The Influence Factors of Regional Eco-efficiency in Mongolia

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ABSTRACT
It is the significance for the region to realize green sustainable development, especially for Mongolia which is an ecologically fragile developing country. In this paper, energy consumption and environmental undesirable outputs were taken as ecological environmental indicators into the input and output system of regional eco-efficiency in Mongolia, combining traditional indicators of economic efficiency to build Mongolia's eco-efficiency input output framework. By collecting period 2007-2016 data and using the SBM model, the eco-efficiency of 22 provincial administrative units in Mongolia were measured. Based on the panel Tobit analysis, we found that the relationship between per capita GDP and eco-efficiency was U-shaped and constrained by economic development. The population density and energy consumption technology had an obvious effect on the improvement of Mongolia's eco-efficiency.

Keywords: *Eco-efficiency, influence factor, SBM mode, Mongolia*

1. INTRODUCTION

Mongolia is located in the Mongolian Plateau, with less arable land and only 9.2% forest coverage. Most of the land is covered by grasslands. There are many mountains in the north and west and desert in the south. The ecological environment of Mongolia is diverse and fragile, which has an important influence on the ecological environment of East and Central Asia. Economic development is the objective requirement of human development, which is particularly important for developing countries. Faced with the fragile ecological environment, Mongolia's economic development needs to consider the influence of the ecological environment comprehensively, regard it as an ecological economic system, and adhere to the strategy of sustainable economic development.

In the past ten years, with the promotion of international organizations such as OECD and WBCSD and many scholars, the concept of eco-efficiency has attracted the attention of policymakers, researchers, and enterprise managers, and has been popularized and applied in many fields. Mickwitz et al [1] pointed out that eco-efficiency is a tool for analyzing sustainability, reflecting the practical relationship between economic activities and environmental costs and environmental impacts. Therefore, under the background of global sustainable development and ecological civilization construction, eco-efficiency can become an important means of scientific evaluation of ecological environmental effects and economic effects.

Regional and larger scale eco-efficiency evaluation and management system research has become the focus [2; 3; 4; 5]. Beltran-Esteve [6] contrasted and analyzed the environmental performance level at both ends of the European Union's economic crisis, then found that the level of environmental performance in the two periods was well. It was suggested to re-establish the level of the ecological innovation investment before the crisis. Moutinho [7] analyzed the economic and environmental efficiency of the 26 European countries from 2001 to 2012. It was found that the share of renewable and non-renewable energy was

important to explain the differences in emissions. The effect of environmental tax was negative in inefficient countries, while transport tax was disadvantage of countries with higher eco-efficiency, and energy taxes may have a positive impact on low eco-efficiency countries [7]. Huang [8] based on the total factor eco-efficiency of economic efficiency, energy efficiency and environmental efficiency, the regional total factor eco-efficiency of 30 provinces and regions of China in period 2001-2014 was analyzed, it was found the different provinces and regions showed significant spatial heterogeneity in different development modes [8]. Diaz-Villiavicencio [9] analyzed the eco-efficiency level of urban garbage management in 143 municipalities directly under the central government of Spain through the DDF model, and analyzed the driving factors of the level of eco-efficiency of urban garbage in Spain by using Tobit regression. Yue [10] combined with ecological footprint and DEA method established the total factor eco-efficiency evaluation method, and evaluated the total factor eco-efficiency of 28 inland provinces in China. Yang [3] analyzed the environmental efficiency of China inland 28 provinces and analysis the shadow price of the pollutant agglomeration through the establishment of super efficiency DEA model. Yang [11] analyzed the sustainable development level of Taiwan through total efficiency and decomposition efficiency. Masternak-Janus [4] evaluated the eco-efficiency of provinces of Poland through DEA.

Through the above research, it can find that scholars have carried out empirical research on regional eco-efficiency of different scales based on basically consistent core concepts of eco-efficiency. The research areas were mainly concentrated in the economies of the EU, G7, BRICs and so on. However, there was less research on underdeveloped economies and regions with a fragile ecology.

This study introduces eco-efficiency as a tool to measure regional economic development and ecological environment protection in Mongolia, comprehensively analyzes the eco-efficiency level and of the 22 regions of Mongolia (including 21 provinces and capital Ulaanbaatar), and analyzes the main driving factors affecting the spatial differentiation of eco-efficiency in Mongolia by econometric analysis. It aims to expand the main research areas of regional eco-efficiency research and provide some references for similar economies and inland countries to provide green and sustainable economic development.

