A Study of the Impact of Functional Zoning of Land Space on Ecological Efficiency: Evidence from Hunan Province in China

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Abstract: The major function-oriented zone planning (MFOZP) is a major measure to implement the construction of national ecological civilization. ecological efficiency is one of the important indicators to measure sustainable economic and social development and ecological civilization construction. Based on the input-output relationship of unit ecological footprint, a stochastic frontier production function is constructed to estimate the ecological efficiency of each county and urban area in Hunan Province from 2009 to 2019. In this paper, the MFOZP is used as a quasi-natural experiment, and the Difference-in-Difference model is used to study the impact of the MFOZP on ecological efficiency.
Keywords: MFOZP; Ecological Efficiency; Stochastic Frontier Production Function; Difference-In-Difference

1. Introduction

At present, China is considered to be the largest developing country. It is undeniable that the extensive economic growth mode once promoted the enhancement of economic strength and improved the living standards of residents. However, many environmental problems such as soil erosion, increased hazy weather, and water pollution have emerged in recent years. The question of how to effectively maximize economic activities whilst minimizing environmental degradation has aroused great interest from governments and scholars all over the world (Harjanne and Korhonen, 2019; Fanet al., 2020). " Ecological efficiency" is a popular key indicator consistent with the sustainable development goals. Achieving optimum ecological efficiency is key to improving environmental conditions while ensuring economic growth (Qu et al., 2020). As an important metric of sustainable development, the change of ecological efficiency has attracted the attention of society and scholars. Ecological efficiency has an important role in the unified development of the environment and society (Govindan et al., 2019).The Hunan Provincial People's Government released the Hunan Main Functional Area Plan on December 2012, which classifies key development areas, main agricultural product producing areas and key ecological functional areas by counties as basic units.

The most popular math models used to measure ecological efficiency are DEA and SFA. In evaluating environmental efficiency issues, SFA was adopted as an effective method for such issues by comparing DEA and SFA (Dong and Wu, 2020;Khan et al 2021).Land cover is being continuously transformed at an accelerating pace because of urbanization and economic development, which is, in turn, impacting ecosystem services and human well-being（Den and Gibson,2020;）On the one hand, the area of natural ecological land decreased from 2008 to 2019 and was mainly converted from artificial land. On the other hand, in key development areas, agricultural production areas and key ecological function areas, forest land was mostly converted from cropland and grassland, which is because grassland was also involved in afforestation during this period（Zhang et al.,2021). It is a new trend in academia to study the relationship between main function zoning and ecological environment from the perspective of efficiency, which has important research significance.

2. Methodology

2.1 Measurement of ecological efficiency

In combination with the objectives and contents of this study and the difficulty of collecting relevant data, this paper constructs a stochastic frontier production function model based on ecological footprint as a calculation method for measuring the ecological efficiency of Hunan Province. The model expression is:

$$\ln \frac{Y_{it}}{EF_{it}} = \beta_0 + \beta_1 \ln \frac{L_{it}}{EF_{it}} + \beta_2 \ln \frac{K_{it}}{EF_{it}} - U_{it} + V_{it} \quad (1)$$

$$EE_{it} = e^{-u_{it}} \quad (2)$$

$$U_{it} = e^{-\eta(t-T)u_i} \quad (3)$$

In formula (1), EE_{it} is the ecological efficiency. i and t respectively represent counties, cities and years in Hunan province; Y is GDP, L is labor force, K is capital stock, EF is ecological footprint, U_{it} is technological inefficiency; β is the parameter to be estimated, β_0 represents the output contribution of other elements except labor force and capital stock, β_1 represents the output elasticity of labor force, and β_2 represents the output elasticity of capital.

Among, U_i obeys nonnegative one-sided normal distribution $U \sim N(\mu, \delta_U^2)$, V_{it} is random error, obeys normal distribution $V_{it} \sim N(0, \delta_V^2)$, and is independent of U_{it} , μ , δ_U^2 and δ_V^2 as parameters to be estimated; t is the t year; T is the total number of periods; e is a natural constant; η is the parameter to be estimated.

