mathrm{n} \end{cases} \tag{9}$$

To obtain the optimal solution for the multi-goal planning objective, we adopt an objective planning model to give the two objective functions the same weight. As a result, solving the multi-objective planning model is transformed into solving the single objective model:

$$\min \sqrt{\left(\sum_{i=1}^{n} \alpha_i f(x_i) - A\right)^2 + \left(\sum_{i=1}^{n} \frac{2}{\lambda_i + \gamma_i} \beta_i x_i - B\right)^2}$$
$$s.t. \begin{cases} \sum_{i=1}^{n} x_i = E \\ x_i \geqslant 0, i = 1, 2, 3, \ldots, \mathrm{n} \end{cases} \tag{10}$$

Constants A and B in Equation (10) are the optimal solutions for the economic optimization objective function and the environment and fairness optimization objective function, respectively.

4. Data Simulation for Lake Tai of China

We conduct a simulation using data from the Tai Lake tributary in the Jiangsu Wujin area to test the theoretical model in Section 3. Tai Lake is China's third-largest freshwater lake, with a water area of 2338 square kilometers. It is located in the center of the Tai Lake Valley and is the major water source in the valley. Because Tai Lake is one of the three largest freshwater lakes in China, since the blue-green algae outbreak in 2007 the Tai Lake valley has become the key valley for China's water pollution control.

The area around the Tai Lake Valley is in the Wujin district, which is south of Jiangsu province. Since the 1980s, the economy in Wujin has developed rapidly. Printing, dyeing, and brewing have become the pillar industries. Because the core industries in the area are also the major sources of pollution of Tai Lake, we chose corporate data in Wujin to conduct the simulation for the model. A map of Tai Lake and the location of the selected companies is in Figure 1.

To investigate the industrial preferences and the impact of geographic location on primary emission distribution rights, we choose six typical enterprises in Wujin as examples. Summary statistics are shown in Table 2. Agents labeled A–D denote the types of companies we have classified in Table 1 based on enterprise scale and waste treatment ability. Agents E and F are the comparatives introduced into the investigation for A with respect to geographic location and industry (agents A and E are similar companies in the same industry but one is located the upstream of the river and one downstream; agents A and F are of the same economic scale and are located similarly but belong to different industries), respectively.

Table 2 shows the six companies selected as simulation agents from the printing, dyeing, and brewing industries. According to the "Study on price systems for compensated use of water pollution emission rights in Tai Lake valley", printing, dyeing, and brewing are major industries for COD emissions and therefore require special attention (Zhang [30], Yao [31]). Because the unit emissions of the brewing industry are low, we assume the preferred coefficient α in the printing and dyeing industry. The textile industry is 1.0 and the preferred coefficient α in the brewing industry is 1.2, because the pollution from the brewing industry is lower. The geographic location coefficient can be obtained from the balance between the COD river discharge amount and the COD emissions.

