Application of the environmental Gini coefficient in allocating water governance responsibilities: a case study in Taihu Lake Basin, China

Shenbei Zhou, Amin Du and Minghao Bai

ABSTRACT

The equitable allocation of water governance responsibilities is very important yet difficult to achieve, particularly for a basin which involves many stakeholders and policymakers. In this study, the environmental Gini coefficient model was applied to evaluate the inequality of water governance responsibility allocation, and an environmental Gini coefficient optimisation model was built to achieve an optimal adjustment. To illustrate the application of the environmental Gini coefficient, the heavily polluted transboundary Taihu Lake Basin in China, was chosen as a case study. The results show that the original environmental Gini coefficient of the chemical oxygen demand (COD) was greater than 0.2, indicating that the allocation of water governance responsibilities in Taihu Lake Basin was unequal. Of seven decision-making units, three were found to be inequality factors and were adjusted to reduce the water pollutant emissions and to increase the water governance inputs. After the adjustment, the environmental Gini coefficient of the COD was less than 0.2 and the reduction rate was 27.63%. The adjustment process provides clear guidance for policymakers to develop appropriate policies and improve the equality of water governance responsibility allocation.

Key words | adjustment programmes, environmental Gini coefficient, responsibility allocation, Taihu Lake Basin, water governance contribution, water pollution contribution

INTRODUCTION

Water is a public liquid resource, and water governance responsibilities must be allocated among many stakeholders. However, equitably allocating water governance responsibilities is a challenge. Currently, in both developed and developing countries, no appropriate method or standard exists for water governance responsibility allocation.

The Gini coefficient is a commonly used economic measurement for the inequality of income or wealth distribution (Bosi & Seegmuller 2006). In recent years, scholars have attempted to use the Gini coefficient in the governance of liquid resources or pollutants. Heil & Wodon (2000) used the Gini coefficient to analyse future carbon emission inequality, within and between countries and named the method the ‘environmental Gini coefficient’. Millimet & Slottje (2002) used the environmental Gini coefficient to measure inequality in the distribution of per capita emissions across US counties and states. Vass et al. (2013) evaluated the fairness of EU carbon emission policies by calculating the Gini coefficients for six criteria of policy outcomes. Cho & Lee (2014) introduced the environmental resource-based Gini coefficient into the waste load allocation (WLA) model to compute the inequality in waste load discharge with respect to the environmental resources in each region. The suitability of the WLA model was verified by its application to the total maximum daily load of a heavily polluted river in South Korea. In China, the environmental Gini coefficient is widely used for the allocation of regional water pollutant emissions (Sun et al. 2010; Zhang et al. 2010; Wang et al. 2011; Zhang et al. 2012a, b; Chen et al. 2012) and for the inequality analysis of urban water use (Zhang & Shao 2010). To build the environmental Gini coefficient model, these studies generally use the cumulative proportion of various water pollutant emissions as the vertical axis and the cumulative proportion of the GDP or ecological capacity as the horizontal axis to establish the environmental Lorenz curve. Then, the environmental Gini coefficient can be computed. In addition, the inequality...
factors are based on the efficiency coefficient (Sun et al. 2010, etc.).

As described above, the Gini coefficient (or the environmental Gini coefficient) is increasingly used in the inequality assessment of carbon emissions and water WLA. The environmental Gini coefficient is seldom used in governance responsibility allocation which is very important for environmental governance but is challenging for policymakers.

To improve the equality of water governance, the environmental Gini coefficient was applied in the allocation of water governance responsibility. This research first attempted to apply the environmental Gini coefficient to evaluate the inequality of water governance responsibility allocation. Then, an environmental Gini coefficient optimisation model was established to achieve the optimal adjustment. To verify the practicality of the method, Taihu Lake Basin, a heavily polluted basin in China, was chosen as a case study.

