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Relationship Between Water Pollution and Regional Economic Development: Empirical Evidence from Hubei, China

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ABSTRACT

Water pollution affects the regional economic development, but no consensus about the internal relationship between the two exists in literature. To identify the relationship between water pollution and regional economic development, the effects of water pollution on regional economic development were explored by using a multiple regression model and relevant data on Hubei Province in China from 2008 to 2017. Results show that despite the steady and rapid economic development of Hubei, water pollution is alleviated. However, the overall situation remains unoptimistic. A significant inverted U-shape relationship is observed between the industrial wastewater discharge and per capita gross domestic product (GDP) and between urban domestic sewage and per capita GDP. At the initial stage, the industrial wastewater discharge and urban domestic sewage are positively correlated with per capita GDP. The industrial wastewater discharge and urban domestic sewage increase with the increase of per capita GDP. When the curve reaches its peak, the two exhibit a negative correlation; that is, with the increase in per capita GDP, the discharge of industrial wastewater and urban domestic sewage decrease. These conclusions provide insights for water environment governance, sustainable economic development, and policy formulation.

INTRODUCTION

Water pollution seriously threatens the safety of water resources in China. Such pollution deteriorates the water quality of the surface water environment and the related ecological environment, such as the soil, groundwater, offshore waters, and even the atmosphere. It also affects the safety of drinking water and agricultural products and ultimately threatens the human health and leads to the loss of social welfare. The problem of pollution is widespread, and it is difficult to mitigate or solve completely. Technology, capital, time, institutional innovation, and strict scientific management are required. The challenges in national governance faced by developing countries with considerable regional differences, such as China, are enormous. Water pollution and its prevention and control are not simply environmental problems but strategic security issues related to the long-term development of a country. In this study, water environmental safety refers to whether the quality of water resources meets the needs of sustainable social and economic development or not. In city development, water resources have functions in water supply, transportation, recreation, cultural and historical origin, ecological environment, and landscape. Therefore, given the increasingly scarce global water resources at present, water pollution is expected to intensify water scarcity. As a result, the relationship between water pollution and economic development has become a popular topic in sustainable development research.

A close relationship exists between economic development and water pollution. Human economic activities inevitably produce sewage, and water pollution eventually exerts negative impacts on economic development. Although economic development contributes to the gross domestic product (GDP), sewage treatment and ecological environment damage entail increased costs. Correctly identifying the damage of water pollution on humans and the relationship between water pollution and economic development is crucial to the environmental control of water pollution and the promotion of sustainable economic development.

PAST STUDIES

Melloul et al. (2003) argued that the relationship between water environment management and social needs should be coordinated to achieve sustainable development of the water environment. Judova et al. (2005) indicated that the high rate of pesticide loss and the high cost of wastewater treatment are the main causes of agricultural pollution and wastewater pollution. Improving the rural water environment requires not only advanced technology but also appropriate governance systems and policies. Simon et al. (2004) found that the coordination of economic and water environment systems involves a balance between the social economy and water environment with the goal of sustainable development. Lee et al. (2010) used a water environment index and per capita GDP to test the shape of the environmental Kuznets curve (EKC) in different regions, such as the United States, Britain, Asia, Africa, and Oceania. The study found that the curve in the first two countries had an inverted U shape, whereas different curve shapes were observed in the other regions. Using a time series, Vincent (1997) examined the correlation between Malaysia's water pollution index and per capita GDP and found that the EKC in this region is linear. Starting with an economic analysis of water rights and water markets, Wang (2007) analysed the background, challenges, and prospects of water control transformation in China by using relevant theories in institutional economics and combining them with historical changes in the water control structure. Wang (2007) analysed the causes of environmental pollution from the perspective of economics and game theory and asserted that the fundamental causes of environmental pollution lie in the property rights, externalities, and market failure of environmental resources. Zheng (2013) studied the relationship between water environmental pollution and socioeconomic development in Yingkou, China, by utilizing data on the social economy and environment from 1999 to 2008. The change process and causes of five environmental pollution discharge indicators, including local industrial wastewater discharge, industrial chemical oxygen demand discharge, and domestic sewage discharge, were analysed in detail. Lu (2010) reported an EKC inverted U-shaped relationship between global water pollution indicators and per capita GDP. A linear relationship was also established between the total amount of wastewater discharged in China and per capita GDP. The relationship between the amount of ammonia nitrogen discharged in wastewater and per capita GDP was U-shaped. Li (2011) adopted Qingdao, China, as the research object and used data on water environment and economic development indicators from 1996 to 2008 to test the characteristics of the local water EKC. The study found that an increase in the per capita GDP of the local people leads to an increase in wastewater discharge. The main factors that affect the change in the Kuznets curve of the local water environment include the government's efforts to strengthen the management of sewage treatment. Sun (2010) pointed out that in the process of harnessing the water environment, project management should be strengthened, an environmental evaluation system should be implemented, environmental monitoring should be fortified, and law enforcement should be standardized.