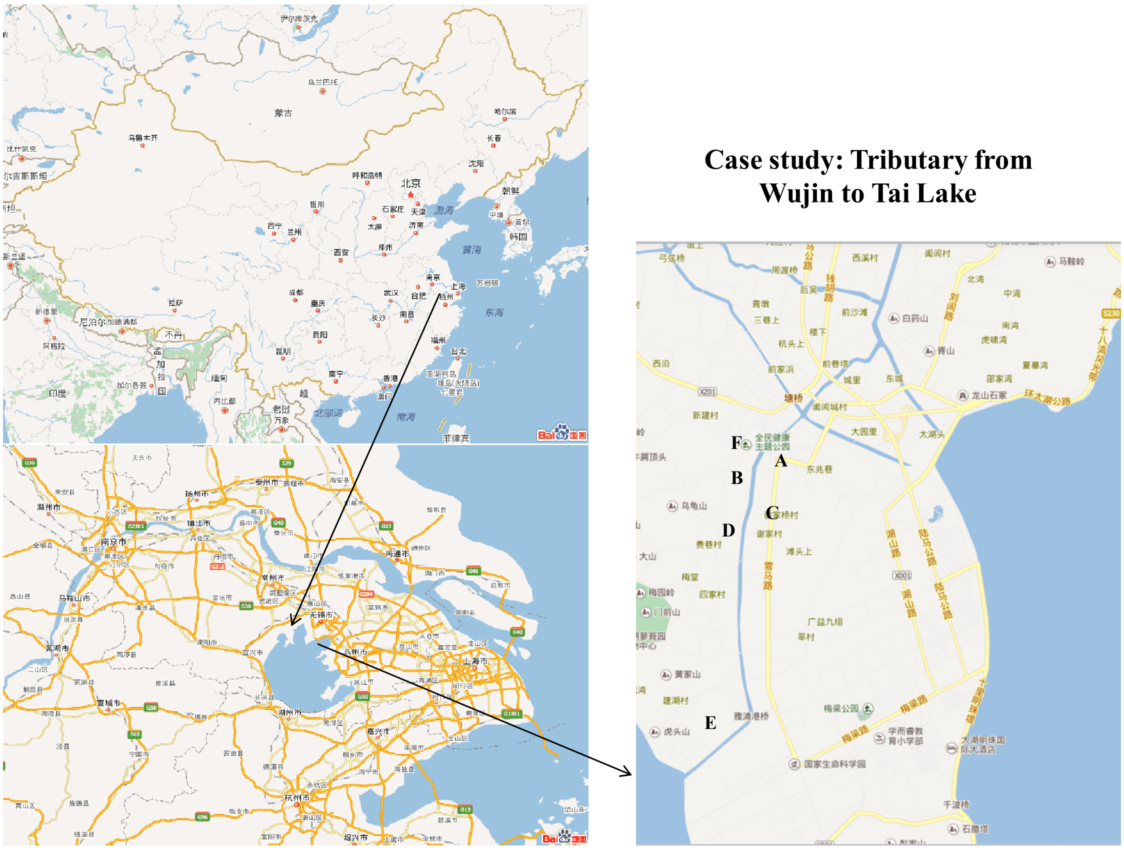

Figure 1. Agent location map. Date Source: ditu.baidu.com.

Table 2. COD production and to the river.

Agent Code	Company Name	COD Produced (Ton)	COD Emission (Ton)	COD To the River (Ton)
A	PINYTEX	917.54	917.54	357.84
B	Wuxi Liansheng Dyeing and Printing	1066.92	71.04	27.71
C	Changzhou Jinghua Dyeing	220.96	19.64	7.66
D	Changzhou Jiada Dyeing	165.35	165.35	64.49
E	Jiangsu Huasheng	286.05	33.21	33.21
F	Snowbeer Wuxi	1016.70	50.80	19.81

Because the COD of the river is detected at the lake cross section of the river, it can be easily seen from Table 2 that, with the exception of the COD river discharge amount of agent E, which is equal to the emission amount, the other companies' COD river discharge amount is one-third of the emission amount. We conclude that E is a downstream agent and the other companies are upstream agents and are close to each other. Therefore, this study assumes that β, the geographic location coefficient of agent E, is 0.3 and the geographic location coefficient of the other companies β is 0.1. Additionally, because λ_i, the environment contribution index, is positively correlated with the amount of disposed wastewater, and γ_i, the economic contribution index, positively correlates with the enterprise size, we use the wastewater disposed (company value) for each agent we picked divided by the total value of the selected agent group to represent the λ_i (γ_i) for one agent. The coefficients of the six typical companies are included in Table 3.

Table 3. Coefficient for companies.

Agent Code	Company Name	α	β	γ	Λ
A	PINYTEX	1.0	0.1	0.25	0.001
B	Wuxi Liansheng Dyeing and Printing	1.0	0.1	0.29	0.41
C	Changzhou Jinghua Dyeing	1.0	0.1	0.06	0.08
D	Changzhou Jiada Dyeing	1.0	0.1	0.05	0.001
E	Jiangsu Huasheng	1.0	0.3	0.08	0.10
F	Snowbeer Wuxi	1.2	0.1	0.28	0.40

Based on Zhang's [32] findings of the emission rights in Wujin, the required amount of emission rights for the six companies selected by this study is 353.35 tons. To control the total amount, the regulator set the distribution amount of emission rights at 90% of the demand amount, which is E = 318.02 tons. Assuming that the discharges are homogenous, the earnings function based on pollutant emissions is likely similar. Assuming that the enterprise utility function is $f(x_i) = Ax_i^{\kappa} + C$, among which A and C are constants and $0 < \kappa \leqslant 1$, the COD and revenue of the six companies are shown in Table 4.

Table 4. COD production and company revenue.[1]

Agent Code	Company Name	COD Produced (Ton)	Revenue (Million RMB)
A	PINYTEX	917.54	121
B	Wuxi Liansheng Dyeing and Printing	1066.92	132
C	Changzhou Jinghua Dyeing	220.96	50
D	Changzhou Jiada Dyeing	165.35	30
E	Jiangsu Huasheng	286.05	80
F	Snowbeer Wuxi	1016.70	211

[1] Revenue data from: http://company.ch.gongchang.com/.