METHODS

Environmental Gini coefficient model

This research applied the environmental Gini coefficient to evaluate the inequality of the environmental governance responsibility allocation of water. The method consists of the following three steps: (1) to establish an environmental Lorenz curve; (2) to calculate the environmental Gini coefficient; and (3) to determine the criteria of the overall inequality evaluation.

Establishment of the environmental Lorenz curve

We assumed that water responsibilities were allocated to \( n \) decision-making units (DMUs). The term ‘DMUs’ first proposed by Chames et al. (1978) represented the units whose efficiency were assessed based on the same inputs or outputs, such as different countries, companies, departments, etc (Chames et al. 1978, 1985; He & Lyu 2008). In this paper, DMUs were used to represent different water governance units within a region or basin, such as the \( n \) cities within one state or the \( n \) pollution control districts within one basin. The environmental Lorenz curve was established by using the \( n \) DMUs’ water pollution contribution and water governance contribution (see Figure 1). As shown in Figure 1, the horizontal axis represents the cumulative proportion of the water pollution contribution, while the vertical axis represents the cumulative proportion of the water governance contribution.

The pollution contribution coefficient was calculated from the weighted sum of \( m_1 \) pollution contribution indicators. The formulae are as follows:

\[
C_{Pi} = \sum_{j=1}^{m_1} w_j C_{Pij}
\]  

\[
C_{Pij} = \frac{P_{ij}}{\sum_{i=1}^{n} P_{ij}}
\]

where \( C_{Pi} \) represents the pollution contribution coefficient of the \( i \)th DMU, \( C_{Pij} \) represents the pollution contribution coefficient of the \( j \)th pollution contribution indicator in the \( i \)th DMU, \( w_j \) represents the weight of the \( j \)th pollution contribution indicator, \( P_{ij} \) represents the original value of the \( j \)th pollution contribution indicator in the \( i \)th DMU, and \( n \) represents the number of DMUs.

The governance contribution coefficient was calculated from the weighted sum of \( m_2 \) governance contribution indicators. The formulae are as follows:

\[
C_{Gi} = \sum_{k=1}^{m_2} w_k C_{Gik}
\]  

\[
C_{Gik} = \frac{G_{ik}}{\sum_{i=1}^{n} G_{ik}}
\]
where $C_{Gi}$ represents the governance contribution coefficient of the $i$th DMU, $C_{Gik}$ represents the governance contribution coefficient of the $k$th governance contribution indicator in the $i$th DMU, $w_k$ represents the weight of the $k$th governance contribution indicator, $G_{ik}$ represents the original value of the $k$th governance contribution indicator in the $i$th DMU, and $n$ represents the number of DMUs.

**Calculation of the environmental Gini coefficient**

Based on the definition of the Gini coefficient (Sun et al. 2010), the environmental Gini coefficient is expressed as

$$G_E = \frac{S_A}{S_A + S_B}$$

where $S_A$ represents the area between the practical distribution curve and the absolutely equitable distribution curve, and $S_B$ represents the area below the practical distribution curve, as shown in Figure 1.

The calculation of the Gini coefficient can be completed using a variety of methods, such as the geometric method, Gini’s mean difference method (or relative mean difference method), the covariance method or matrix methods (e.g., Sadras & Bongiovanni 2004; White 2007; and Groves-Kirkby et al. 2009). In this study, we used a trapezoidal approximation algorithm, which is expressed as follows:

$$G_E = 1 - \frac{1}{n} \sum_{i=1}^{n} (x_i - x_{i-1})(y_i + y_{i-1})$$

where $x_i$ represents the cumulative proportion of the water pollution contribution, and $y_i$ represents the cumulative proportion of the water governance contribution. When $i = 1$, $(x_{i-1}, y_{i-1}) = (0, 0)$.

**Determination of evaluation criteria**

The Gini coefficient has values within the range of 0 (perfectly uniform distribution) to 1 (complete inequality) (Groves-Kirkby et al. 2009). Many scholars have noted that a reasonable range for the environmental Gini coefficient is 0–0.2 (e.g., Xie et al. 2006; Qin et al. 2013). Therefore, we set a value of $\leq 0.2$ as the expected range for the environmental Gini coefficient and as the absolute equality criteria for the governance responsibility allocation.

