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Equilibrium between economic growth and emission reduction of nitrogen and phosphorus: A case study in Poyang Lake Watershed, China

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Abstract

Eutrophication is one of a series of villains hindering economic growth and ecological conservation at various scales. Based on the social-economic statistical data, survey data and the first national pollutant sources census data of Poyang Lake Watershed, the emissions of Total Nitrogen (TN) and Total Phosphorus (TP) of three major industries and ten sub-intermediate sectors were estimated and a Input-Output (IO) table was created, embedded with TN/TP emission quadrants. The reduction efficiency of pollutants emission was calculated and was equilibrated to economic growth. The primary industry was the main source of TN/TP load in Poyang Lake Watershed, emitting 6.43×10^4 ton and 1.14×10^4 ton, respectively, among which animal husbandry and fishery sector were the major contributors, contributing 77.3% (TN) and 73.4% (TP), and 13.7% (TN) and 20.3% (TP) of total emission. According to the influence coefficient and sensitivity coefficient, manufacturing, construction and the tertiary sectors played a dominant role in promoting economic growth in this area. Furthermore, mining, water-electricity-gas production and supply, construction sectors were highly sensitive to the economic growth. As long as emission reduction efficiency is concerned, TN/TP emission can be mitigated largely by decreasing the proportion of animal husbandry, fishery and manufacturing sectors in economic structure. This paper can provide valuable references for policy formulation to balance economic growth and environmental conservation in Poyang lake basin.

Key words: Input-output analysis, economic growth, emission reduction, Poyang Lake Watershed.

Introduction

Eutrophication caused by rapid economic development and escalated total nitrogen/total phosphorus (TN/TP) loads has become one of the global environmental concerns [1]. Environmental issues in terms of algal bloom, water pollution, ecosystem degradation resulted from eutrophication are seriously threatening the sustainable development of the social-economic-environmental integrated system [2, 3]. Researches on the mechanism of eutrophication and corresponding mitigation strategies have gained imperative scientific concerns worldwide. Eutrophication mitigation management should not only comply with the natural laws during the process of employing high technologies to decrease the pollution level, but also abide to economic principles while reducing pollutants emission as well as pursuing rapid economic development [4]. Poyang Lake Watershed was located in the middle of Yangtze River Catchment, covering an area of 16.2×10^4 km^2, 97.2% of Jiangxi province. In recent years, water ecosystem there degraded conspicuously owning to the rapid economic growth and irrational industrial structure. Specifically, extensive agricultural management triggered the cumulated TN/TP load in Poyang Lake Watershed to a large extent. Accordingly, a multi-discipline study was carried out to reasoning the equilibrium between economic growth and emission reduction in Poyang Lake Watershed.

Data Collection

Input-output analysis was employed to explore the relationship between economic development and TN/TP emission reduction in Poyang Lake Watershed. Two sets of data were collected.

(1) *Input-output table (IO table)*. Social-economic statistical data was collected covering most of the intermediate-sectors. Intermediate-sectors were classified into three major industries. The primary industry consists of agriculture, forestry, animal husbandry, fishery and agri-forest-husbandry-fishery services sector (services sector); the secondary industry includes mining, manufacturing, water-electric-gas production and supply sector (supply sector), construction; the tertiary industry consists of only itself. Relevant information was collected mainly from statistical yearbook, sampling survey data.

(2) *TN/TP emission information.* Statistical data and investigation data were gathered to estimate emission status. Pollutants mainly produced by agriculture, animal husbandry, fishery, mining, manufacturing and supply sectors [5]. Consequently, the dataset

was mainly oriented from fertilization, pesticide usage, animal husbandry and fishery. The emission coefficient was calibrated basing on the first national pollutant sources census data, research findings and field survey.

Methodologies

Input-output analysis: Based on the TN/TP emission estimation and traditional input-output table frame [6], environmental-economic IO table, embedded with the pollutants emission quadrants (K_{ij}^{p}), was established to calculate the influence coefficient and sensitivity coefficient of various sectors (Table 1), furthermore, pollutants emission reduction model was developed to specific the potential sectors which shoulder comparatively heavier responsibilities for environment restoration in Poyang Lake Watershed [7, 8].

Reduction efficiency: E_{ij}, pollutants emission reduction efficiency of per unit total output, stands for the efficiency of varies of sectors in Poyang Lake Watershed [9]. The k_{ij}, calculated based on the integrated IO table, represents the constant TN/TP emission coefficient of j^{th} sector, namely pollutants emission per gross output of j^{th} sector (here the variable i represents the pollutants, not the intermediate sectors); w_j is the adjustment range (%) of j^{th} sector, determined by the influence coefficient, sensitivity coefficient, pollutants emission reduction efficiency and the social-economic scenarios of Poyang Lake Watershed b_{ij} is the full demand coefficient of j^{th} sector. Assumed that the direct consumption coefficients would not change sharply in a short time period, total output would diverse in accordance with the adjustment of the j^{th} sector, which could be demonstrated by the following formula:

$$k_{ij} = K_{ij}^{p} / Z_{j}^{p} \quad (1)$$

$$E_{ij} = \frac{\partial E_{ij}}{\partial p_j} = \frac{\sum_{i=1}^{n} N_j^p b_{ij} w_j k_{ij}}{\sum_{i=1}^{n} N_j^p b_{ij} w_j} \quad (2)$$

Specific restriction on those sectors with high reduction efficiency could effectively reduce the emissions of TN and TP.