2. STUDY AREA

The study area of Mongolia is in the middle of Asia, $41^0$35'N, $52^0$08'N, $87^0$44'E, $119^0$55'E, north to Daka mountain, south to Taylor mountain, west to Monte mountain, east to Mao Tak. The two ends of the east and the west are 2392 km, and the north and south ends are 1259 km. The border is 8161.9 km long and the land area is 1564116 km². In this study, 22 regions of Mongolia (including 21 provinces and capital Ulan Bator) were used as the main research areas. As the decision-making unit of the eco-efficiency analysis of Mongolia, the eco-efficiency evolution of the 22 regions from 2007 to 2016 was analyzed, and the spatial and temporal characteristics of the eco-efficiency of Mongolia were analyzed.

3. METHOD AND DATA

3.1. The analysis method of eco-efficiency: SBM model

In this study, an Undesirable outputs SBM model was constructed with undesirable outputs to measure the eco-efficiency of Mongolia. Each space unit includes three vectors: input, expected output and undesirable output. Expressed as $x \in R^m$, $y^g \in R^{s_1}$, $y^b \in R^{s_2}$, Define matrices X, Y^g, Y^b as follows: $[X] = [x_1, \cdots, x_n]^T \in R^{m \times n}$, $[Y^g] = \left[y_1^g, \cdots, y_n^g\right]^T \in R^{s_1 \times n}$ and $[Y^g] = \left[y_1^g, \cdots, y_n^g\right]^T \in R^{s_1 \times n}$, X>0, Y^g>0, Y^b>0. The SBM-Undesirable model based on variable returns to scale is expressed as Cooper et al, 1999.

3.2. Influence factors analysis method: panel Tobit analysis

The Tobit regression model is proposed by Tobin. It belongs to the regression model with limited dependent variables. It can solve the problem of modelling restricted or truncated dependent variables [8; 12]. So, the panel Tobit model is selected to identify the influencing factors of regional eco-efficiency in Mongolia. The model expression as follows:

$$\begin{aligned} & y_{it}^* = \alpha x_{it} + \varepsilon_{it} \\ & y_{it} = \begin{cases} y_{it}^*, y_{it}^* \geq 0 \\ 0, y_{it}^* \leq 0 \end{cases} i = 1, \cdots, 22, t = 1, \cdots, 10 \\ & \varepsilon_{it} \sim N(0, \sigma^2) \end{aligned} \quad (1)$$

Where *i* represents the 22 regions of Mongolia, *t* represents different years, x_{it} as an independent

variable, β is regression parameters, ε_{it} represents the perturbation term.

3.3. Indicators and data

In the traditional production function, the economic input index mainly includes labor and capital, and the output indexes is mainly the GDP. The input-output index of the economic efficiency of Mongolia is the traditional labor input and capital input, and the output is GDP. The index of regional eco-efficiency is selected from the input-output indexes of traditional economic efficiency. It is necessary to increase the ecological environment index of evaluation of regional eco-efficiency. The input indexes can include energy, land, water resources and so on [14; 15], the output indexes mainly include waste water, SO_2, NO_2, $PM_{2.5}$, garbage and so on [16; 17]. Combined with existing research, according to the acquisition of ecological environmental indicators in Mongolia, in this study, energy is used as the input indexes of the ecological environment, and SO_2 is used as an undesired output index of the ecological environment, and the energy consumption and SO_2 emissions are used to measure the regional eco-efficiency level of Mongolia. The labor force, GDP and SO_2 data in Mongolia are from the Mongolia statistical yearbook (2007-2016) with the table of Economically Active Population, Gross Domestic Product (at current prices), Annual Average Concentration of Pollutants in Air.

4. RESULTS

During the research period, there were 6 highly efficient areas in 2007, including Bayan-Olgii, Arkhangai, Ulaanbaatar, Govisumber, Orkhon and Bulgan, increasing to 8 in 2016, including Dundgovi, Selenge, Tov, Dornod. The new highly efficient areas mainly concentrated in the relatively developed central region of Mongolia, and mostly adjacent to the high efficiency areas in 2007. It was indicated that the spatial pattern of highly efficient areas showed an agglomeration and obvious spatial spillover effect. Bayan-Olgii in Mongolian western region is the inefficiency areas with the relatively less developed. It can be seen that good location conditions and high level of economic development lead a good running on input-output of ecological-economic system central of Mongolia, and promote the coordinated development for eco-efficiency and economic efficiency. On the other hand, the input-output efficiency of eco-economy has been at a low level in the western region due to the constraints of production technology and the resource allocation structure.

