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Original Research Paper

Study on the Relationship Between Agricultural Economic Growth and Agricultural Nonpoint Source Pollution in Inner Mongolia Autonomous Region of China

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ABSTRACT

As an environmental problem arousing worldwide concern, agricultural nonpoint pollution affects sustainable economic development. As a traditional agricultural province, the economic structure in Inner Mongolia Autonomous Region is currently being industrialized. However, the rapid development of agriculture causes serious damage to the environment. The agricultural nonpoint source pollution index and economic growth data from 2000 to 2014 in Inner Mongolia Autonomous Region were selected to explore the short-term and long-term dynamic relationship between agricultural economic growth and agricultural nonpoint source pollution in this region and ensure the existence of an environmental curvilinear relationship. Whether agricultural economic growth and agricultural nonpoint source pollution are co-integrated was analysed, and their environmental curvilinear relationship was determined. Results show that nonpoint pollution and economic development appear positively correlated during the research period. The per capita output value of farming, forestry, husbandry, and fishery relates to fertilizer, pesticides, and agricultural film loss per unit area in an inverted U-shaped curve, whereas the livestock and poultry manure emission present an "inverted U-shaped + U-shaped" curve during the transition period. This study has theoretical and practical significance in effectively understanding agricultural nonpoint source pollution, addressing the problem, and proposing operative suggestions for economic growth in Inner Mongolia Autonomous Region.

INTRODUCTION

Agricultural nonpoint source pollution refers to air, soil, and water pollution caused by nutrient substances (e.g., nitrogen and phosphorus), pesticides, heavy metals, other organic and inorganic pollutants, and sediments, such as soil particles in different forms, during agricultural production, particularly water pollution by these pollutants through farmland runoff and underground leakage. Agricultural nonpoint pollution is difficult to monitor, quantize, and manage because of its extensive coverage and randomness. In addition to the universality of agricultural production, agricultural nonpoint pollution has become a major pollution source influencing the quality of the current rural economic environment in China. The developing trend of agricultural nonpoint pollution is certainly alarming. Meanwhile, the serious fertilizer and pesticides loss in China has led to water eutrophication and groundwater pollution.

Inner Mongolia Autonomous Region is a large agricultural province. As such, the demand for agricultural factors and products is considerable. However, the continuous resource-intensive development of agriculture causes significant damage to the agro ecological environment. The increasingly serious agricultural nonpoint pollution also restricts the sustainable development of the agricultural economy in this autonomous region. The rapidly developing economy in this region results in a critical agricultural nonpoint pollution. Moreover, the economic scale expansion, industrialization, and urbanization require additional agricultural factors and products. Consequently, agriculture undergoes intensive production, causing extreme environmental pollution pressure in rural areas. The principal cause of rural nonpoint pollution is actually the unreasonable use of fertilizer and pesticides. For example, 74,750,000 t of fertilizer were applied in 2000. However, with the economic growth and agricultural scale expansion, the amount tripled to 2.2267 million t in 2014, causing grievous environmental pressure. Agricultural film residue, serious pollution of the livestock and poultry industry, unreasonable layout, waste aggregation, and uncontrolled discharge of domestic wastewater in rural areas worsen agricultural nonpoint source pollution, which is also harmful to agricultural production and farmer health.

With various agricultural climates, farming system, and rural income levels in this region, agricultural pollution is managed only technically. The close relationship between agricultural pollution and rural economic management system and that between traditional production mode and way of life have not been clearly elucidated. Thus, the relationship between economic development level and agricultural nonpoint source pollution areas were investigated and policy suggestions were proposed in the hope of facilitating pollution control to improve the agro ecological environment and ensure a sustainable and healthy development of the agricultural economy.

EARLIER STUDIES

Theoretically, as an important section of national economy, natural force and resources are used in agricultural production and materials are exchanged directly. Therefore, agricultural nonpoint source pollution is closely correlated with the development of the agricultural economy. With economic development, the influences of people on the environment increase and the release level enters the intermediate stage. When the development is weak, no other forces can be used to improve the environment, worsening agricultural nonpoint source pollution. If the relationship between economy and environment is not handled ideally, then pollution becomes irreversible and reaches the highest level. Therefore, most domestic and foreign studies on this relationship are contingent on this basic thought.

