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Intensity of China's Agricultural Environmental Regulation and Progress of Production Technology

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ABSTRACT

The increasingly serious agricultural pollution in China poses the question of whether the Chinese government can adopt environmental protection policies to achieve a "win-win" situation of promoting the progress of agricultural production technology and environmental regulation. This research adopts data envelopment analysis method to measure the progress index of production technology of 31 provinces in China to evaluate the effects of environmental regulations on the progress of agricultural production technology. Panel data method is also used to conduct an empirical test to explore the relationship of the intensity of agricultural environmental regulation, human capital, industrial structure, income level, and related technical factors with the progress of production technology. Results indicate that an increase in the intensity of environmental regulations causes first a decrease in the level of agricultural production technology in the central and eastern regions of China, which then gradually increases, thereby indicating a significant "U" curve trajectory and high statistical significance. By contrast, the western region did not form a statistically significant U-type relationship. In the process of promoting agricultural environmental protection policy, the Chinese government should devote more efforts to strengthening agricultural environmental protection and should attach greater importance to the methods and implementation of agricultural environmental regulations.

INTRODUCTION

China has achieved a remarkable 12-year continuous increase in grain production since 2003. This grain production not only feeds 19% of the population of the world, but also meets the needs for social and economic development. However, agriculture in China has paid a large environmental cost for this extensive high-intensity growth pattern. In 2010, the Ministry of Environmental Protection of China announced the results of the first national pollution source census, which showed that agricultural pollution emissions accounted for half of the pollution emissions in China. Agricultural wastewater pollution was severe, with chemical oxygen demand (COD) emissions in agricultural wastewater accounted for more than 47.9% of the national COD emissions in wastewater in 2013, while ammonia nitrogen emissions accounted for 31.72% of the total ammonia nitrogen emissions. This phenomenon had serious impacts on the sustainable development of agriculture in China.

From the perspective of economics, environment is public goods, and environment consumption should be non-competitive and nonexclusive. Thus, effective environmental protection requires the active implementation of environmental regulation policies by the government. The 2016 World Environmental Performance Index (EPI) published jointly by the Yale University and the Columbia University indicated that the EPI score of China was 65.1, which ranked only 109 among 180 countries and regions. The scores for wastewater treatment and nitrogen utilization efficiency associated with agricultural environment were 78 and 58, which ranked 55 and 139, respectively. These EPI scores and rankings reflect the weak environmental protection efforts of China to some extent. China has approximately 70.17 million poor people in 2016, and the majority of them live in rural areas. The Chinese government is committed to achieving a comparatively well-off life and eliminating poverty before 2020. This aim means that China should also consider economic growth, especially agricul-tural economic growth, when implementing environmental protection. This task is a considerable challenge for the Chinese government.

A worrying problem is that increasing the intensity of environmental regulations by the government is likely to increase the production costs of agricultural enterprises or farmers and reduce the market competitiveness of agricultural products (Gray 1987). Such worry is not groundless. Testa et al. (2011) investigated some industrial enterprises in the United States and found that environmental regulation policy reduced the total factor productivity by 10% to 30% by exerting direct and indirect effects on industrial enterprises. Rammer et al. (2011) also confirmed this view. However, the above-mentioned analysis was conducted from a static point of view, and conclusions were drawn under the premise that technology, resource allocation, and consumer demand remain unchanged. From a dynamic point of view, reasonable and rigorous environmental regulations can stimulate enterprises to take more innovative activities to optimize the allocation of resources and promote the progress of production technology, thereby resulting in the "innovation compensation" effect that can partially or even completely compensate for the increased enterprise costs caused by environmental protection and enhance the productivity and market competitiveness of enterprises (Porter et al. 1995). The groundbreaking view of Porter was called "Porter Hypothesis," and it systematically expounds on the possibility of achieving the win-win outcome of corporate competitiveness and environmental regulation. Lanoie et al. (2011) investigated the manufacturing enterprises in Quebec during the period of 1985-1944 and found that environmental regulations had negative impacts on productivity. In the long term, the intensity of environmental regulation improves productivity of enterprises, thereby confirming that a "U" relationship exists between environmental regulation level and technological innovation in time dimension.