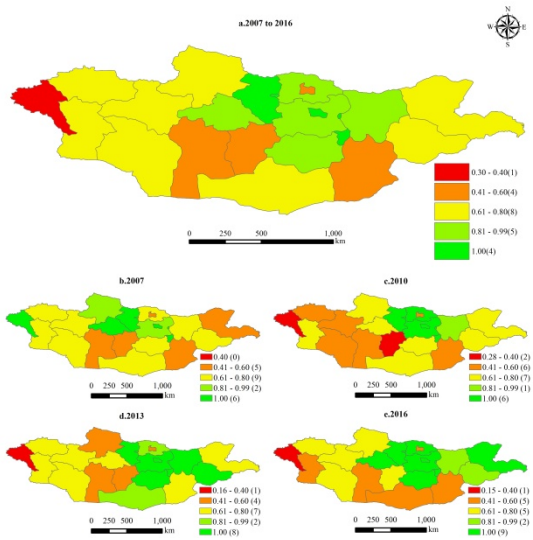

Figure 1. The spatial pattern of eco-efficiency in Mongolia

The main factors that affect regional eco-efficiency include scale effect, structural effect, capital effect, technological effect, population effect, and environmental policy effect [18] This study used panel Tobit regression model to analysis the influences factors of eco-efficiency, including economic scale, industrial structure, capital effect, technical effect, population density, environmental regulation. Combined with existing research [19; 20; 21], the model selected GDP, the proportion of the output value of the service industry (IS), GDP capital input (RI), unit GDP energy input (RE), population density (PD), and waste facility input (EI) representing above influence factors to explain the effect of spatial variation on eco-efficiency in Mongolia. According to the Kuznets theory of environment [22], with the increase of income, the ecological environment will deteriorate, and when the economy develop to a higher level, it will be improved. In order to find out the relationship between economic development and eco-efficiency, the quadratic term of per capita GDP was incorporated into our Tobit model [23]. In order to avoid the non-stationary problem of parameter estimation caused by different data dimension, the natural logarithm of the relevant variables was taken to preserve the characteristics of panel data (Table 1).

Table 1. Panel Tobit regression analysis on influence factors of eco-efficiency in Mongolia

Variable	Coef.	Std.Err.	z	P>|z|
lnGDP	-1.674	0.516	-3.24	0.001
$lnGDP^2$	0.111	0.033	3.33	0.001
lnEI	-0.044	0.025	-1.8	0.072
IS	0.032	0.064	0.5	0.620
lnPD	0.091	0.037	2.45	0.014
RI	-0.059	0.040	-1.48	0.138
RE	-0.652	0.225	-2.89	0.004
Constant	7.350	1.998	3.68	0.000
Log likelihood=21.1311				

(1) The relationship between per capita GDP and eco-efficiency is U curve, because the first order coefficient is negative, and the quadratic term is positive. This shows that the eco-efficiency of Mongolia was first decreased with the growth of per capita GDP, and the level of eco-efficiency would increase when the per capita GDP reaches a high level. From the regression results, the average per capita GDP increased by 1% and the eco-efficiency level dropped by 1.67%, indicating that the economic and social development at the present stage of the economic and social development of Mongolia still has a higher elastic coefficient of energy consumption and exhaust emission, and the economic development is still an unsustainable state of extensive and high energy consumption.

(2) The parameter coefficient of population density is 0.091 and through 5% significant test, which indicates that the population density increases by 1% and the eco-efficiency increases by 0.09%. The positive impact of population density on eco-efficiency is mainly the high reserve of human capital to improve the technical research and development level of the efficient allocation of the ecological environment factors in the economic development. The population distribution in Mongolia is not balanced, and nearly half of the population of the country lives in the capital of Ulaanbaatar, promoted the high population density of Ulaanbaatar and its surrounding areas with hot spot regions and high efficiency in eco-efficiency.

5. CONCLUSIONS

Through the analysis of Mongolia's influencing factors, it was found that population density and energy consumption were the important factors to improve Mongolia's eco-efficiency. The relationship between per capita GDP and ecological efficiency was U-shaped, but at present, the relationship between eco-efficiency and GDP growth was still significantly negative. Environmental regulation by terminal pollution management has not played a positive role on Mongolia's eco-efficiency. In the short run, it was difficult to directly improve Mongolian eco-efficiency by terminal pollution management. We should adopt energy saving and emission reduction measures, train relevant technical and theoretical personnel for sustainable development, improve the level of technological research and development, to realize the efficient allocation of ecological environment factors in economic development.

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