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Research Article

The Impact of Environmental Regulation on Agricultural Ecological Efficiency from the Perspective of High-Quality Agricultural Development: Based on Evidence from 30 Provinces in China

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Based on the data of 30 provinces in China, the super-efficiency EBM model is used to calculate the agricultural ecological efficiency in China, and analyze the impact of different environmental regulations on the agricultural ecological efficiency. The results show that: China's agricultural ecological efficiency is not optimal. Specifically, the main grain production areas and grain balance areas have not reached the optimal efficiency, and the main grain sales areas have basically reached the optimal efficiency. In addition, among the influencing factors, the influence degree of different environmental regulations is well distinguished, which is the focus of this paper. We can find that command control environmental regulation and market incentive environmental regulation have a significant positive effect on different regions. Among them, market incentive environmental regulation has a significant positive impact on the agricultural ecological efficiency of the whole country and the grain balance areas. Command controlled environmental regulation has a significant positive impact on the agricultural ecological efficiency of the whole country and the main grain producing areas. So, it is necessary to formulate environmental policies according to the actual needs of development.

1. Introduction

As of 2022, my country's grain output has achieved a "nineteenth consecutive harvest," which has remained above 1.3 trillion kilograms. With the harvest of grain, we also need to pay attention to the worsening ecological environment. In 2015, the Ministry of Agriculture's "Implementation Opinions on Fighting the Battle for the Prevention and Control of Agricultural Non-point Source Pollution" clearly pointed out that it needs to be strictly controlled. In the same year, the Action Plan for Zero Growth of Fertilizer and Pesticide Use by 2020 was promulgated. This marks the official launch of the reduction and efficiency increase action. Relevant statistics show that by the end of 2020, fertilizer utilization rate of three grain crops in China will reach 40.2%, and the utilization rate of pesticides will reach 40.6%, basically reaching the utilization rate of 40%–60% of pesticides and chemical fertilizers in the world. In 2019, the intensity of chemical fertilizer application in my country dropped to 325.7 $kg\,hm^{-2}$, which is still far above the safe upper limit of chemical fertilizer application; the intensity of pesticide use dropped to 8.8 $kg\,hm^{-2}$, which is also higher than the world average level, still stands out. In 2022, the Central No. 1 document also pointed out that we need to continue to promote the reduction of volume and efficiency. At this stage, the policy of reducing the amount and increasing efficiency has achieved certain results in controlling the application amount of agricultural production factors, and the grain output has not decreased with the reduction of chemical fertilizers and pesticides. This policy has a positive impact on the green development of agriculture.

The green development of agriculture is based on protecting the natural ecological environment, achieving high-quality agricultural growth as the condition, and improving and improving people's life satisfaction as the ultimate goal [1]. Realizing agricultural modernization is an important part of agricultural development, it is necessary to reduce resource consumption, reduce environmental damage. Agricultural ecological efficiency is an important part of analyzing the green sustainable development of agriculture. Environmental regulation is an important policy tool to deal with social problems. There are many types of environmental regulation, different types for different situations, but the fundamental purpose is to maintain the ecological environment. In terms of environmental pollution control, Government promulgation of policies and regulations is one of the main tools used by the government. This kind of environmental regulation is authoritative and mandatory. Short-term command control environmental regulation has good effects, but long-term command control environmental regulation may have negative effects. Analysis of environmental regulation is of momentous significance for solving practical problems. Therefore, this study chose two kinds of environmental regulations as the research focus, and analyzed their impact on agricultural ecological efficiency.