Results

TN/TP emission: Environmental-economic IO table, embedded with the TN/TP emission quadrants, was derived from the original IO table of Jiangxi province in 2007, modified with statistical data and survey data. Among the three major industries in Poyang Lake Watershed, the primary industry was responsible for the highest emission of TN/TP, while provided the lowest total output value. Furthermore, the emission coefficient of TN/TP of the primary industry was particularly outstanding, among which the animal husbandry and aquaculture contributed the most (Table 2). The secondary industry, with highest gross output, was responsible for comparatively lower discharge of total emissions than that of the primary industry, and was labeled with mediate emission. The water-electric-gas production and supply sector and manufacturing sector contributed most of the emissions.

Table 1. The environmental-economic IO table.

	Intermediate use	Final products	Gross output
Intermediate input	X_{ij}^{p}	Y_{i}^{p}	X_{i}^{p}
Value-added	N_{j}^{p}		
Total input	Z_{j}^{p}		
Emissions of pollutants	K_{ij}^{p}		

In this table, X_{ij}^{p} represents the amount of products from i^{th} sector consumed by j^{th} sector; K_{ij}^{p} represents the pollutant emission of j^{th} sector; N_{j}^{p} represents the value-added of j^{th} sector when producing the j^{th} product; Y_{i}^{p} represents the final product of i^{th} sector; X_{i}^{p} represents the gross output of i^{th} sector; Z_{i}^{p} represents the total input of the j^{th} sector; the total input of every sector in the IO table is equal to its gross output, in other word, $Z_{j}^{p} = X_{i}^{p}$.

Key sectors for economic stimulation in Poyang Lake Watershed: Sectors would play different roles in the regional economic development in different phase, possibly distinct from their original inherited characters. Some sectors took the role as leaders in economic development, and those sectors were supposed to promote industry structure adjustment, accelerate economic development. Meanwhile, Influence Coefficient (IC) and Sensitivity Coefficient (SC) were identified as the important indicators to estimate the accelerating/hindering roles of sectors in regional economic growth, which were applied to identify the key sectors in Poyang Lake Watershed.

Based on the direct consumption coefficient and full demand coefficient, IC/SC was applied to analysis the key sectors of Poyang Lake Watershed (Table 3). Results showed that coefficients of the secondary industry are highest, while these of the primary industry are lowest. The secondary industry is of great significant to the economic development and structure regulation in Poyang Lake Watershed, however, its sensitivity coefficient is merely larger than 1 while is higher than the other two industries. Due to its large intermediate consumption, the secondary industry exerts a high dependency on other industries' products. In summary, the secondary industry, followed by the tertiary industry, plays a dominant role in economic growth in watershed. Consequently, more attention should be paid to the secondary industry development in the later social-economic planning of Poyang Lake Watershed.

In terms of the intermediate sectors, within the primary industry, agriculture, animal husbandry take the leading role compared to other three sectors. At the same time, characterized by "Industrial Province", the influence coefficient of intermediate-sectors of the secondary industry is much higher than all the other intermediate-sectors in this watershed. The manufacturing and construction sector, especially, played a decisive role in promoting the economic development, as well as stimulating other intermediate-sectors simultaneously. The mining, water-electric-gas production and supply and manufacturing sectors, characterized with a sensitivity coefficient larger than 1, consume most of the products from other sectors.

Pollutants emission reduction efficiency of various sectors: The TN/TP emission reduction efficiency of the primary industry, 2.692 and 0.476 kg/10^4 yuan, respectively, is higher than that of the other two industries and is 4 to 10 times of the second industry and tertiary industry. In addition, compared with other two major industries, the stimulation effect of the primary industry is conspicuously weaker with a lowest IC. So reducing its proportion

Table 2. Gross output and emissions of TN and TP of various sectors.

Emissions	The primary industry	Sectors			The secondary industry	Sectors			The tertiary industry
		Agriculture	Animal husbandry	Fishery		Mining	Manufacturing	Supply sector	
Gross output	198.95	89.74	58.74	23.96	1045.48	39.51	661.20	45.73	514.94
TN	64.27	5.74	49.70	8.83	10.93	0.19	5.90	3.29	1.14
TP	11.38	0.71	8.36	2.31	0.45	0.02	0.35	0.09	0.11

unit: billion yuan/1000 ton.