**Environmental Gini coefficient optimisation model**

To achieve the optimal adjustment for the inequality assessment results, an environmental Gini coefficient optimisation model was established. The basic concept of this model was to achieve the optimal adjustment target by establishing and following particular adjustment rules. The rules mainly include the adjustment criterion, the adjustment paths, and the upper and lower adjustment limits.

**The adjustment criterion: what should be adjusted**

To establish the optimisation model, the first step was to set an adjustment criterion to determine what should be adjusted or what the inequality factors are. The ratio of the water governance contribution coefficient to the water pollution contribution coefficient was proposed as the criterion for determining the inequality factors.

The ratio of the water governance contribution coefficient to the water pollution contribution coefficient of each DMU can be expressed as

$$C_{PGi} = \frac{C_{Gi}}{C_{Pi}}$$

where $C_{Gi}$ and $C_{Pi}$ represent the water governance contribution coefficient of the $i$th DMU and the water pollution contribution coefficient of the $i$th DMU, respectively.

If $C_{PGi} < 1$, then the water governance contribution coefficient of the $i$th DMU is less than the pollution contribution coefficient; thus, the $i$th DMU is an inequality factor that should be adjusted.

**The adjustment paths: how the inequality factors should be adjusted**

To establish the optimisation model, the second step was to determine how the inequality factors should be adjusted or how to set the adjustment paths. Following the adjustment guideline of ‘less water pollution and more governance inputs’, the adjustment paths were limited to two types: (1) reducing the amount of the pollution contribution; and (2) increasing the amount of the governance contribution. The path that should initially be selected for the DMU adjustment depends on the ratio of the industrial production contribution coefficient to the water pollution contribution coefficient. If the ratio of the industrial production contribution coefficient to the water pollution contribution coefficient is less than 1, then the pollution contribution
should first be adjusted; otherwise, the governance contribution should first be adjusted.

The upper and lower adjustment limits: when should the adjustment stop

To establish the optimisation model, the third step was to determine when the adjustment (including the partial and the overall adjustments) should stop. The upper and lower limits for the water pollution contribution reduction rate and the water governance contribution increase rate were set as the partial constraints. A $G_E$ value of 0.2 or less was set as the overall constraint. For example, in the adjustment process, if the water pollution contribution reduction rate of one DMU exceeds the constraint, then the reduction of the water pollution contribution will stop and return to the previous step. If the value of $G_E$ is still greater than 0.2, then the adjustment path will change. When the value of $G_E$ is no more than 0.2, the overall adjustment stops.

The overall constraint is

$$G_E < 0.2$$

The partial constraints are

$$L_{Pi} \leq \frac{C_{Pi} \cdot T_P - C_{P0} \cdot T_P}{C_{P0} \cdot T_0} \leq U_{Pi}$$

$$L_{Gi} \leq \frac{C_{Gi} \cdot T_G - C_{G0} \cdot T_G}{C_{G0} \cdot T_0} \leq U_{Gi}$$

where $L_{Pi}$ and $U_{Pi}$ represent the lower and upper limits of the water pollutant emissions reduction rate, respectively. $L_{Gi}$ and $U_{Gi}$ represent the lower and upper limits of the water governance inputs increase rate, respectively. $C_{P0}$ and $C_{Pi}$ represent the water pollution contributions before and after the adjustment, respectively. $C_{G0}$ and $C_{Gi}$ represent the water governance contributions before and after the adjustment, respectively. $T_{P0}$ and $T_P$ represent the total amount of water pollutant emissions before and after the adjustment, respectively. $T_{G0}$ and $T_G$ represent the total amount of water governance inputs before and after the adjustment, respectively.

The upper and lower adjustment limits were determined by comprehensively considering the actual situation of the DMU and the feasibility of the adjustment programmes. The optimisation model presented the result of each adjustment step. Specifically, the final adjustment target was achieved using several steps within a particular period. Therefore, the regional water resource management plan was developed and achieved according to the results of each adjustment step.