The obtainment of a certain degree of "innovation compensation" is the key to achieving agricultural economic growth, competitiveness of agricultural enterprises (farmers), and environmental protection in China. However, this obtainment is dependent on whether environmental regulation can promote the progress of production technology for agricultural enterprises. The rapid development of agricul-tural economy and the deterioration of agro-ecological environment in China have led to the crucial discussion on the relationship between the environmental regulation and agricultural production in the country. Related studies have focused mainly on two aspects; one is verifying the impact of agricultural environmental regulation on economic growth or agricultural productivity (Li et al. 2009, Ge et al. 2011, Li et al. 2011, Zhang et al. 2009), and the other is exploring the impacts of the environmental regulation in China on pollution-control technological innovation and technical efficiency (Peng et al. 2012, Hu et al. 2015, Yue et al. 2013). However, considering that the above-mentioned studies adopted different methods or selected different indicators, their final conclusions also differed. Most findings suggested that environmental regulation can exert positive impacts on agricultural productivity, economic growth, and the progress of production technology. This conclusion differs from the "Porter Hypothesis," which argues that agricultural enterprises will increase costs by following environmental regulations in the short term. They are likely to reduce innovative inputs for production to maximize benefits, thereby resulting in the situation in which environmental regulations exert negative impacts on the progress of production technology. In the long term, the reasonable and rigorous environmental regulations due to innovation compensation will encourage enterprises to strengthen the recycling of resources, optimize potential innovation opportunities, and further stimulate enterprises to carry out technological innovation and organizational innovation, thereby enhancing the competitiveness of enterprises and leading to the situation in which environmental regulations exert positive impacts on the progress of production technology. The combined effect of these two impacts finally forms the positive impact in the above-mentioned research.

Existing studies suggest that the need to verify the impact of the environmental regulations in China on the progress of production technology of agricultural enterprises and analyse the impact that intensity of environmental regulation has on the progress of production technology. However, few studies have focused on these topics, although these issues are essential to the effective implementation of environmental pollution control and environmental protection in the agricultural sector of China. The agricultural growth model of China should be investigated from the perspective of scientific development.

In this view, an empirical model and data description of environmental regulation and the progress of production technology are constructed in the second part. An empirical analysis on the impact of environmental regulations on the progress of production technology is made in the third part. Finally, conclusions are presented in the fourth part.

MATERIALS AND METHODS

This study takes each province as a decision-making unit, adopts the data envelopment analysis-based Malmquist productivity index method, examines the production technological progress index, analyses the effect of environmental regulation on each province, and explores whether a U-type relationship exists in terms of time and intensity.

Production Technological Progress Index

The input of each decision-making unit is assumed to be $x^t = (K_t, L_t)'$ in the period of t, where K and L are the capital and the labour input, respectively. y^t is the output. $x^{t+1} = (K_{t+1}, L_{t+1})'$ and $y^{t+1}$are the input and output of the decision-making unit in the period t+1, respectively. According to the method of Sten Malmquist (Malmquist 1953), the Malmquist index (total factor productivity change) of the decision-making unit at t period can be defined as

$$M^t(x^t, y^t, x^{t+1}, y^{t+1}) = \frac{D^t(x^{t+1}, y^{t+1})}{D^t(x^t, y^t)} \qquad \dots (1)$$

The Malmquist index for the t+1 period is

$$M^{t+1}(x^t, y^t, x^{t+1}, y^{t+1}) = \frac{D^{t+1}(x^{t+1}, y^{t+1})}{D^{t+1}(x^t, y^t)} \quad \text{... (2)}$$

The Malmquist productivity index that reflects the productivity change from period t to period t+1 is

$$M^{t+1}(x^t, y^t, x^{t+1}, y^{t+1}) = \left[\frac{D^t(x^{t+1}, y^{t+1})}{D^t(x^t, y^t)} \times \frac{D^{t+1}(x^{t+1}, y^{t+1})}{D^{t+1}(x^t, y^t)} \right]^{1/2} \quad \text{...(3)}$$

Drawing from the practice of Färe (Färe & Grosskopf 1997), Formula (3) can be decomposed further into the product of two parts and modified into the following formula:

$$M^{t+1}(x^t, y^t, x^{t+1}, y^{t+1}) = \left[\frac{D^{t+1}(x^{t+1}, y^{t+1})}{D^t(x^t, y^t)} \right] \cdot$$

$$\left[\frac{D^t(x^{t+1}, y^{t+1})}{D^{t+1}(x^{t+1}, y^{t+1})} \times \frac{D^t(x^t, y^t)}{D^{t+1}(x^t, y^t)} \right]^{1/2} \quad \text{...(4)}$$

Where the former refers to technical efficiency index (efficiency change index, EFFCH), and the latter refers to the production technological progress index (technical change index, TECH). Therefore, the Malmquist productivity index is equal to the product of technological efficiency and technological progress. Technological progress is the progress level of production technology in each province that will be examined in the current study.