Let $r = \delta_U^2 / (\delta_U^2 + \delta_V^2)$, and we can see that $0 < \gamma < 1$. When γ is large and significant, it is considered necessary to introduce the technical inefficiency term. The estimation process of ecological efficiency is calculated by the calculation program Frontier 4.1.The ecological footprint is calculated using the following formula:

$$EF_l = \sum_{j=1}^{m} C_j / P_j \; EF_l = \sum_{j=1}^{m} C_j / P_j \quad (4)$$

In formula (4), EF is the total ecological footprint of counties and cities; l is the land type. Considering the actual situation of Hunan Province and the availability of data, six types of land are selected as the land type: cultivated land, forest land, grassland, fossil energy land, construction land and water area. λ is the equivalent factor of each type of land. C_j is the total production of a biological product on a type of land; P_j represents the global average production per unit area of this type of biological products; j represents the type of biological product.

When calculating the ecological footprint of Hunan Province, this paper first classifies the bio-productive land into two categories, namely, biological resource account and energy account, and selects a total of 24 projects of 6 types of land consumption for calculation. the ecological footprint of cultivated land uses a total of 11 kinds of agricultural products such as grain, wheat, beans, etc. The ecological footprint of forest land uses camellia seeds and citrus. The ecological footprint of grassland uses three consumption items: beef, mutton and dairy products; fossil energy uses seven energy resources: raw coal, coke, gasoline, kerosene, diesel oil and liquefied petroleum gas; the construction land uses electricity consumption; and the water ecological footprint uses aquatic products. The global average energy footprint of electricity is 1000GJ/ 10,000 kWh, and the conversion coefficient is 360,000 kWh.

2.2 Estimation model of the impact effect: a DID model

DID is a quantitative evaluation method. It is a quantitative evaluation method used to evaluate public policies. In this paper, the stochastic frontier production function is used to calculate the ecological efficiency as the explained variable, the key ecological function areas are the experimental group, the key development zones and the main agricultural production areas are the control group, the premise of double difference is the consistency of the long-term trend between the experimental group and the control group, and then the samples are used for DID analysis. The specific model is as follows:

$$Y_{it} = \alpha_0 + \alpha_1 \left(D_i \times T_t \right) + \alpha_2 D_i + \alpha_3 T_t + U_i + V_t + \sum_j \lambda_j X_{it} + \varepsilon_{it} \tag{5}$$

In formula (5), Y represents the explained variable, i represents specific districts and counties, t represents the year, and D represents the virtual variable of the main function zones in Hunan Province. If a county is a key ecological function zone, the value of D is 1, and vice versa is 0; T is the virtual variable of the implementation time of Hunan province's main function zoning plan. Hunan province issued the "main function zoning plan" in December 2012. therefore, this paper takes the time virtual variable T from 2013 to 2019 as 1, and the time virtual variable T from 2009 to 2013 as 0; $D_i \times T_t$ represents the interaction term between the virtual variable of the main functional area and the virtual variable of the planning implementation time of the main functional area, α_1 is the estimation coefficient for testing the policy effect of the main functional area, U_i is the regional fixed effect and V_t is the year fixed effect; X is a control variable that affects ecological efficiency and changes with time and region. ε select fixed effect double difference model for error term to test.

2.3 Variables Description

The variable explained is the ecological efficiency of Hunan Province.After the implementation of the main function zoning, the land and space control belongs to the counties and urban areas of the key ecological function zones, which are the interactive items. Control variables chose economic development level (X1), the unit is ten thousand yuan. the degree of industrial structure upgrading (X2), population size (X3). The data used in this paper are the population of each county in Hunan province at the end of the year.

Table 1 Descriptive statistics of the main variables

Variable type	Variable name	Observed value	average	Standard error.	Min	Max
Interpreted variables	Ecological efficiency	1342	0.376	0.135	0.173	0.99
Control variables	Level of economic development	1338	1.139	0.728	0.577	3.109
	Degree of industrial structure	1338	0.428	0.14	0.103	0.957
	Population size	1342	3.86	0.601	1.599	4.944

2.4 Data source

The data in this paper are mainly from Hunan Statistical Yearbook, Hunan Rural Statistical Yearbook, China County Statistical

Yearbook over the years, statistical bulletins of counties, cities and districts in Hunan Province from 2010 to 2020, The average productivity of the ecological footprint consumption project in China is derived from the database of FAO.