The EKC results from these numerous studies are not simple repetitions. The outcomes differ because of the different research objects, pollutant indicators, and research methods used. However, previous studies were based on simplified models that do not reflect the feedback effect of environmental quality on economic growth. Thus, environmental quality was regarded as the output of economic growth. The impact of economic growth on environmental quality was directly estimated in extant empirical literature. Notably, in addition to the impact of economic growth on environmental quality, environmental quality degradation may affect economic growth by reducing or restricting production (Jansson et al. 1994) and by producing factors (Pearce et al. 1993) or indirectly affecting production through increased pollution reduction costs. Therefore, economic growth and environmental change are mutually affected (Van Ewijk et al. 1995).

Against this background and in accordance with the EKC model, regression models of industrial wastewater discharge, urban domestic sewage, and per capita GDP were constructed by selecting the water environment and economic data of Hubei Province in China from 2008 to 2017. The curve characteristics of the relationship between water pollution and economic growth were analysed. The EKC curve shape of the water environmental quality index was determined, and the factors that influence water environmental quality were identified to provide a theoretical basis for water pollution environmental control and economic sustainable development.

CURRENT WATER POLLUTION AND ECONOMIC DEVELOPMENT IN HUBEI, CHINA

Current water pollution: Hubei is one of the important provinces in the Yangtze River Economic Zone of China. The current situation of water pollution in Hubei Province was analysed from two aspects of industrial wastewater discharge and urban domestic wastewater discharge, as shown in Fig. 1. The industrial wastewater discharge in Hubei Province exhibited a gradual increase from 936.87 million tons in 2008 to 104.34 million tons in 2011. With the public and government's attention on environmental pollution and the transformation of the economic development mode from extensive to intensive growth, economic development relies on scientific and technological progress and on improving the quality of workers for increased production efficiency. The discharge of industrial wastewater in Hubei Province showed a decrease from 916.09 million tons in 2012 to 44.158 million tons in 2017, with a decline rate of 207.46%. Meanwhile, the urban domestic wastewater discharge in Hubei Province in 2008 was 2019.09 million tons. The said discharge increased from 1644.12 million tons in 2009 to 2096.2 million tons in 2016, with a growth rate of 127.5%. In 2017, the figure dropped to 12987.7 million tons. Evidently, the water pollution in Hubei Province was

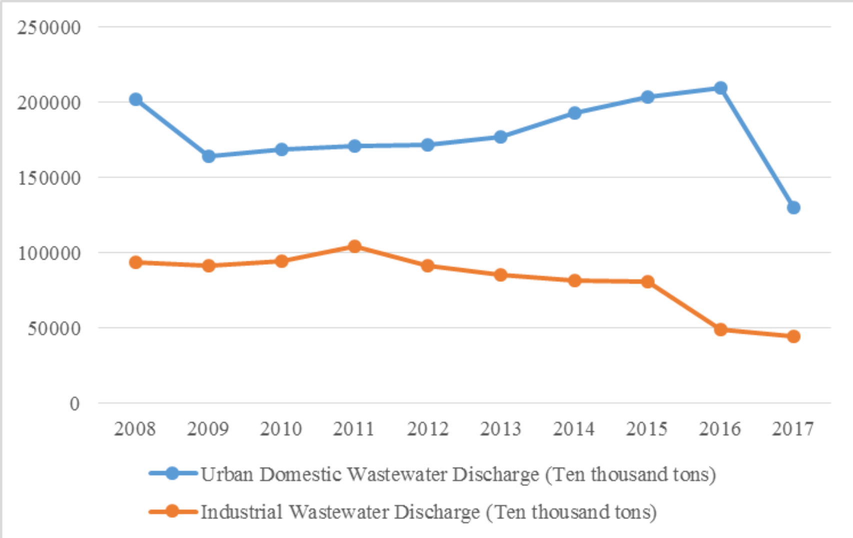

Fig. 1: Water pollution in Hubei Province of China from 2008 to 2017.

alleviated in recent years, but the overall situation remains unoptimistic.