Table 3. Coefficients of TN/TP emission, efficiency, influence, sensitivity in Poyang Lake Watershed.

Industries and sectors	Emissio n factor of TN	Emission factor of TP	Influence coefficient	Sensitivity coefficient	Emission reduction efficiency of TN	Emission reduction efficiency of TP
The primary industry	3.158	0.560	0.611	0.885	2.692	0.476
Agriculture	0.639	0.079	0.681	0.982	0.637	0.084
Forestry	-	-	0.484	0.867	0.026	0.004
Animal husbandry	8.461	1.423	0.639	0.806	6.218	1.042
Fishery	3.685	0.966	0.500	0.581	3.372	0.877
Services	-	-	0.455	0.761	0.053	0.009
The secondary industry	0.098	0.004	1.547	1.133	0.679	0.112
Mining	0.049	0.004	0.591	2.005	0.176	0.020
Manufacturing	0.089	0.005	3.100	1.191	0.840	0.127
Supply sector	0.719	0.019	0.666	1.366	0.621	0.029
Construction	-	-	1.297	0.501	0.443	0.065
The tertiary industry	0.021	0.002	0.843	0.982	0.278	0.046
The tertiary sector	0.022	0.002	1.587	0.939	0.612	0.096

unit: kg/10000 yuan.

in economic structure will effectively decrease emissions of TN/TP without hindering the rapid development of economy. On the intermediate sector level, the TN/TP reduction efficiency of most intermediate sectors within the primary industry is higher than that of the others, among which animal husbandly, fishery as well as the agriculture sectors are particularly outstanding. Within the second industry, the reduction efficiency of manufacturing sector is highest, followed by supply sector and construction sector, while mining sector is lowest.

Conclusions

A IO table was constructed based on the original IO table (2007), modified with social-economic statistical data and survey data, to analysis the equilibrium between economic growth and pollutants emission reduction, with specific focus on the TN and TP. Results indicate that the TN/TP emissions of the primary industry are largest, mainly come from the animal husbandry and fishery, followed by the manufacturing and supply sectors of the secondary industry. Additionally, this paper figured out the most influential sectors to economic growth and contaminants emission reduction in Poyang Lake Watershed based on the comparison analysis of IC/SC and reduction efficiency. The results indicated that the manufacturing, construction, agriculture and the tertiary sectors are the trigger sectors of economic development in Poyang Lake Watershed. Furthermore, with reduction efficiency, the key sectors for the pollutants emission mitigation are identified, including animal husbandry, fishery and manufacturing. This paper provides new perspectives and opportunities to analyse economic growth and pollutants emission reduction in river basin, and also provides scientific supports to the policymaking for the regional sustainable development.

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References

[1]Jin, X. C., Liu, H. L., Tu, Q. Y. *et al.* 1990. Lake Eutrophication of China. China Environmental Science Press, Beijing (in Chinese).

[2]Liu, J. M. and Deng, X. Z. 2011. Influence of different land use on urban microenvironment in Beijing City, China. Journal of Food, Agriculture & Environment **9**(3&4):1005-1011.

[3]Vuorenmaa, J., Rekolainen, S., Lepist., A., Kentt¡mies, K. and Kauppila, P. 2002. Losses of nitrogen and phosphorus from agricultural and forest areas in Finland during the 1980s and 1990s. Environmental Monitoring and Assessment **76**(2):213-248.

[4]Chen, M., Chen, J. and Sun, F. 2008. Agricultural phosphorus flow and its environmental impacts in China. Science of the Total Environment **405**(1-3):140-152.

[5]Chen, D. J., Lu, J., Shen, Y. N. 2009. Estimation of critical nutrient amounts based on input-output analysis in an agriculture watershed of eastern China. Agriculture, Ecosystems and Environment **134**(3-4):159-167.

[6]Hawdon, D. and Pearson, P.1995. Input-output simulations of energy, environment, economy interactions in the UK. Energy Economics **17**(1):73-86.

[7]Chen, G. Q. and Zhang, B. 2010. Greenhouse gas emissions in China 2007: Inventory and input-output analysis. Energy Policy **38**(10):6180–6193.

[8]Zhou, S. Y., Chen, H. and Li, S. C. 2010. Resources use and greenhouse gas emissions in urban economy: Ecological input-output modeling for Beijing 2002. Commun. Nonlinear Sci. Numer. Simulat. **15**(10):3201-3231.

[9]Deng, X. Z., Zhao, Y. H., Wu, F., Lin, Y. Z., Lu, Q. and Dai, J.2011. Analysis of the trade-off between economic growth and the reduction of nitrogen and phosphorus emissions in the Poyang Lake Watershed, China. Ecological Modelling **222**(2):330-336.