Foreign studies on the relationship between agricultural nonpoint source pollution and economy focus on the relationships between environmental pollution and economic development and between agricultural nonpoint source pollution and control measures. A linear relationship between environmental pollution and per capita income has been observed by Grossman in the North America Free Trade Agreement, indicating that environmental pollution becomes increasingly serious with the growth of per capita income; however, when the growth of per capita income increases to a certain level, environmental pollution is improved (Grossman et al. 1992). Borrowing the inverted U-shaped linear relationship proposed by Kuznets-the concept of Kuznets curve, Panayotou originally names the curve environmental Kuznets curve (EKC) (Panayotou 1993). Griffin leads the systematic theoretical analysis on policies regarding the management and control of agricultural nonpoint source pollution; by referring to policies, such as pollution charges and discharge standard, he proposed four types of control policies, namely, taxing and standard based on input as well as taxing and standard based on desired output (Griffin et al. 1982). Shortle believes that many input factors (e.g., fertilizer, pesticides, and mulching film) simultaneously affect the discharge of agricultural pollutants during agricultural production and that the discharge varies because of various types of land and soil as well as different geographic locations of farmland (Shortle et al. 1986). Ribaudo propose the most practical incentive system-award; providing those who employ clean technology with subsidy can effectively control nonpoint source pollution (Ribaudo et al. 1999). Shafik reveals that the quality and sanitary condition of drinking water worsen before improving with the growth of per capita GDP (Shafik et al. 1992). When assessing the discharge of four pollution gases, Selden observes the "inverted U-shaped" relationship between gases and economic development level (Selden et al. 1997). Ryan believes that the principal motivation toward the best management lies in personal management philosophy, responsibility, commitment, and feasibility of environmental awareness education (Ryan 2009). Terry determines that practice can help different groups realize and manage environmental pollution caused by pig waste (Terry et al. 2009). Gourley notes that nonpoint pollution must be investigated and developed and that many factors (e.g., politics, economy, culture, and environment) must be considered in making effective measures to control agricultural nonpoint source pollution (Gourley et al. 2005). Li also believes that an inverted U-shaped relationship exists between nonpoint source pollution caused by fertilizer input and practical per capita GDP in China and that the growth of resident income and environmental requirement levels can weaken the agricultural nonpoint source pollution (Li et al. 2011). Wu et al. (2013) believes that economic growth is steadily co-integrated with nitrogen production in agricultural nonpoint source pollution, which implies the long-term conflict between economic growth and agricultural nonpoint source pollution. Liang et al. (2013) explores the inner driving mechanism of agricultural nonpoint source pollution, revealing that a large proportion of commercial crops and livestock and poultry industry aggravate agricultural nonpoint source pollution. Based on data in Hebei Province, regression studies on the total output value of farming, forestry, husbandry, and fishery are conducted by Jia, who also tests the relationship between agricultural economic growth and major agrichemical input (Jia 2015). All of these studies target the relationship between environmental pollution and economic growth as well as the measures of controlling agricultural nonpoint source pollution. Many studies reveal that rural economic growth is correlated with environment quality. Based on previous research, the EKC model is adopted in this study to verify whether an "inverted U-shaped" relationship exists between agricultural nonpoint source pollution and agricultural economic growth in Inner Mongolia Autonomous Region. This study aims to determine the right time to improve the relationship between agricultural environment and economic development, which is of considerable theoretical and practical significance for an enhanced understanding of agricultural nonpoint source pollution in Inner Mongolia Autonomous Region.

RESEARCH METHODS AND INDEX DESCRIPTION

Correlation coefficients: According to the analysis on agricultural economic growth and agricultural nonpoint source pollution, both of which grow simultaneously, Pearson's correlation coefficient should be tested initially. The coefficient is presented in Formula (1):

$$r = \frac{1}{n-1}\sum_{i=1}^{n}(\frac{x_i - \bar{x}}{s_x})(\frac{y_i - \bar{y}}{s_y}) \quad ...(1)$$

Where r is the coefficient; x_i and y_i are the values of agricultural economic growth and agricultural nonpoint source pollution each year, respectively; s_x and s_y are the respective standard deviations; $\bar{x}$ and $\bar{y}$ are the respective average values; and n is their time span.

Introduction to the EKC model: EKC is a curve with the economic index as abscissa axis and environmental index as vertical axis. The curve reflects the long-term relationship between economic growth and agricultural nonpoint source pollution. Based on different assumptions, several scholars design various equations expressing the relationship while considering different dominant factors. The most common cubic function was employed in this study, which is shown as follows:

$$E_t = c_1 + c_2 Y + c_3 Y^2 + c_4 Y^3 + u_t \quad ...(2)$$

In Formula (2), E_t is the index of agricultural nonpoint source pollution at t, y_t is the per capita output value of farming, forestry, husbandry, and fishery, c_t is the regression coefficient, and u_t is the random disturbance term. When $c_2 > 0, c_3 < 0, c_4 = 0$, agricultural nonpoint source pollution exhibits a U-shaped curve. When $c_2 > 0, c_3 > 0, c_4 = 0$, agricultural nonpoint source pollution exhibits an "inverted U-shaped" curve.