Current economic development: Hubei is an important economic province in the Yangtze River Economic Zone of China, and demonstrates satisfactory economic development, as shown in Fig. 2. The total GDP of the province increased from 1132.892 billion RMB in 2008 to 3547.809 billion RMB in 2017, with a growth rate of 313.16%. The per capita GDP increased from 19837.02 RMB in 2008 to 60111.98 RMB in 2017, with a growth rate of 303.03%. The GDP and per capita GDP growth rates are comparatively similar, and economic development shows steady and rapid growth.

RELATIONSHIP BETWEEN WATER POLLUTION AND ECONOMIC DEVELOPMENT

EKC: The EKC was proposed by American environmental economists Grossman & Krueger in the 1990s (Grossman et al. 1995) to reflect the correlation between per capita income and several environmental indicators. The EKC model shows that the change in environmental indicators presents an inverted U-shaped distribution with economic growth. That is, at a certain level of development, the trend of environmental deterioration is expected to reach an inflection point when economic development reaches a certain level. Subsequently, the environmental situation and environmental quality will gradually improve.

Variable selection and data: Water pollution is mainly measured by industrial wastewater discharge (*Indwater*) and urban domestic sewage (*Urbwater*), and economic development is measured by per capita GDP (*Pergdp*). The data are collected from China Environmental Statistics Yearbook and China Statistical Yearbook from 2009 to 2018, as shown in Table 1.

Table 1: Statistics of major variables.

Year	Pergdp (RMB)	Urbwater (Ten thousand tons)	Indwater (Ten thousand tons)
2008	19837.07	201909	93687
2009	22659.27	164412	91324
2010	27876.41	169150	94593
2011	34095.62	170698	104434
2012	38502.25	171706	91609
2013	42751.91	177323	84993
2014	47075.69	192893	81657
2015	50495.88	203363	80817
2016	55506.17	209620	49090
2017	60111.98	129877	44158.22

Modelling: Models for industrial wastewater discharge, urban domestic sewage and per capita GDP are constructed as Models (1) and (2), respectively.

$$Pergdp = \alpha_1 + \beta_1 Indwater + \beta_2 Indwater^2 \quad ...(1)$$

$$Pergdp = \alpha_2 + \beta_3 Urbwater + \beta_4 Urbwater^2 \quad ...(2)$$

In Models (1) and (2), $\beta 1, \beta 2, \beta_3$ and β_4 are the regression coefficients of the models, and α_1 and α_2 are random error terms. When β_2 and β_4 are greater than 0, the curve is U-shaped, and EKC has a minimum value. When β_2 and β_4 are less than 0, the curve is inverted U-shaped, and EKC has a maximum value.

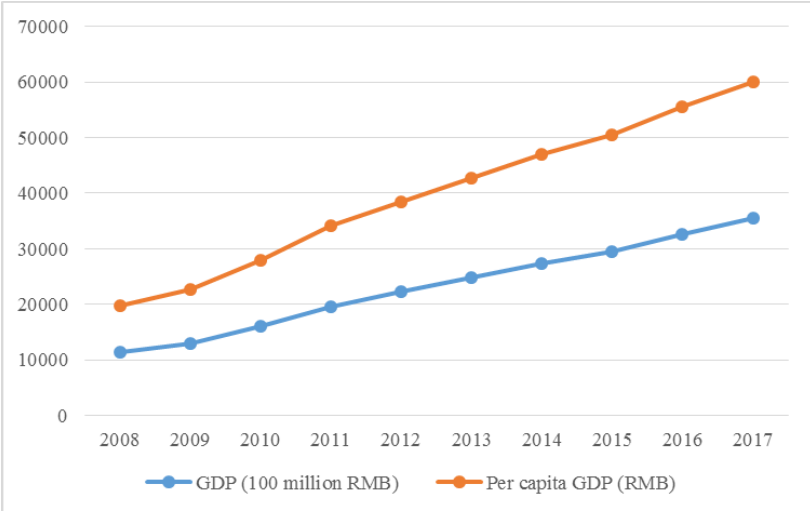

Fig. 2: Economic development in Hubei Province of China from 2008 to 2017.

Table 2: Regression analysis results.