For the research on agricultural ecological efficiency, different scholars have expounded the relevant content of agricultural ecological efficiency from different perspectives. From the perspective of research methods, many scholars mainly use data envelopment analysis (DEA) to measure agricultural ecological efficiency. This method has been widely used in efficiency measurement [2]. Scholars are relatively mature in the application of DEA models, and different types of DEA methods have emerged to meet the research needs. It mainly includes SBM model, super-efficiency SBM model, SSBM-ESDA model [3], network DEA model [4], and so on. In the scope of study, it mainly focuses on the measurement of agricultural ecological efficiency in the macro fields and medium fields. Ji Xueqiang et al. pointed out that there is a large gap between the leading provinces and the backward provinces in agricultural ecological efficiency [5]. In the medium fields, Liang Yaowen et al. calculated the agricultural ecological efficiency in the Bohai Rim region and found that although the overall level of agricultural ecological efficiency in this region was low, it showed a gradual upward trend with large differences between regions [6]. Liu Peng et al. pointed out that the agricultural ecological efficiency of the main grain-producing areas has not reached an effective state as a whole [7]. From the research of influencing factors, many scholars have analyzed the influencing factors of agricultural ecological efficiency from different perspectives. Wang Chenxuan et al. pointed out that the scale of agricultural science and technology investment has a significant spillover effect on agricultural ecological efficiency [8]. Hu Pingbo et al. also pointed out that the integration of agriculture and tourism under the support of the government is beneficial to improve the agricultural ecological efficiency, especially when the level of integration is high, the promotion effect will be enhanced [9]. Hou Mengyang et al. pointed out that the transfer of rural labor force to the ecological efficiency of grain production has a significant role in promoting [10]. Li Lu et al. pointed out that the aging of rural population has a negative impact on agricultural eco-efficiency. This kind of negative influence decreases first, then rises after reaching a certain degree, namely "U" type change [11]. Shang Jie et al. pointed out that the development of urbanization can promote the improvement of agricultural ecological efficiency as a whole. Among them, the per capita disposable income of urban residents and urban economic density has a positive impact on agricultural ecological efficiency. Area negatively affects agricultural ecological efficiency [12]. Huang et al. expressed the impact of environmental regulation intensity analysis on agricultural ecological efficiency from two aspects: order regulation and publicity regulation [13]. Fang Yongli pointed out that there are obvious spatial differences in the level of agricultural ecological efficiency among provinces in China, and the development and change trends are different. The main reasons for the loss of efficiency are redundant input of factors and excessive undesired output [14]. Among them, plastic film, water resources, and fertilizer input elements have the highest degree of redundancy [15]. In addition, the low skills of agricultural laborers and the inefficiency of land use are also causes of efficiency losses [16].

These documents show that there are abundant results in the measurement of agricultural ecological efficiency, and scholars are relatively mature in their research on the influencing factors of agricultural ecological efficiency. However, there is still a lack of research from the perspective of environmental regulation. On the one hand, different scholars have different cognitive perspectives on environmental regulation, this leads to differences in the specific selection of variables and the results obtained are also different; on the other hand, there is a lack of analysis of the impact mechanism of phased policy of reducing quantity and increasing efficiency. This paper considers the use of the super-efficiency EBM model to measure agricultural ecological efficiency. It can clearly distinguish the regions with an efficiency value of 1 for effective comparison. Taking the policy of reduction and efficiency increase as the variable of control command type environmental regulation, combined with the market incentive type environmental regulation, this paper examines the impact on agricultural ecological efficiency, and judges whether the current environmental regulation has any effect on agricultural ecological efficiency, in order to provide policy basis for how to control pollution and promote the green and sustainable development of agriculture in China in the next step.

2. Materials and Methods

2.1. Research Methods. DEA model. The traditional DEA models are divided into two types, one is the radial BCC model and the CCR model, the other is the SBM model. Since the input-output variables in the traditional DEA must increase or decrease in equal proportions, the changes in the slack variables cannot be calculated. Although the SBM model based on undesired output can incorporate slack variables into the model, it is difficult to reflect the situation between actual situation and best case scenario, and there is also a certain defect. Therefore, in order to improve the defects of the traditional DEA, Tone et al. proposed the EBM model, which combined the radial and non-radial distance functions. The model can clearly calculate the gap between actual situation and best case scenario, and accurately calculate the relative efficiency of the research target. Usually, the maximum efficiency value measured by the traditional DEA is 1, but when the number of research objects increases, and when there are multiple research objects with an efficiency value of 1, we cannot differentiate effectively. The super-efficiency model can be greater than 1, which is an effective tool to realize discrimination [17]. Just like the methods used by other researchers in the previous article, SBM model cannot distinguish multiple research objects with efficiency of 1. The super efficiency SBM model is difficult to embody the difference between the actual value and the best value; SSBM-ESDA is a spatial difference analysis; Network DEA is to calculate the efficiency by stages according to the different stages of the research object. Combined with the above analysis, this paper mainly selects the EBM model to measure the agricultural ecological efficiency, and compare regional differences, the specific formula is as follows:

$$\gamma = \min \frac{\theta - \varepsilon_x \sum_{i=1}^{m} \omega_i \overline{x}_i / x_{ik}}{\eta + \varepsilon_y \sum_{r=1}^{s} \omega_r^{+} \overline{y}^{+} / y_{rk} + \varepsilon_b \sum_{p=1}^{q} \omega_p^{b-} \overline{y}^{b-} / b_{pk}},$$

$$\sum_{j=1}^{n} x_{ij}\lambda_j + \overline{x}_i = \theta x_{ik}, \quad i = 1, \ldots, m,$$

$$\sum_{j=1}^{n} y_{rj}\lambda_j - \overline{y}_r^{+} = \theta y_{rk}, \quad r = 1, \ldots, s, \tag{1}$$