Establishment of Environmental Regulation Model

Based on the previous analysis and research results, this study adopts the environmental Kuznets curve, which is used for analysing economic growth and environmental pollution, and constructs the following empirical model of agricultural production technological progress and environmental regulation:

$$TECH_{it} = C + \eta_1 ER_{it} + \eta_2 ER_{it}^{\ 2} + \eta_3 HR_{it} + \eta_4 DI_{\text{it}} +$$

$$\eta_5 IP_{it} + \eta_6 EE_{it} + \eta_7 IA_{it} + \eta_8 GP_{it} + \varepsilon_{it} \quad \text{...(5)}$$

Where i refers to the i^{th} province; t is the year; TECH is the production technological progress index of the agricultural sector; ER is the intensity of environmental regulation; HR is the human capital variable; DI is the income level; IP is the industrial structure variable; EE refers to the level of knowledge capital input; LA and GP represent the level of agricultural planting structure and the level of water technology, respectively; C is a constant term; η is the parameter to be estimated; and ε is a random error item. If the progress of agricultural production technology changes with time and intensity of environmental regulation and exhibits a U-type trend, then η_1 should be a negative value, whereas η_2 is a positive value.

Data Explanation

The sample data used in this study are the panel data prepared by agricultural departments of 31 provinces in China from 2011 to 2014. The data of this period are selected because the Chinese statistical department has been publishing data indicators of agricultural pollution since 2011. Data used in the empirical study are sorted and calculated according to the China Statistical Yearbook and local statistical yearbooks from 2011 to 2015.

The approach of Yu et al. (2012) is adopted to calculate the production technological progress index of agricultural departments. The added value of the primary industry is selected as output variable and is adjusted according to the constant price in 2009. Crop acreage (hm^2) and number of employees (people) in the primary industry are set as land input and labour input, respectively. Capital input is represented by the total power of agricultural machinery (10^4 Kw) and amount of fertilizer application (10^4 tons).

Obtaining data on the intensity of environmental regulations can be difficult and data quality is poor. Thus, carrying out effective, relevant empirical research is difficult. The present research follows the treatment method (Zhang et al. 2011) and uses the proportion of agricultural-related chemical oxygen demand (COD) emissions in wastewater over agricultural added value as measurement index of environmental regulation intensity (ton/ten thousand Yuan). Such treatment is adopted for two reasons: 1. Current agricultural non-point source pollution in China comes mainly from the application of pesticides and fertilizers. Pollutants are discharged through water and agricultural COD emission in the waste water can reflect, to some extent, the degree of agricultural environment pollution. 2. The Chinese government has limited the use of pesticides and fertilizers by issuing various policies to ensure the quality and safety of agricultural products and to reduce pollution of soil and water sources (Song et al. 2013). The changing ratio of agricultural chemical oxygen demand emissions over agricultural added value can also reflect the implementation status of the environmental regulation policy.

The following control variables are selected. Human capital variable (HR_{it}) is represented by the number of students at vocational schools (people) per ten thousand people. Income level (DI_{it}) is represented by disposable income per capita (yuan). Industrial structure variable (IP_{it}) is measured by the proportion of the added value of the primary industry over regional gross production value (%). Knowledge capital input (EE_{it}) is measured by the expenditure per capita on educational, cultural and recreational goods and services (Yuan). The level of agricultural planting structure (LA_{it}) is represented by the ratio of grain planting area over the total planting area of corps (%). The level of agricultural water technology (GP_{it}) is measured by the proportion of effective irrigation area over the total planting area of corps (%).

RESULTS

Total Factor Productivity and Production Technological Progress of China's Agricultural Sector

To analyse the total factor productivity, technological efficiency, and production technological progress of China's agricultural sector, this research divides China into three regions: eastern, central and western regions. The provinces of each region are given in Table 1. From a national point of view, the total factor productivity of China's agriculture had an average growth of 9.6% from 2011 to 2014, which can be attributed mainly to the improvement of production technology by 8.9%. Except for Shanghai, the total factor productivity of agriculture in 31 provinces is greater than 1, indicating that these provinces achieved growth in the total factor productivity. The total factor productivity of agriculture in Shanghai is less than 1 because agriculture has a small proportion in Shanghai. Cultivated land in Shanghai is only 2 million mu (1 hectare = 15 mu) and the city has limited space for agricultural development. From the perspective of space, the total factor productivity of the central and western regions is 1.103231 and 1.097022, respectively, which is higher than 1.088247 of the eastern region. These numbers are related closely to the development strategy of China's midwest.