The adjustment process was completed by developing a secondary algorithm using the MATLAB platform. The basic concept was to set an adjustment step length for the pollutant emission reduction rate and governance input increase rate; the loop calculation did not stop under the constraints until the environmental Gini coefficient was no greater than 0.2.

**CASE STUDY**

The described method was applied for Taihu Lake Basin, China. Since the reform and opening up policy (1978), industrialisation has rapidly advanced in the Taihu Lake Basin. Meanwhile, industrial pollution has become the most serious problem for water governance in the trans-boundary basin.

**Study area**

Taihu Lake Basin is located in Southeast China and is the core area of the Yangtze River Delta (see Figure 2). The basin is the most industrialised area in China, with a high population density and high urbanisation. Dense river networks and numerous lakes constitute the basin. Taihu Lake, the water body of the basin, is the third largest freshwater lake in China. Before the 1980s, the water of Taihu Lake was chilly and the entire area was characterised by beautiful scenery. In the 1990s, rural industries were developed in Sunan (southern Jiangsu Province), Shanghai’s economy grew rapidly and the private economy developed extremely quickly in Zhejiang (Jiangsu, Shanghai and Zhejiang are the main locations around Taihu Lake, as shown in Figure 2). Taihu Lake Basin became the most desirable area of the Yangtze River Delta. However, because of the rapid industrialisation and urbanisation, the water quality of the Taihu Lake Basin has been severely compromised. In 2007, a large bloom of blue-green algae in Taihu Lake caused the water quality to deteriorate, which seriously threatened the water supply for residents near the lake. The incident attracted substantial attention from the Chinese Government. To improve the water quality of Taihu Lake and to ensure safe drinking water, ‘the integrated water resources governance planning for Taihu Lake Basin’ was proposed, and a substantial amount of money has been
invested in the programme. Currently, the water quality in the basin has improved, but it is not yet satisfactory.

According to ‘the integrated water resources governance planning for Taihu Lake Basin’, the control areas in Taihu Lake Basin include the following: Suzhou, Wuxi, Changzhou, and Zhenjiang (four cities in Jiangsu Province); Huzhou, Jiaxing, and Hangzhou (three cities in Zhejiang Province); and Qingpu, Jinze, and Zhujiajiao (three towns in Shanghai). Considering data availability and the comparability of DMUs, the seven DMUs of Suzhou, Wuxi, Changzhou, Zhenjiang, Hangzhou, Jiaxing, and Huzhou were chosen as the study areas to explore the allocation equality of water resource governance responsibility in the Taihu Lake Basin.

**Environmental Gini coefficient model application**

**Selection of the pollution contribution indicator**

The industrial wastewater chemical oxygen demand (COD) discharge of different industries was chosen as the water pollution contribution indicator and as the water pollution control index.

The industrial wastewater COD discharge is not the only water pollution contribution indicator for this method. Many other water pollution contribution indicators can be used, such as the biochemical oxygen demand (BOD), pH value, ammonia nitrogen (NH$_4^+$–N), total nitrogen (TN), total phosphorus (TP), total number of bacteria, and so on. For example, Cho & Lee (2014) used the BOD as the water pollution contribution indicator, while Wang et al. (2011) used the NH$_4^+$–N. A single indicator or a combination of indicators can be used in this method. The indicator which should be used depends on the specific research and governance objectives of the specific circumstances. A variety of factors should be considered. For example, since COD was one of the main pollutants and had significantly exceeded its standard in recent years, Sun et al. (2010) and Zhang et al. (2012b) use it as the pollution contribution indicator when the local governments were very serious about COD discharge. In this study, we selected

![Geographical location and administrative boundary of the Taihu Lake Basin.](https://iwaponline.com/wst/article-pdf/71/7/1047/469211/wst071071047.pdf)
the industrial wastewater COD discharge for the following reasons: (1) industrial wastewater treatment in Taihu Lake Basin was our main focus; (2) COD is an important index in the analysis of industrial wastewater pollution; (3) the Chinese government attaches great importance to monitoring and controlling wastewater COD discharge; and (4) the representation, importance and correlation of the indexes were considered.