$$\sum_{j=1}^{n} b_{pj}\lambda_j + \overline{y}_p^{b-} = \eta b_{pk}, \quad i = 1, \ldots, q,$$

$$\lambda_j \geq 0, \quad \overline{x}_i, \overline{y}_r^{+}, \overline{y}_p^{b-} \geq 0,$$

where γ represents the value of the agricultural ecological efficiency. The input of agricultural production in decision-making unit k, the expected output of agricultural production, and the undesired output of agricultural production are x_{ik}, y_{rk}, and b_{pk}, respectively. The slack values of agricultural production input, agricultural production expected output, and agricultural production undesired output are $\overline{x}_i$, $\overline{y}_r^{+}$, and $\overline{y}_p^{b-}$, respectively. ω_i, ω_r^{+}, and ω_p^{b-} are the weights of agricultural production input, agricultural production expected output, and agricultural production undesired output. εx, εy, and εb are the key parameters of agricultural production input, expected output of agricultural production, and undesired output of agricultural production, $\varepsilon \in [0, 1]$.

Panel Tobit Model. The agricultural ecological efficiency values measured by the EBM model are all greater than 0, which are restricted dependent variables. The value of agricultural ecological efficiency is discontinuous, and there is no situation without agricultural ecological efficiency, so Tobit model is suitable for this study. Whether it is better to use a FE Tobit model or a RE Tobit model, existing studies have not reached a consensus. Fixed-effect Tobit models measure panel data, and the results are often inconsistent or biased [18]. This paper adopts the random-effect Tobit model to analyze the influencing factors hence. The specific formula is as follows:

$$Y_{it} = \alpha + \beta_1 ER_{it} + \beta_2\, \mathrm{POLICY}_{it} + \lambda CV_{it} + \varepsilon_{it}. \tag{2}$$

Among them, Y_{it} represents agricultural ecological efficiency, ER_{it} represents the intensity of environmental regulation, POLICY_{it} represents the policy of reducing quantity and increasing efficiency, $\mathrm{CV}_{\mathrm{it}}$ represents other control variables, and εit represents the random error term.

2.2. Data Source and Processing. From the agricultural perspective in a narrow sense, combined with agricultural practice, and referring to the research results of previous scholars, this paper selects relevant input-output indicators. Table 1 shows the details.

We select agricultural practitioners, crop-sown area, fertilizer application amount, plastic film usage amount, pesticide usage amount, agricultural machinery power, and effective irrigation area as input indicators; the total agricultural output is selected as the expected output index; the amount of fertilizer pollution, pesticide residue, and plastic film residue is selected as the undesired output index. Among them, the official data on agricultural employees do not provide direct statistical data, so this article refers to the processing method of relevant scholars, obtain the number of agricultural employees through calculation; in order to eliminate the objective influence of some indicators such as prices, output indicator adjusts the data to the output value at constant prices in 2007. In the undesired output indicators, combined with the practices of Lai, Shi, and Wu [19–21] and other scholars, the amount of fertilizer pollution, pesticide residues, and plastic film residues were measured. The pesticide residue rate was set to 50%, and the plastic film residue rate was set to 10%; the fertilizer pollutants are mainly nitrogen and phosphorus emissions. Calculated according to the pure chemical composition of chemical fertilizers: The TN pollution coefficients of nitrogen fertilizer, phosphorus fertilizer, and compound fertilizer (n, P, K ratio of 1: 1:1) were 1, 0, and 0.33, respectively. TP pollution coefficients were 0, 0.44, and 0.15, respectively. Therefore, the specific expression is: nitrogen (phosphorus) fertilizer production amount = chemical fertilizer application amount ∗ loss rate ∗ pollution production coefficient, compound fertilizer pollution production amount = chemical fertilizer application amount ∗ loss rate ∗ nitrogen (phosphorus) pollution production coefficient ∗ (1/3). Table 1 shows the basic data of 30 provinces in China within the research range. We can see that the gap between the values of various indicators has increased. We can see that there is a big gap between regions in each indicator. In particular, from the perspective of mean, maximum and minimum values, the distance between mean and maximum value is larger, which indicates that, on the whole, the index values of most of the 30 provinces in China are relatively low,

Table 1: Descriptive statistics of input-output indicators of agricultural ecological efficiency.