Index selection and data declaration: Relative data from 2000 to 2014 in Inner Mongolia Autonomous Region were employed in this study. Considering the situation of agricultural nonpoint source pollution in this region, unit area fertilizer loss amount (HFL), unit area pesticide loss amount, unit area residual amount (NMC), and poultry manure discharge amount (XQP) were selected. Per capita output of farming, forestry, husbandry, and fishery (RCZ) was used as the index of agricultural economic growth and exponentially smoothed with the index of primary industry. These five indices were obtained from the Statistical Yearbook of Inner Mongolia Autonomous Region (2001-2015) and China Rural Statistical Yearbook (2001-2015).

EMPIRICAL STUDY AND RESULTS ANALYSIS

Correlation coefficients analysis: According to Formula (1), the test was completed through the analysis software SPSS20.0. The analysis results are displayed in Table 1.

RCZ is evidently correlated with HFL, NYL, NMC, and XQP, and its correlation coefficients are 0.947, 0.874, 0.906, and 0.884, respectively. All coefficients are higher than 0.8. Therefore, agricultural economic growth is closely correlated with nonpoint source pollution in terms of statistics, and the two are strongly interdependent.

Augmented Dickey-Fuller test: In practice, sample data in random time series should be initially judged by their stationarity. Graphical analysis, autocorrelation function analysis, and augmented Dickey-Fuller test (ADF) are commonly used to test stationarity. ADF was adopted in this study. For theoretical analysis, data stationarity was initially tested to determine whether the indices have roots of unity. Otherwise, non-stationary time series were directly regressed when "spurious regression" may occur. To avoid this problem, the stationarity of each index should be primarily tested. The original data of RCZ, HFL, NYL, NMC, and XQP were tested non-stationary in ADF through Eviews 7.0. However, after the first difference, they became stationary (Table 2).

Regression analysis: Optimal fitting model was selected after fitting the regression equation into the data of agricul-

Table 1: Pearson's correlation coefficient of RCZ, HFL, NYL, NMC, and XQP.

Correlation coefficient	RCZ	HFL	NYL	NMC	XQP
RCZ	1	-	-	-	-
HFL	0.947	1	-	-	-
NYL	0.874	-	1	-	-
NMC	0.906	-	-	1	-
XQP	0.884	-	-	-	1

Table 2: ADF of each variable.

Variables	ADF test value	Critical value	Findings
RCZ	-1.087	-3.067	Non-stationary
HFL	-2.147	-3.874	Non-stationary
NYL	-4.478	-3.041	Non-stationary
NMC	-3.447	-3.277	Non-stationary
XQP	-0.784	0.187	Non-stationary
ΔRCZ	-6.181	-3.784	Stationary
ΔHFL	-3.674	-1.641	Stationary
ΔNYL	-5.569	-3.189	Stationary
ΔNMC	-4.477	-3.974	Stationary
ΔXQP	-1.245	0.174	Stationary

Note: Δ is the first difference treatment of variables.

Table 3: Regression results.

Statistics, Variables	HFL	NYL	NMC	XQP
Adjusted R^2	0.967	0.915	0.963	0.897
F value	274.684	367.545	49.674	38.745
Constant term	84.321*	2.169*	1.489**	2,645.124*
RCZ	0.052*	0.0028*	0.0017*	7.897**
RCZ^2	-4.23E-06*	-2.41E-07*	-1.34E-07*	-0.0027**
RCZ^3	-	-	-	-2.47E-07*

Note: **Significance level of 5%, *Significance level of 1%

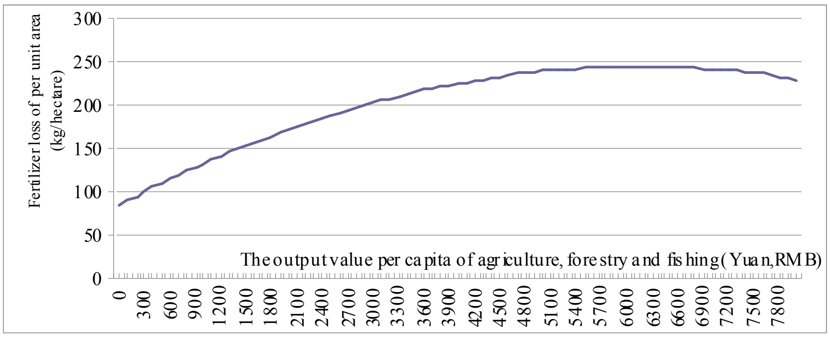

Fig. 1: Fitting curve of HFL.

tural economic growth and agricultural nonpoint source pollution in Inner Mongolia Autonomous Region according to Formula (2). Finally, unitary quadratic and cubic curve equations were used in the regression simulation. HFL, NYL, NMC, and XQP were used as independent variables and RCZ was used as dependent variable. Regression results are displayed in Table 3.