Currently, no uniform or distinct criteria exist for classifying pollution industries. Zhao (2003) used the equally weighted sum average method to classify the pollution industries using the data for various pollutant emissions (i.e., wastewater, waste gas and solid waste) per unit production from 1991 to 1999 in China. Jiang (2010), based on the method of Zhao (2003), adopted the pollutant emissions per unit production as a classification criteria. The current study applied the classification criteria proposed by Jiang (2010). A total of 18 polluting industries’ wastewater COD discharges were selected as the pollution contribution indicators, as shown in Table 1.

According to the COD discharges from each industry’s wastewater discharged per unit industrial production in China in 2012, the COD discharge coefficient of each industry was calculated. The proportion of each industry’s COD discharge coefficient, which accounts for the total COD emission coefficient, was calculated as the weight coefficient. The results are shown in Table 1.

### Selection of the governance contribution indicator

Based on the water pollution control contribution, the ecological capacity contribution, and the data availability, six environmental governance contribution indicators of water were selected. The weight coefficients of each indicator were obtained using the Delphi method, as shown in Table 2.

### Assessment results and discussion

The pollution contribution coefficient and governance contribution coefficient of each DMU were calculated using formulas (1)–(4). The results are shown in Table 3.

The environmental Gini coefficient of the COD was calculated using formula (6). The result shows that the environmental Gini coefficient of the COD was 0.275.

### Table 1 | Environmental pollution contributions of different industries

<table>
<thead>
<tr>
<th>Industry sector</th>
<th>COD discharge coefficient</th>
<th>COD weight coefficient</th>
</tr>
</thead>
<tbody>
<tr>
<td>Manufacturing of paper and paper products</td>
<td>48.512</td>
<td>0.380</td>
</tr>
<tr>
<td>Manufacturing of raw chemical materials and chemical products</td>
<td>4.774</td>
<td>0.037</td>
</tr>
<tr>
<td>Smelting and pressing of ferrous metals</td>
<td>1.086</td>
<td>0.009</td>
</tr>
<tr>
<td>Mining and processing of non-metal ores</td>
<td>1.699</td>
<td>0.013</td>
</tr>
<tr>
<td>Manufacturing of non-metallic mineral products</td>
<td>0.715</td>
<td>0.006</td>
</tr>
<tr>
<td>Manufacturing of foods</td>
<td>7.061</td>
<td>0.055</td>
</tr>
<tr>
<td>Manufacturing of liquor, beverages and refined tea</td>
<td>17.149</td>
<td>0.134</td>
</tr>
<tr>
<td>Manufacturing of medicines</td>
<td>5.450</td>
<td>0.043</td>
</tr>
<tr>
<td>Manufacturing of chemical fibres</td>
<td>21.704</td>
<td>0.170</td>
</tr>
<tr>
<td>Smelting and pressing of non-ferrous metals</td>
<td>0.722</td>
<td>0.006</td>
</tr>
<tr>
<td>Manufacturing of metal products</td>
<td>1.092</td>
<td>0.009</td>
</tr>
<tr>
<td>Printing and reproduction of recording media</td>
<td>0.477</td>
<td>0.004</td>
</tr>
<tr>
<td>Processing of petroleum, coking and processing of nuclear fuel</td>
<td>2.036</td>
<td>0.016</td>
</tr>
<tr>
<td>Manufacturing of rubber and plastic products</td>
<td>0.541</td>
<td>0.004</td>
</tr>
<tr>
<td>Manufacturing of leather, fur, feather and related products</td>
<td>5.472</td>
<td>0.043</td>
</tr>
<tr>
<td>Manufacturing of electrical machinery and apparatus</td>
<td>0.139</td>
<td>0.001</td>
</tr>
<tr>
<td>Manufacturing of computers, communication and other electronic equipment</td>
<td>0.472</td>
<td>0.004</td>
</tr>
<tr>
<td>Manufacturing of textiles</td>
<td>8.602</td>
<td>0.067</td>
</tr>
</tbody>
</table>

Note: The units of the COD discharge coefficient are tons/10^8 yuan.