	Variable	Observed value	Average value	Standard error	Minimum	Maximum
Input indicators	Agricultural employees (10,000 people)	420	506.2	427.0	11.44	2226
	Crop sown area (square kilometers)	420	54285	37070	886	149101
	Fertilizer application amount (10,000 tons)	420	187.8	143.7	5.500	716.1
	Plastic film usage (10,000 tons)	420	4.360	4.120	0.0400	24.27
	Pesticide usage (10,000 tons)	420	5.560	4.240	0.120	17.35
	Effective irrigation area (square kilometers)	420	21211	15977	1092	61776
	Total power of agricultural machinery (10,000 kilowatts)	420	3240	2870	94	13353
Output indicators	Gross agricultural output value (100 million yuan)	420	1580	1219	44	5579
Unexpected output indicators	Fertilizer pollution production (10,000 tons)	420	17.64	14.75	0.310	65.56
	Pesticide residues (10,000 tons)	420	2.780	2.120	0.0600	8.670
	Residual amount of plastic film (10,000 tons)	420	0.560	0.430	0.0100	2.380

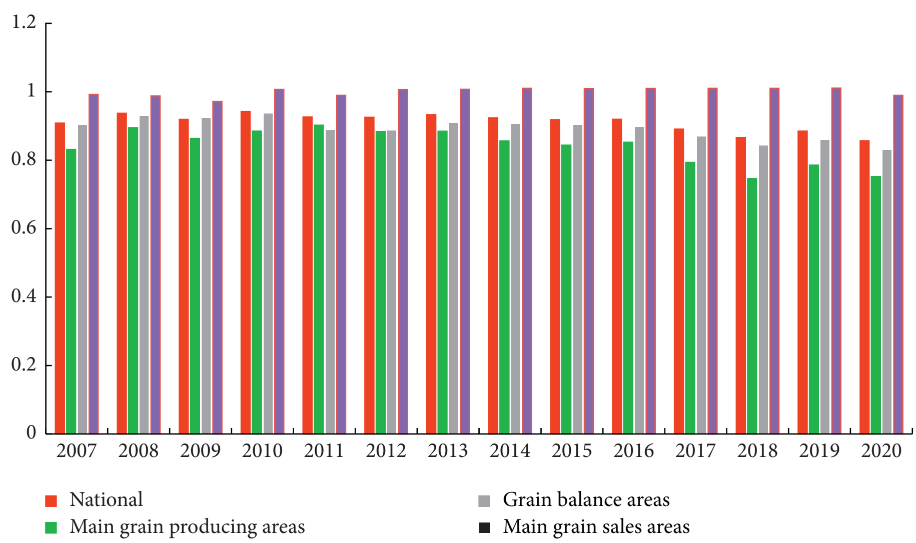

Figure 1: Changes in the agricultural ecological efficiency by region from 2007 to 2020.

and the provinces with large index values occupy a minority. Therefore, the division and specific analysis of 30 provinces in China can better reflect the changes in agricultural ecological efficiency and help to put forward targeted policies.

3. Agricultural Ecoefficiency Calculation Results

MAXDEA was mainly used for calculation in this study, and Figure 1 shows the details. The agricultural ecological efficiency of the whole country and each region was calculated by software. In 2001, China implemented the reform of the grain circulation system. Based on the overall characteristics of grain production and consumption in each province, and taking into account the differences in resource endowments and the historical traditions of grain production, 31 provinces (including Tibet) were divided into major selling areas, production areas, and marketing balance areas. On the whole, China's agricultural ecological efficiency has not reached the optimal level. Due to the traditional agricultural production mode in China in the past, the agricultural production efficiency has been improved, but the continuous production mode of high input and high consumption has reduced the growth rate of efficiency, and agricultural environmental problems have become increasingly apparent. China has a vast territory, and the agricultural production level of each province varies greatly, which leads to the limited improvement of China's overall agricultural ecological efficiency. The agricultural ecological efficiency is also different in different areas, among which only the main food sales area has achieved the best efficiency. Grain main sales areas > grain balance areas > grain production areas. However, all areas show a fluctuating downward trend. In recent years, the increasing frequency of extreme weather has brought serious challenges to agricultural production. The

Table 2: Average value of agricultural ecological efficiency in 30 provinces in China from 2007 to 2020.

Regional classification	Areas	Efficiency value	Regional classification	Areas	Efficiency value
Main grain production areas	Anhui	0.67	Grain balance areas	Guizhou	0.94
	Hebei	0.81		Ningxia	0.82
	Henan	0.84		Qinghai	1.02
	Heilongjiang	1.02		Shanxi	0.73
	Hubei	0.82		Shǎnxi	1.03
	Hunan	0.78		Xinjiang	1.02
	Jilin	0.67		Yunnan	0.65
	Jiangsu	1.00		Chongqing	0.98
	Jiangxi	0.73	Grain main sales areas	Beijing	1.02
	Liaoning	0.87		Fujian	1.01
	Inner Mongolia	0.70		Guangdong	1.02
	Shandong	0.83		Hainan	1.03
	Sichuan	0.99		Shanghai	1.00
	Gansu	0.77		Tianjin	0.99
	Guangxi	0.98		Zhejiang	0.98

weak ability of agricultural production to withstand natural disasters leads to farmers' increasing inputs to ensure grain output. Especially since the outbreak of COVID-19, the urgency of production materials transportation and the decrease of production conditions will urge farmers to increase production inputs, which indirectly leads to the reduction of efficiency, so it is necessary to take effective measures to adjust production and management.