3. Results

3.1 Calculation results and analysis of ecological efficiency

As can be seen from Figure 1, the average ecological efficiency of key development zones is slightly higher than that of major agricultural production zones and key ecological functional zones. The average ecological efficiency of key development zones decreased from 0.41 in 2009 to 0.35 in 2019, and the ecological efficiency of key ecological function zones decreased from 0.39 in 2009 to 0.32 in 2019, which decrease of about 6% and a decrease of 15.8% year on year.

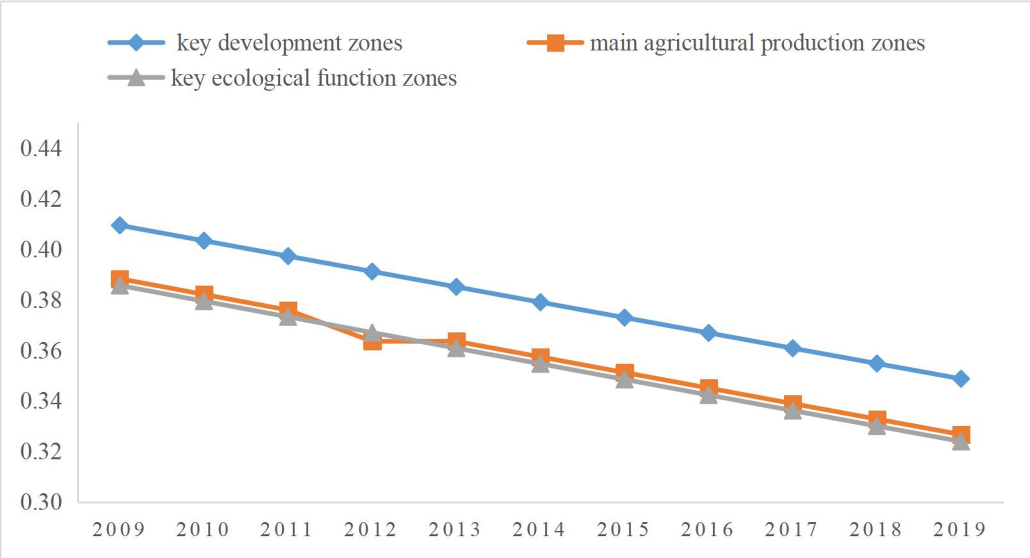

Figure 1 Ecological efficiency of main functional areas in Hunan

3.2 Empirical results

Table 2 shows the results of double differential regression, in which column (1) does not add control variables, it can be seen that the interaction coefficient is significantly negative at the significant level of 1%, indicating that after the implementation of the policy, the ecological efficiency of key ecological function areas is lower than that of key development zones and major agricultural production areas, and the implementation of the main function planning policy reduces the ecological efficiency of key ecological function areas by 0.13% on average, while column (2) adds control variables for regression. When the significance level is 1%, the coefficient is still significantly negative, but the inhibition effect is reduced. The coefficient of economic development level X1 and industrial structure is significantly negative, which also indicates that economic development will consume more resources and thus discharge more pollution, thus reducing ecological efficiency.

Table 2 Test results of policy effects of main functional area planning.

	(1)	(2)
	Y	Y
D*T	-0.0013***	-0.0010***
	(0.0000)	(0.0002)
lnx1		-0.0031**
		(0.0477)
X2		-0.0101***
		(0.0028)

lnX3		0.0141***
		(0.0001)
_cons	0.3764***	0.3289***
	(0.0000)	(0.0000)
N	1342	1342
adj. R^2	0.9995	0.9996

Time Effect	yes	yes	yes	yes
R^2	0.9809	0.9994	0.8935	0.9994
N	1342	1342	1342	1342

4. Conclusion

The eco-efficiency of the counties and urban areas ranged from 0.2 to 1.0, and the eco-efficiency of the pilot areas was generally low. Further empirical study shows that the main function zoning policy significantly inhibits the increase of eco-efficiency in key eco-functional areas, and the main function zoning policy reduces the eco-efficiency value of key eco-functional areas by 0.0013 on average at a significant level of 1%, which indicates that the implementation of the main function zoning policy in Hunan Province has not achieved significant results in improving the eco-efficiency of the pilot areas, and the relevant policy implementation is not yet in place, which requires Further adjustment of relevant policies is needed to improve eco-efficiency.

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