### Table 2 | Environmental governance contribution indicators of water

<table>
<thead>
<tr>
<th>Indicator</th>
<th>Weight coefficient</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water pollution control contribution</td>
<td>Number of employed persons in the management of water conservancy and the environment</td>
</tr>
<tr>
<td></td>
<td>Urban drainage network density</td>
</tr>
<tr>
<td></td>
<td>Sewage treatment rate of sewage treatment plants</td>
</tr>
<tr>
<td></td>
<td>Comprehensive utilisation rate of industrial solid wastes</td>
</tr>
<tr>
<td>Ecological capacity contribution</td>
<td>Landscape green area</td>
</tr>
<tr>
<td></td>
<td>Green coverage of completely urban regions</td>
</tr>
</tbody>
</table>
Thus, the environmental Gini coefficient of the COD was not within the range of ‘absolute equality’ and should be adjusted.

The ratio of the governance contribution to the pollution contribution of each DMU was calculated using formula (7). The results showed that the ratios of the governance contribution to the pollution contribution of Hangzhou, Suzhou, Jiaxing, Wuxi, Zhenjiang, Huzhou, and Changzhou were 0.622, 0.600, 0.918, 1.232, 2.431, and 2.642, respectively. Therefore, the ratios of the governance contribution to the pollution contribution of Hangzhou, Suzhou, and Jiaxing were less than 1 and thus should be adjusted.

**Environmental Gini coefficient optimisation model application**

**Adjustment path setting**

Two main adjustment paths exist: reducing the water pollution contribution by reducing the water pollutant emissions, and increasing the water governance contribution by increasing the water governance inputs. The ratio of the industrial production contribution coefficient to the water pollution contribution coefficient was proposed as the basis for the choice of the path. For example, if the ratio of the industrial production contribution coefficient to the water pollution contribution coefficient of Hangzhou is less than 1, then its pollution contribution should first be adjusted; otherwise, the governance contribution should first be adjusted.

**Adjustment constraint setting**

Considering feasibility, efficiency and equality, the adjustment targets for each DMU were set as follows: (1) the lower and upper limits of the water pollutant emissions reduction rate were $-20\%$ and $0\%$, respectively; and (2) the lower and upper limits of the water governance input increase rate were $0\%$ and $20\%$, respectively.

**Adjustment results and discussion**

According to the adjustment path and targets set above, the water pollutant emissions and the water governance inputs of Hangzhou, Suzhou, and Jiaxing were adjusted by using the environmental Gini coefficient optimisation model. The adjustment results are shown in Table 4.

As shown in Table 4, the water pollutant emissions decreased by $19.84\%$ in Hangzhou, $14.85\%$ in Suzhou, and $19.84\%$ in Jiaxing. The water governance inputs increased by $12.68\%$ in Hangzhou, $19.61\%$ in Suzhou, and $7.21\%$ in Jiaxing. Using the adjustment, the total amount of water pollutant emissions ($TP$) decreased by $12.92\%$, and the total amount of water governance inputs ($TC$) decreased by $12.92\%$. The values and rates of change of the parameters after the adjustment are shown in Table 4.