At the same time, we also obtained the agricultural ecological efficiency values of all provinces, and Table 2 shows the details. There are also obvious gaps between provinces. In this paper, agricultural ecological efficiency is divided into three levels, including high efficiency, medium efficiency, and low efficiency. High efficiency refers to achieving the best efficiency, that is, the research object is at the forefront of agricultural production, and the value of agricultural ecological efficiency is greater than or equal to 1; Efficiency refers to inefficiency research objects, and there is efficiency loss. Specifically, the value of agricultural ecological efficiency of medium-efficiency groups is between 0.8 and 1, and the value of agricultural ecological efficiency in the low-efficiency group is less than 0.8 [14]. On the whole, the provinces with high efficiency level in China are Heilongjiang, Jiangsu, Qinghai, Shǎnxi, Xinjiang, Beijing, Fujian, Guangdong, Hainan, and Shanghai; the provinces with medium efficiency level are Hebei, Henan, Hubei, Liaoning, Shandong, Sichuan, Guangxi, Guizhou, Ningxia, Chongqing, Tianjin, and Zhejiang; provinces with low efficiency levels are Anhui, Hunan, Jilin, Jiangxi, Inner Mongolia, Gansu, Shanxi, and Yunnan. In addition, there is great potential for improvement in regional agricultural development. Although there are differences in functional positioning, in order to improve the overall agricultural ecological efficiency level of the country, it is necessary to balance the production levels of each functional area, stabilize the optimal efficiency, and improve the inefficient areas. Specifically, in the main grain producing areas, only Heilongjiang and Jiangsu, and among the grain balance areas, only Qinghai, Xinjiang and Shanghai have the best efficiency. The main grain producing areas bear the supply of commercial grain in China. At the current production level, a large number of chemical factors still need to be invested to ensure grain production, so it has a strong impact. Although the grain balance areas are not mainly responsible for the supply of commodity grain, these still bear part of the pressure of agricultural production, the grain balance areas are at a higher level of agricultural production and production.

4. Analysis of Influence of Environmental Regulation on Agricultural Ecological Efficiency

4.1. Variable Description

4.1.1. Core Explanatory Variable. All kinds of policies on environmental governance designated by the government are collectively referred to as environmental regulation, which is not a new policy tool. In actual research, different scholars also choose different indicators to represent the intensity of environmental regulation from different angles. This study mainly selects the proportion of environmental pollution control investment to represent the market-oriented environmental regulation, and at the same time, we take 2015 as the time node, dummy variables were set and represented as command-and-control environmental regulations. Environmental regulation plays an important part in controlling pollutant discharge. Therefore, this study believes that environmental regulation can improve agricultural ecological efficiency.

4.1.2. Control Variable

Industrial organization (IO). Changes in the industrial structure will lead to the change of agricultural production input according to the direction of industrial change, which will promote or hinder the development of agriculture to varying degrees. Therefore, it is difficult to accurately judge the impact of industrial structure on agricultural ecological efficiency.

Agricultural financial support (AFS). The intensity of agricultural financial support represents the degree of government intervention in agricultural production. The higher the support, the more problems need to be solved in agricultural production. There is a risk of over-investment and environmental risks are aggravated. Therefore, the intensity of agricultural financial support hinders agricultural ecological efficiency.

Agricultural disaster rate (ADR). The agricultural disaster rate represents the degree to which agricultural production is affected by natural disasters. In order to reduce the loss of their own economic interests, the production entities that are greatly affected by natural disasters will reduce the negative impact of natural disasters by increasing the input of agricultural production factors. Although it has ensured its own economic interests to a certain extent, the risk of environmental pollution has significantly increased. Therefore, the agricultural disaster rate hinders agricultural ecological efficiency.

Planting structure (PS). There are obvious differences in the growth patterns and environmental conditions of different crops. Therefore, in the production process, the input of agricultural production factors should also be adjusted according to the actual production conditions and crop growth requirements, that is, there is a possibility of increasing the input of production factors and reducing it. Increasing or reducing agricultural input requires specific analysis of specific problems. Therefore, it is difficult to accurately judge the impact of planting structure on agricultural ecological efficiency.