From the perspective of technical efficiency and production technological progress, the technical efficiency of the eastern region is less than 1, whereas that of the central and western regions is greater than 1, indicating that growth in the total factor productivity of the eastern region is caused mainly by the production technological progress. China's eastern region has a highly developed economy and high agricultural technical efficiency but has limited space for improvement, which is confirmed by the production technological progress of the eastern region being more advanced than that of middle and western regions. The production technological progress level of the three regions is higher than 1 (1.091856, 1.09110 and 1.085128, respectively). These numbers indicate that the level of agricultural production technological progress in various regions of China is growing rapidly.

Analysis on the Effect of the Intensity of Environmental Regulations on Agricultural Production Technological Progress

This paper measures the panel data model constructed by Formula 5. The Hausman test (Hausman 1978) results support the selection of the fixed effect model. The treatment results of stochastic effect model are no longer presented due to limited space. The estimated impacts of the intensity of China's environmental regulations on the progress of agricultural production technology are depicted in Table 2.

The results of national estimates indicate that the intensity of environmental regulation has a negative one-order term coefficient and a positive quadratic term coefficient and is statistically significant. This result is consistent with the expectation of this study. The intensity of environmental regulations first has a negative impact on the progress of agricultural production technology and then a positive impact on the progress of agricultural production technology when the intensity increases, which is consistent with the U-type relationship. Environmental regulations have a similar impact on the progress of agricultural production technology in the eastern and central regions, which is consistent with the results of the national estimates. The results from the western region are different because the intensity of environmental regulations has a negative one-order term coefficient and positive quadratic term coefficient. However, the quadratic term coefficient does not have significant statistical significance, and its change trend does not form a significant U curve. This result may be caused by the western region not having a high level of economic development and hence, does not experience high pressure for environmental protection. Another argument is that the result may be caused by the poor implementation of environmental regulations. The U-type relationship between the intensity of environmental regulation and the progress of agricultural production technology is further explained. When the government strengthens the intensity of environmental regulations, agricultural operators respond to this policy by reducing the application of pesticides and chemical fertilizers, especially high-concentration agricultural inputs, thereby reducing agricultural income and production technology. However, such operating results do not meet the requirements and interests of operators in the long run. Agricultural operators achieve the win-win situation of environmental regulations and agricultural income by taking some measures, such as improving the planting structure, scientific level of planting technology, and operational management level.

The economic level, economic structure, and agricultural industrial structure differ significantly from region to region in China. Thus, significant differences may be observed in the control variables in terms of the progress of production technology in each region. From a nationwide

Table 1: TFP, EFFCH and TECH of agriculture in 31 provinces of China from 2011 to 2014.

	Region	TFP	EFFCH	TECH
Eastern regions	Beijing	1.11798	1.017662	1.100551
	Tianjin	1.09828	1.003985	1.097503
	Hebei	1.088278	0.993457	1.095788
	Liaoning	1.092079	1	1.092079
	Shanghai	0.972224	0.919605	1.053375
	Jiangsu	1.12915	1.040476	1.084967
	Zhejiang	1.109201	1.010592	1.096314
	Fujian	1.100737	1.00211	1.099834
	Shandong	1.087375	1	1.087375
	Guangdong	1.072968	0.976284	1.100187
	Hainan	1.102449	1	1.102449
	Average value	1.088247	0.996743	1.091856
Central regions	Shanxi	1.074371	0.975885	1.102087
	Jilin	1.098062	1.002627	1.095829
	Heilongjiang	1.192814	1.123967	1.065526
	Anhui	1.120044	1.023636	1.095005
	Jiangxi	1.107948	1.012524	1.096095
	Henan	1.074808	0.986228	1.090703
	Hubei	1.090858	1.000425	1.089917
	Hunan	1.066946	0.974446	1.093675
	Average value	1.103231	1.012467	1.091105
Western regions	Inner Mongolia	1.100264	1.009849	1.08951
	Guangxi	1.084815	0.982697	1.10269
	Chongqing	1.08462	1	1.08462
	Sichuan	1.07007	0.986762	1.083322
	Guizhou	1.180248	1.089553	1.084415
	Yunnan	1.132927	1.04508	1.083158
	Tibet	1.06304	0.969088	1.100187
	Shanxi	1.122674	1.027139	1.092072
	Gansu	1.100418	1.004226	1.097414
	Qinghai	1.148476	1.051904	1.093265
	Ningxia	1.024707	0.973387	1.055412
	Xinjiang	1.052011	1.001894	1.055473
	Average value	1.097022	1.011798	1.085128
China	Average value	1.095511	1.006629	1.089058

Table 2: Results of the model estimates on the impact of the intensity of environmental regulation on the progress of agricultural production technology.