<table>
<thead>
<tr>
<th>DMU</th>
<th>Water pollutant emissions</th>
<th>Water governance inputs</th>
<th>Water pollution contribution</th>
<th>Water governance contribution</th>
<th>Governance contribution/pollution contribution</th>
<th>Production contribution/pollution contribution</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hangzhou</td>
<td>$0.254TP_0\ (-19.84%)$</td>
<td>$0.222TC_0\ (12.68%)$</td>
<td>$0.291\ (-7.94%)$</td>
<td>$0.208\ (5.72%)$</td>
<td>$0.715\ (14.84%)$</td>
<td>$0.486\ (8.63%)$</td>
</tr>
<tr>
<td>Suzhou</td>
<td>$0.234TP_0\ (-14.85%)$</td>
<td>$0.197TC_0\ (19.61%)$</td>
<td>$0.268\ (-2.22%)$</td>
<td>$0.185\ (12.22%)$</td>
<td>$0.689\ (14.77%)$</td>
<td>$1.417\ (2.27%)$</td>
</tr>
<tr>
<td>Jiaxing</td>
<td>$0.104TP_0\ (-19.84%)$</td>
<td>$0.127TC_0\ (7.21%)$</td>
<td>$0.119\ (-7.94%)$</td>
<td>$0.120\ (0.59%)$</td>
<td>$1.003\ (9.26%)$</td>
<td>$0.571\ (8.63%)$</td>
</tr>
<tr>
<td>Wuxi</td>
<td>$0.100TP_0\ (0.00%)$</td>
<td>$0.176TC_0\ (0.00%)$</td>
<td>$0.115\ (14.84%)$</td>
<td>$0.165\ (-6.18%)$</td>
<td>$1.439\ (-18.30%)$</td>
<td>$1.646\ (-12.92%)$</td>
</tr>
<tr>
<td>Zhenjiang</td>
<td>$0.086TP_0\ (0.00%)$</td>
<td>$0.106TC_0\ (0.00%)$</td>
<td>$0.098\ (14.84%)$</td>
<td>$0.099\ (-6.18%)$</td>
<td>$1.006\ (-18.30%)$</td>
<td>$0.699\ (-12.92%)$</td>
</tr>
<tr>
<td>Huzhou</td>
<td>$0.048TP_0\ (0.00%)$</td>
<td>$0.117TC_0\ (0.00%)$</td>
<td>$0.055\ (14.84%)$</td>
<td>$0.109\ (-6.18%)$</td>
<td>$1.986\ (-18.30%)$</td>
<td>$0.718\ (-12.92%)$</td>
</tr>
<tr>
<td>Changzhou</td>
<td>$0.046TP_0\ (0.00%)$</td>
<td>$0.121TC_0\ (0.00%)$</td>
<td>$0.053\ (14.84%)$</td>
<td>$0.114\ (-6.18%)$</td>
<td>$2.158\ (-18.30%)$</td>
<td>$2.142\ (-12.92%)$</td>
</tr>
<tr>
<td>Total</td>
<td>$0.871TP_0\ (-12.92%)$</td>
<td>$1.066TC_0\ (6.59%)$</td>
<td>$1.000\ (0.00%)$</td>
<td>$1.000\ (0.00%)$</td>
<td>$8.996\ (-11.86%)$</td>
<td>$7.678\ (-7.88%)$</td>
</tr>
</tbody>
</table>
increased by 6.59%. These results meet the adjustment guideline of ‘less water pollution and more governance inputs’. After the adjustment, the environmental Gini coefficient of COD was 0.199, and the reduction rate was −27.63%.

CONCLUSIONS

In this study, the environmental Gini coefficient was applied to the allocation of water governance responsibilities to improve the allocation equality. The environmental Gini coefficient optimisation model was proposed to achieve the optimal adjustment for the assessment results of the water governance responsibility allocation inequality.

To verify the suitability of the method, Taihu Lake Basin, a heavily polluted transboundary basin in China, was chosen as a case study. The case study showed that: (1) the environmental Gini coefficient model can scientifically evaluate the inequality of water governance responsibility allocation and identify the inequality factors; and (2) the environmental Gini coefficient optimisation model can significantly improve the equality of water governance responsibility allocation and optimise water pollutant emissions and water governance inputs.

This research gives decision makers the ability to assess the equality of water governance responsibility allocation and provides clear guidance for developing appropriate policies to optimise water governance responsibility allocation.

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