Urbanization rate (UR). The urbanization rate represents the transfer of rural labor. In areas with a high degree of mechanization, agricultural production does not require a large amount of labor input, and labor can be liberated and agricultural production efficiency can be steadily improved with the help of agricultural machinery. In areas with a low degree of mechanization, agricultural production still needs to invest a large amount of labor to meet production. The increase in urbanization rate will lead to reduction in labor force. Instead, increase the input of other agricultural production factors to meet the actual needs, resulting in the emergence of environmental problems. Therefore, it is difficult to accurately judge the impact of planting structure on agricultural ecological efficiency.

Agricultural science and technology investment intensity (ASTII). Combined with the research of relevant scholars, the index of R&D investment intensity of research and experimental development is selected to reflect the status of agricultural science and technology investment [22]. A sound agricultural science and technology support system is the inherent requirement and inevitable path to realize agricultural modernization [23]. Increasing the output of high-quality research results, and converting the results into agricultural productivity are irreplaceable keys to promoting high-quality agricultural development, improving agricultural risk resistance, and improving the agricultural production environment. Therefore, it hinders agricultural ecological efficiency.

Explanations of all variables and assumptions are described in detail in Table 3.

5. Empirical Results of Influencing Factors of Agricultural Ecoefficiency

This study mainly uses STATA16.0 software for analysis. Considering that there may be multicollinearity among variables, first perform a multicollinearity test on each explanatory variable. The multicollinearity diagnosis was carried out using the variance inflation factor method, and it is found that the variance inflation factors of all independent variables in the model are between 1 and 5, indicating that there is basically no multicollinearity between variables [24], and Table 4 shows the details. It can be seen that at the 10% level, the market-driven environmental regulation significantly and positively affects the agricultural ecological efficiency of the whole country and the grain balance areas, but it has no significant impact on others. Under the current technological level, the main grain producing areas need to invest a certain amount of chemical production factors to ensure grain output. Although subsidies and other policies can encourage farmers to carry out green production, compared with economic and ecological benefits, farmers are more inclined to economic benefits. Due to the small production scale of farmers and the lack of subsidies and other policies, the impact on farmers in the main grain sales areas is limited, and farmers' production behavior is more inclined to their own experience. The input of agricultural production factors in China is still unreasonable. Agricultural infrastructure construction, financial subsidies, etc. are all important parts of environmental pollution control investment. Encouraging enterprises and research institutions to update agricultural production technology and widely publicizing and promoting it, on the other hand, improving agricultural production conditions will improve agricultural production efficiency. For the grain balance areas, the positioning of this functional area is that the grain production meets the production and living needs of the region, and a certain scale of agricultural production is required, but its agricultural production capacity is weaker than that of the main grain producing areas and stronger than that of the main grain sales areas. The risk of pollution problems in the production process is also relatively large. At the 1% level, command-and-control environmental regulation significantly and positively affects the ecological efficiency of the whole country and major grain producing areas. In 2015, Government policy was very effective, and agricultural economy and agricultural environment played a positive role. In controlling the amount of input, the policy has a good effect. The main grain producing areas are responsible for the supply of national commodity grains and play a key role in stabilizing food security and ensuring social stability. The traditional extensive agricultural production method has improved agricultural production efficiency for a certain period of time, but high input and high pollution have made environmental

Table 3: Agricultural ecological efficiency factors.

Variable	Variable explanation	Influence judgment
ER	Proportion of total investment in environmental pollution in regional GDP (%)	Positive
IO	The proportion of the output value of the primary industry in the total regional output value (%)	Unknown
AFS	The proportion of spending on agriculture, forestry, and water conservancy in local government spending (%)	Negative
ADR	Proportion of area affected by natural disasters to crop-sown area (%)	Negative
PS	Ratio of sown area of food crops to sown area of non-food crops (%)	Unknown
UR	Proportion of urban population in total population (%)	Unknown
ASTII	Research and experimental development (R&D) funding intensity (%)	Positive
POLICY	Before implementing the policy of reducing volume and increasing efficiency = 0, after implementing the policy of reducing volume and increasing efficiency = 1	Positive

Table 4: Empirical results of influencing factors of agricultural eco-efficiency.

Variable	National (1)	Grain main sales areas (2)	Main grain production areas (3)	Grain balance areas (4)
ER	0.0146* (0.00786)	0.0156 (0.0109)	0.0170 (0.0162)	0.0211* (0.0117)
IO	0.00759*** (0.00243)	0.00305*** (0.000848)	0.0103* (0.00526)	0.0114** (0.00486)
AFS	−0.00307 (0.00278)	0.000203 (0.00244)	0.00155 (0.00466)	0.000323 (0.00534)
ADR	−0.000264 (0.000379)	−0.000438 (0.000384)	−0.000356 (0.000666)	−0.000457 (0.000687)
PS	−0.00839*** (0.00281)	0.00157 (0.00565)	−0.00734* (0.00434)	−0.0424*** (0.0162)
UR	−0.000860 (0.00129)	0.00169* (0.000892)	−0.000433 (0.00289)	−0.00112 (0.00285)
ASTII	0.0226 (0.0139)	−0.00570 (0.00989)	0.0343 (0.0373)	−0.0272 (0.0380)
POLICY	0.0325*** (0.0116)	0.00986 (0.0113)	0.0581*** (0.0211)	0.0298 (0.0238)
C	0.881*** (0.0812)	0.856*** (0.0690)	0.692*** (0.170)	0.926*** (0.138)
Number of samples	420	84	182	140
Number of regions	30	6	13	10