According to the COD volume and the companies' revenues, we use SPSS software for fitting and obtain the earnings function for the selected companies selected as follows: $f(x_i) = 72.1x^{0.778}$. Here, Equation (8) shows the optimal economic objective of the area. For the same area, under the condition of economic optimization, Equation (9) only addresses the water quality at the lake section, the local environment, and the fairness optimization.

When we look for an optimal solution to the multi-goal planning model, we adopt an objective planning model and give the same weight to the two objective functions. As a result, solving the multi-objective model is transformed into solving the single-objective model of Equation (10). This study adopts Lingo11 to seek the optimal solution for the multi-objective model, and the results are shown in Table 5.

Table 5. Primary pollution rights allocation.

Agent Code	Company Name	Initial Pollution Rights Allocated (Ton)	Initial Pollution Rights Demand (Ton)
A	PINYTEX	6.61	303.64
B	Wuxi Liansheng Dyeing and Printing	163.6117	1.76
C	Changzhou Jinghua Dyeing	0.83	−3.84
D	Changzhou Jiada Dyeing	0.01	45.35
E	Jiangsu Huasheng	0.02	22.19
F	Snowbeer Wuxi	146.94	−16.19

In Table 5, row three describes the initial pollution rights allocated to different agents by the model simulation, and row four describes the requirements for each agent based on Zhang's [32] findings for the six agents' initial pollution rights demands, which follows the basic government requirement—fixed total amount of pollution, and maximizing the total economic gain. The simulation result shows that the distribution amount of emission rights of agent A is extremely low; it needs to buy emission rights or improve its technology to meet pollution discharge requirements. The agent type A represented is a to-be-improved company that has large-scale production and poor pollution treatment technology; the new design would conform to the political expectation that large-scale manufacturers with poor technology can take the initiative to reduce emissions through emission-rights distribution. In other words, the actual cost for agent A's production, including its environmental cost, was finally accurately discovered. At the same time, as a leading large-scale enterprise with high pollution treatment technology, agent B can create economic value and make a contribution by refusing special treatment as a star enterprise for its emission-rights distribution. This is consistent with the actual situation in the pilot areas. As an innovative and developing company in the industry, agent C is under little pressure for emission rights and will be encouraged to expand its production scale. Agent D is a small-scale workshop with poor technology and will be severely restricted under the emission-rights distribution pattern. This type of enterprise will be eliminated as a result of the anti-discrimination of initial pollution right distribution.

As a downstream manufacturer that is similar to agent A, agent E's pollutant level in the control section is the most severe, and it will be discriminated against in the emission-rights distribution. This type of prejudice will force those manufacturers that discharge growing amounts of pollutants and that are located in special locations to finally take action, such as by moving away from the lake cross section. In the end, as the type of industry preferred by the government and the one that could most effectively contribute to the economy and environment at the same time, agent F will receive the most distribution rights. The simulation confirms that the emission-rights distribution and trading in the market based on both the manufacturer's geographic location and the government's preference can help facilitate industrial structure optimization toward the local regulator's preference.

5. Conclusions

The diffusion feature of water means that geographic location is an important factor when considering the distribution rights of any valley-type pollution emissions, especially for areas of major pollution focus such as lakes. Thus, a primary pollution rights decision that combined a company's geographic location differences with the consideration of industry differences could help China's central government and local public administrators to strike a balance between economic development, industrial transformation, and environmental protection to achieve sustainable development. In terms of the market's primary distribution of emission rights, this study establishes a multi-goal and non-linear planning distribution model for lake-water pollution by introducing geographic location, industrial preference, and anti-discrimination of initial pollution right distribution.

Based on the simulation, which uses data from typical corporate agents of the Tai Lake basin in Wujin, we can see that in terms of the primary emission distribution pattern, manufacturers who have advanced wastewater treatment technology, a favorable geographic location, and high levels of production technology in the industry can win the recognition of distributors. Meanwhile, the results of the emission-rights distribution of manufacturer's wastewater could be more reasonable after giving consideration to factors such as industrial differences and geographic locations. A reasonable primary distribution would also benefit trading in the secondary market and the sustainable utilization of water resources in the areas concerned.

It should also be noted that the distribution of emission rights is just a step towards establishing an emission trade market. Reasonable primary rights distribution can help to effectively distinguish key polluters, which is valuable because it helps the administration to achieve the unified deployment of the local industry and water pollution control. After the primary distribution of emission rights is determined, it is necessary to establish various prices for different pollutants based on the treatment costs. To determine the price in the primary market and conduct effective supervision of the following emission rights, there must be supervision of the trading market to ensure successful trading implementation. In this way, we can ensure that the emission rights trading mechanism can effectively control pollutant emissions.

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