EKC verification of HFL and RCZ: Fig. 1 illustrates that RCZ can effectively explain the HFL in an "inverted U-shaped" curve. According to the figure, when RCZ is 6,150 RMB or more, HFL is at the turning point of EKC. Before RCZ increases to 6,150 RMB, HFL increases with economic growth, whereas environment quality deteriorates. After RCZ reaches 6,150 RMB, HFL decreases with economic growth. Given that the improvement of environment quality is on the right side of "inverted U-shaped" curve, when HFL decreases, the environment quality gradually increases. The irrational application of fertilizer in this autonomous region is a major source of agricultural nonpoint source pollution. Large HFL also aggravates water eutrophication, deteriorating the water quality and restricting the local sustainable development of economy and society.

EKC verification of NYL and RCZ: Fig. 2 coincides with the "inverted U-shaped" curve. Before RCZ reaches approximately 5,800 RMB, NYL increases with economic growth, whereas environment quality worsens. After RCZ reaches 5,800 RMB, NYL decreases with economic growth, whereas environment quality improves. The abusive and irrational application of pesticides in this region leave pesticides inside crops, which affect the agro-products' quality, causes harm to people's health, and cause air and water pollution as well as soil hardening.

EKC verification of NMC and RCZ: Fig. 3 exhibits an "inverted U-shaped" curve. According to the figure, before RCZ reaches approximately 6,300 RMB, NMC increases with economic growth, whereas environment quality deteriorates. When RCZ is more than 6,300 RMB, NMC decreases with economic growth, whereas environment quality improves. The residue mulching film can possibly lead to serious pollution because of the poor recovery of mulching film in this region. This pollution hazard is difficult to manage, becoming a significant threat to sustainable agricultural development.

EKC verification of XQP and RCZ: Fig. 4 reveals the "inverted U-shaped + U-shaped" curve, which tends to rise, fall, and then rise again. When RCZ is 2,050 RMB, which is the turning point of the "inverted U-shaped" curve, XQP decreases, whereas environment quality improves. When RCZ increases to 5,300 RMB, which is close to the turning point of the "U-shaped" curve, XQP increases annually (Fig. 4). The development of the livestock and poultry industry, which is the second largest industry in the region, is gaining mo-

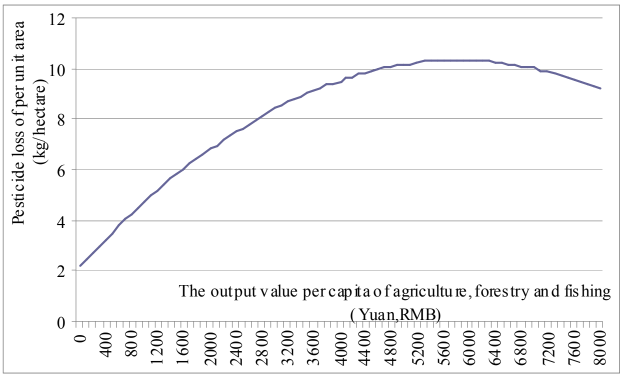

Fig. 2: Fitting curve of NYL.

mentum. As a result, serious pollution occurs and traditional livestock breeding remains delayed, producing a large amount of waste pollutants. Poor pollution control facilities and management also lead to livestock pollution, which is a prime cause of agricultural nonpoint source pollution.

POLICY SUGGESTIONS

To develop clean agriculture and use agricultural technology: In practice, administrative, legal, and economic means should be combined to promote the investigation and application of environment-friendly agricultural technology and limit the emergence of technologies that are harmful to the environment. While examining and approving new studies on agricultural techniques and their extensive application, their influence on the environment should be investigated. Administrative and legal measures should be implemented to increase public awareness of adverse techniques to restrict relevant studies and their applications, if necessary. The innovation of pro-environmental agricultural technology should be adopted in the national science and technology innovation system to improve the application of high and new technologies in agriculture. The market economy system should be used in management. Agricultural achievements in scientific research must also be emphasized to fully realize the potential of agricultural research resources and accelerate the productization of research achievements in every effort.