***, **, * respectively means passing the significance test of 1%, 5%, and 10%.

problems increasingly serious. Therefore, under the premise of ensuring grain output and quality, it is very important to control the input of chemical agricultural production factors, especially in the main grain-producing areas, where the application of chemical fertilizers and pesticides is large, and there is a phenomenon of unreasonable use.

Among other control variables, industrial structure has a significant positive impact on all regions. It can be seen that the industrial structure can have a general positive impact. Through the integration of agricultural resources, scattered farmers will be gathered to form a large-scale operation; increase modern agricultural machinery facilities and equipment and reduce labor input; develop regional characteristic agriculture according to local conditions; allowing a large number of industrial and commercial capital and financial funds to enter agriculture, building a scientific and reasonable investment model, allowing enterprises and banks to build a platform, and allowing entrepreneurs and farmers to become professional industrial workers are important measures to realize the transformation and upgrading of agricultural industrial structure. The planting structure has a negative impact on the agricultural ecological efficiency of the whole country and the grain balance area at the level of 1%, Negative response to agricultural ecological efficiency in main grain producing areas at the level of 10%. Whether it is the whole country, or the main grain producing areas, grain balance areas, these areas are important production areas of commodity grain, bearing the task of grain production. If the planting structure is adjusted at will, it will inevitably lead to the inadaptability of production methods and production conditions, and hinder the improvement of agricultural ecological efficiency. At the level of 1%, the urbanization rate has a significant positive impact

Table 5: Robustness test results.

Variable	National (1)	Grain main sales areas (2)	Main grain production areas (3)	Grain balance areas (4)
ER	0.0165** (0.00799)	0.0217* (0.0114)	0.0217 (0.0167)	0.0210* (0.0120)
IO	0.00821*** (0.00265)	0.00321 (0.00302)	0.0118** (0.00544)	0.0156*** (0.00505)
AFS	3.34e-05 (0.00295)	−0.00551 (0.00412)	0.00362 (0.00479)	0.00419 (0.00554)
ADR	−0.000342 (0.000387)	−4.49e-05 (0.000430)	−0.000318 (0.000693)	−0.000535 (0.000713)
PS	−0.0103*** (0.00308)	0.0196* (0.0103)	−0.0115** (0.00450)	−0.0559*** (0.0199)
UR	−0.00245* (0.00140)	0.00694*** (0.00219)	−0.000317 (0.00323)	−0.00216 (0.00306)
ASTII	0.0187 (0.0149)	0.00122 (0.0114)	0.0199 (0.0416)	0.0281 (0.0410)
POLICY	0.0204* (0.0121)	0.0171 (0.0137)	0.0467** (0.0219)	0.0245 (0.0247)
C	0.935*** (0.0828)	0.495*** (0.165)	0.674*** (0.180)	0.909*** (0.138)
Number of samples	420	84	182	140
Number of regions	30	6	13	10

***, **, * , respectively, mean passing the significance test of 1%, 5%, and 10%.

on the agricultural ecological efficiency of major grain sales areas. The agricultural production scale in the main grain selling areas is small, and does not need a lot of labor input. The improvement of urbanization level will promote the citizenization of farmers, promote non-agricultural employment, and liberate the surplus productive forces.

6. Robustness Check

In order to verify the stability and accuracy of the previous research conclusions, this study uses the fixed effect model to perform regression again, and Table 5 shows the details. It can be seen that the results of the new calculation are basically consistent with those of our previous calculation. Environmental regulation still has a significant positive effect on agricultural ecological efficiency. The results of the study are basically the same as those mentioned above, indicating that the study results are reliable.