Variable	China	Eastern regions	Central regions	Western regions
C	1.8023***(4.74)	1.2831***(9.06)	1.30879**(2.09)	1.95283***(2.98)
ER	-18.824***(-8.65)	-19.54***(-5.63)	-15.739***(-3.89)	-9.512**(-2.45)
ER^2	111.418***(4.63)	95.9653***(4.35)	67.973**(3.69)	13.101(0.42)
HR	0.0000109***(3.61)	0.0005267(0.18)	0.0016207***(3.61)	-0.0014294(-0.55)
DI	3.38e-07**(2.56)	3.25e-06(1.42)	3.12e-07*(1.83)	0.0000592**(2.60)
IP	0.0237**(1.98)	0.0043891(0.29)	0.0257235***(2.53)	0.0232091**(1.80)
EE	1.75e-07(1.34)	0.0000959(1.06)	0.0002659**(2.22)	0.0002696**(2.26)
LA	-0.4431945(-0.77)	-0.4752124(1.14)	2.225352(1.16)	0.6614001***(4.46)
GP	0.0857864(0.34)	0.4596845(1.06)	0.4482389***(2.50)	0.3184415***(3.89)
A-R^2	0.6323	0.4985	0.7079	0.7744
F value	25.72	14.01	29.28	37.69
Observed value	124	44	32	48

Notes: *, ** and *** represent 10%, 5% and 1% significance levels of statistics respectively. The number in parentheses is the standard deviation.

perspective, human capital, income level, and agricultural industrial structure have a significant positive impact on the progress of production technology, and Yin et al. (2014) confirms this conclusion. The influence of control variables on the eastern region is insignificant because agriculture in the region comprise only a small proportion. The eastern region progresses well in agricultural production technology and has reached stability.

Other variables with the exception of agricultural planting structure exert a significant impact on the progress of agricultural production technology in the central region. That is, agriculture of central region is at a fast and high-quality development stage, and the factors yielded good results in promoting the progress of agricultural production technology. Human capital has a negative impact on the agricultural production technological progress of the western region, which is different from other regions. However, the difference is insignificant, but it is the fact that many college students are located in the western region and few would stay in the region to improve the agricultural production technological progress of the western region effectively. Knowledge capital input, agricultural planting structure, and water technology level all have significantly positive impact, indicating that the western region should improve agricultural production technology by enhancing education investment and infrastructure construction and promoting the comprehensive development of agriculture.

CONCLUSIONS

Panel data on agriculture in 31 provinces of China from 2011 to 2014 was used to explore the relationship between the intensity of agricultural environmental regulation and the progress of production technology. The intensity of environmental regulation and progress of agricultural production technology are measured using various control variables, such as human capital, income level, industrial structure, knowledge capital input, agricultural planting structure, and water technology. The following conclusions can be drawn.

1. The total factor productivity of agriculture in the central and western regions of China is higher than that in the eastern region. Thus, China's agricultural development is closely related to China's midwest development strategy. The agricultural production technology levels in the eastern, central, and western regions of China are higher than 1, indicating that the level of agricultural technological progress in various regions of China is still growing.
2. This study proves Porter's U trajectory of change that environmental regulation brings to technological innovation in the dimension of time and identifies that intensity of regulation has such a development trend. That is, environmental regulations may have a negative impact on the progress of agricultural production technology in the short term, but the high intensity of environmental regulation will promote the progress of production technology in the long term.
3. A U-type of relationship between the intensity of agricultural environmental regulation and the progress of production technology all over China exists, particularly in the eastern and central regions. The results also indicate that the relationship is not statistically significant for the western region.

This research reveals certain policy connotation. The Chinese government should exert more effort in ensuring agricultural environment protection, improving the quality of agricultural products, and reducing pollution emissions. China should develop relevant policies, strengthen infrastructure construction, encourage agricultural operators to improve production and management, improve its technological level, and promote agricultural efficiency. When promoting the implementation of agricultural environment protection policy, China should focus primarily on the intensity, manner and implementation of environmental protection, take innovative policy measures, and implement environmental protection according to the development of various regions to prevent the U-type relationship between environmental regulations and the progress of agricultural production technology from occurring. Reaching the inflection point quickly and effectively is difficult. Hence, China should pay attention to the implementation of differentiated environmental protection policies, ensure that the inflection point of the U curve is passed quickly, and that the win-win situation of environmental protection and agricultural development can be achieved.

However, with the limited data, this research does not classify Chinese agricultural sectors further into high and low pollution-intensive industries, which is the direction of our future research.

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