To encourage public participation and construct an agricultural nonpoint source pollution control system: The public possesses an important power that can be used in agricultural nonpoint source pollution control. In Inner Mongolia Autonomous Region, public participation is crucial to overcome the problems in pollution control. Public participation and monitoring should be encouraged in the horizontal and vertical control systems. Setting up an integrated coordinating organ and improving the cooperative capability are the keys to strengthen the control and management function. Management efficiency should be promoted and management width and depth should be expanded to establish a coordination mechanism involving all relevant sectors in the national overall planning.

To promote the monitoring of agricultural nonpoint source pollution and strengthen the management function: An information system covering release, statistical analysis, feedback, and scientific decision making concerning agricultural pollution should be created. This system can regularly inform all farmers about the situation of agricultural nonpoint source pollution; soil, water, and air quality; and control objectives to facilitate their participation in the control and management function. Presently, manual monitoring is difficult because of inadequate methods for monitoring nonpoint source pollution and its wide distribution, the spread of the pollution source, and the uncertain discharge intensity and time.

To establish a price variance system for agricultural means of production and increase punishment: Policies concerning the price variance system for agricultural means of production in different regions should be made to transfer additional agricultural means of production to the districts where agricultural nonpoint source pollution is not serious and instruct farmers how to apply fertilizer scientifi-

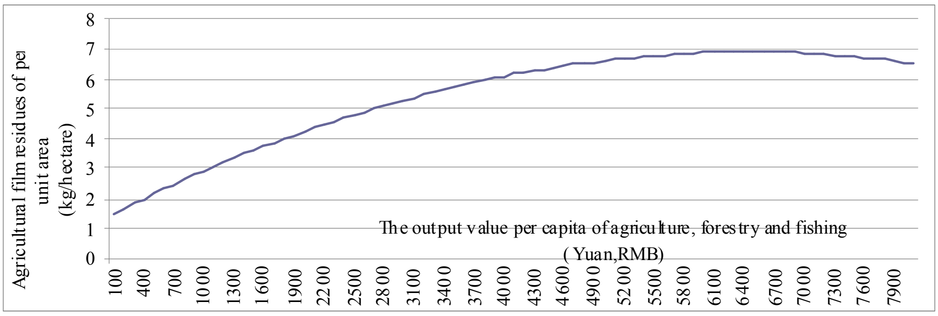

Fig. 3: Fitting curve of NMC.

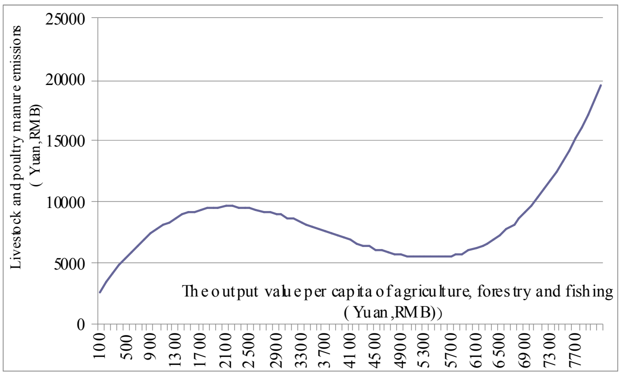

Fig. 4: Fitting curve of XQP.

cally. Fiscal subsidies should be offered to those who use organic fertilizer to improve farmers' enthusiasm toward using the fertilizer and reduce nonpoint source pollution. The innovation of agricultural scientific techniques should be given importance along with training for farmers to sharpen their awareness of environmental protection. The cost–return accounting system should be changed fundamentally, and the external environmental cost of applied fertilizer should be included in the agricultural cost accounting system. Different means, such as pollution charge right exchange and environmental taxes and fees, can be used to control the application of fertilizer to reduce the environmental problems caused by the abuse of fertilizer.

CONCLUSIONS

As an agricultural power, Inner Mongolia Autonomous Region has many causes of agricultural nonpoint source pollution, including large discharge of agricultural pollutants and poor control facilities and management. The analyses on four indices reveal that the "inverted U-shaped" EKC reflects how agricultural economic growth in this autonomous region correlates with HFL, NYL, and NMC. The "inverted U-shaped + U-shaped" EKC also indicates the relationship between agricultural economic growth and XQP. Therefore, the relationship between agricultural nonpoint source pollution and economic growth should be harmonized by developing clean agriculture, using agricultural technologies, encouraging public to participate in pollution control, establishing a control mechanism, improving the monitoring of nonpoint source pollution, intensifying the management function, designing a price variance system for agricultural means of production, and increasing penalties. Further in-depth analysis on agricultural economic growth and agricultural nonpoint source pollution in urban areas can facilitate the identification of the relationship between agricultural economic development and agricultural nonpoint source pollution in each district to provide feasible measures for pollution control policies.

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