7. Conclusion and Suggestion

7.1. Conclusion. After calculation and analysis, we get the following conclusions: (1) China's agricultural ecological efficiency has not yet reached the optimal level, and the differences between regions are obvious. The agricultural ecological efficiency value is the main grain sales areas > the whole country > the grain balance areas > the main grain production areas. The provinces with high efficiency level in China are Heilongjiang, Jiangsu, Qinghai, Shǎnxi, Xinjiang, Beijing, Fujian, Guangdong, Hainan, and Shanghai. These provinces achieve the best efficiency, they can give consideration to economic and ecological benefits in agricultural production. (2) Environmental regulation has a positive impact on agricultural ecological efficiency, indicating that it is an important means to improve agricultural ecological efficiency. Among them, the market-incentivized environmental regulation significantly positively affects the whole country and the grain-balanced areas, and the command-and-control environmental regulation significantly positively affects the ecological efficiency of the whole country and the main grain-producing areas. Among other control variables, the industrial structure significantly positively affects the agricultural ecological efficiency of all regions; the planting structure significantly negatively affects the agricultural ecological efficiency of the whole country, the grain balance areas and the main grain producing areas; the urbanization rate significantly positively affects the main grain sales areas agricultural ecological efficiency. When analyzing the influencing factors in this study, due to the fact that the data do not include the public participation type environmental regulation in the research scope, the control variables only try to find out the factors that affect the agricultural ecological efficiency, so as to avoid multicollinearity and endogenous problems.

7.2. Suggestion. (1) Improve the environmental regulation system. Every environmental regulation has its own field of adaptation, and there are also obvious differences in natural and social conditions between regions. Governments need to tailor policies to specific problems. In the previous conclusions, Market incentive environmental regulation is very important in the overall level of the country and the regional level of the grain balance areas. The effect of efficiency is not obvious in other areas, so more targeted measures are needed for both areas. As the name implies, the main grain producing areas are important grain production bases, and are superior to other areas in terms of infrastructure level and production experience. Simply providing basic support and other policies have limited effects. We need to rely on scientific and technological progress to enhance agricultural productivity. Environmental regulation requirements, put forward technology-based environmental regulation to develop; the agricultural production scale in the main grain sales areas are the smallest, and it depends more on the food supply of other regions. The regional agricultural development is not paid much attention, and the non-agricultural industries are developed. No matter what kind of environmental regulation, the role of these environmental regulations is weak, so the management of scattered small agricultural production units is required for these areas. The policy of reducing quantity and increasing efficiency has an apparent promoting effect on the overall level of the country and the regional level of major grain producing areas. The policy of reducing quantity and increasing efficiency has been promulgated and carried out from top to bottom across the country. In 2015, in the implementation process of the national policies issued by the government, the effects vary from region to region, some regions are effective, while others are not significant. The implementation of the reduction and efficiency increase can achieve good expected results. However, the effect of the reduction and efficiency policy in the grain balance areas and the main grain sales areas are not obvious. This shows that the pertinence of the policy is not enough, and specific problems need to be analyzed. Therefore, it is necessary to formulate different control and order-based environmental regulation policies for different regions, continue to promote reduction and increase efficiency nationwide, continue to realize no growth or negative growth of chemical fertilizers and pesticides for major grain producing areas, and manage existing environmental problems to achieve destocking; for the main grain sales areas and the grain balance areas, we need to combine the present situation of agricultural production with rational allocation of factor input and formulate appropriate environmental regulations in the region to improve agricultural ecological efficiency.

(2) Multiple measures to promote high-quality transformation of agriculture. Industrial structure is one of the important factors. Under the requirements of high-quality agricultural development, we need to get rid of the traditional production methods of high input, high consumption, and high emissions, improve the allocation of factors, vocational education, science and technology, management capabilities, etc. and apply new high-efficiency agricultural production equipment in hardware conditions. Promote soil testing, formula fertilization, biological control technology, etc., improve the quality of agricultural occupations in terms of software, teach new skills in agricultural production, improve agricultural production management capabilities, and achieve high-quality transformation of agriculture. Pollutant discharge, clean production, reduce the negative impact of secondary and tertiary industries on agricultural production, and improve agricultural ecological efficiency.

(3) Develop moderate-scale agricultural operations. Planting structure significantly negatively affects agricultural ecological efficiency, which indicates that blindly expanding grain sown area is not conducive to agricultural development. Based on the scarcity of land, expanding the acreage of grain will encroach on other forms of land use, and land use conversion also requires a series of management of land to meet planting needs, in the process there is a risk of environmental damage, and the expansion of grain sown area means that the input of chemical production factors. It will be increased in the production process, increasing the possibility of agricultural pollution. Therefore, it is feasible to develop agricultural moderate-scale management. There is no uniform standard for agricultural moderate-scale operation, and different regions need to realize moderate-scale agricultural management according to the actual situation of the region.

Data Availability

The basic data of this study are all from the public statistical data published by the Chinese government, including the China Statistical Yearbook, the China Rural Statistical Yearbook and the China Environmental Statistical Yearbook. https://data.cnki.net/Yearbook/Navi?type=type&code=A.

Conflicts of Interest

The authors declare that there are no conflicts of interest in this manuscript.

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