	Constant	β_1	β_2	β_3	β_4	R^2	F	Sig.
Model (1)	1.456	2.987×10^{-5}				0.867	134.56	0.000
	1.234	-3.142×10^{-6}	5.267×10^{-9}			0.917	142.12	0.000
Model (2)	1.195			2.646×10^{-4}		0.921	146.36	0.000
	1.076			-4.314×10^{-5}	6.831×10^{-10}	0.835	128.57	0.000

Result analysis and discussion: SPSS 21.0 software and data were used for regression analysis of the model. The results are shown in Table 2.

When only β_1 is added to Model (1), the coefficient of β_1 is 2.987×10^{-5} and significant at the 0.001 level. When β_1 and β_2 are added to Model (2), the coefficient of β_1 is -3.142×10^{-6}, and the influence relationship changes from positive to negative. Moreover, the coefficient of β_2 is 5.267×10^{-9} and significant at the 0.001 level.

These results indicate that an inverted U-shaped relationship exists between industrial wastewater discharges (*Indwater*) and per capita GDP (*Pergdp*). This outcome is consistent with the traditional inverted U-shaped EKC. At the initial stage, industrial wastewater discharge and per capita GDP show a positive correlation. With the increase in per capita GDP, industrial wastewater discharge also increases. When the curve reaches the highest point, the two show a negative correlation, that is, industrial wastewater discharge decreases with the increase in per capita GDP. The current development situation of Hubei Province is on the right side of the maximum point. Therefore, the discharge of industrial wastewater in Hubei Province is predicted to decrease with the increase in per capita GDP in the next few years.

With regard to the regression results of Model (2), when only β_3 is added, the coefficient of β_3 is 2.646×10^{-4} and significant at the 0.001 level. When β_3 and β_4 are simultaneously added in Model (2), the coefficient of β_3 is -4.314×10^{-5}, and the influence relationship changes from positive to negative. Furthermore, the coefficient of β_4 is 6.831×10^{-10}, and significant at the 0.001 level. These results show that an inverted U-shaped relationship exists between urban domestic sewage (*Urbwater*) and per capita GDP (*Pergdp*). This outcome is also consistent with the traditional inverted U-shaped EKC. At the initial stage, a positive correlation exists between urban domestic sewage and per capita GDP. With the increase in per capita GDP, urban domestic sewage also increases. When the curve reaches its peak, the two show a negative correlation, that is, urban domestic sewage decreases with the increase in per capita GDP.

MEASURES TO CONTROL WATER POLLUTION

Strengthened source control is the first step to control water environmental pollution. We should vigorously promote the use of clean products, reduce the use of substandard household goods (e.g., phosphorus-containing detergent powder), and improve the reuse rate of wastewater. We must treat wastewater according to relevant standards and reuse it for toilet flushing and urban green car washing to remarkably reduce wastewater discharge.

The improvement of technological processes provides a technical guarantee for the treatment of water environmental pollution. Urban sewage treatment plants should simultaneously construct nitrogen and phosphorus removal facilities. Existing centralized sewage treatment plants must complete the transformation of nitrogen and phosphorus removal facilities and innocuous sludge treatment facilities. Conditional centralized sewage treatment plants should carry out tail water ecological treatment. All centralized sewage treatment plants should strictly implement the new sewage treatment discharge standards.

Transforming the concept of the water environment of enterprises and urban residents is the most important task in the current work on water pollution prevention and control. Enterprises are the main source of industrial wastewater discharge and water environment treatment. Although the industrial wastewater pollution in Hubei Province has been controlled in recent years, the tendency of enterprises to maximize their own interests requires the consolidation of various measures and vigorous promotion of these measures among enterprises. To promote the development of a low-carbon and green economy, residents should maximize new media (e.g., Weibo and WeChat), strengthen the propaganda and education about ecological culture, increase the awareness on ecological civilization of the entire society, and advocate a green, low-carbon, civilized, healthy lifestyle and consumption mode.

CONCLUSION

Using empirical data on Hubei Province of China from 2008-2017, this study examines the relationship between water pollution and regional economic development and provides the following conclusions. (1) The economy of Hubei Province is developing steadily and rapidly, and water pollution has been alleviated in recent years. However, the overall situation remains unoptimistic. (2) A significant inverted U-shaped relationship exists between industrial wastewater discharge and per capita GDP. (3) A significant inverted U-shaped relationship exists between urban sewage discharge and per capita GDP.

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