The changes and influencing factors of urban LUCC and EF footprint in energy resource areas: An empirical evidence from China using HLM model

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Abstract. Analyzing urban land use and cover change and its influence factors are of great significance for understanding the situation of regional development and environmental constraints and for evaluating the ability of sustainable development. This paper calculates the three-dimensional ecological footprint and total factor productivity of research cities, these cities have significant individual differences, Yinchuan, Shizuishan, Yan’an, Yulin, Ganzhou, Shaoguan etc. are energy resource areas and comparing to those Guangzhou, Dongguan, Wuzhong, Qingyuan etc. are non-energy resource leading cities. The HLM model is used to decompose the influencing factors of three-dimensional ecological footprint. The study shows the important role of total factor productivity in regional and urban sustainable development. Also, the study shows the inter-group differences of three-dimensional ecological footprint produced by cities with different population sizes. And the inter-group difference of urban three-dimensional ecological footprint under the influence of total factor productivity. Result shows that land, population and technology factors have different impacts on three-dimensional ecological footprint. Also, relying mainly on mining areas of energy resources and other industries dominated areas of mining land proportion and industrial structure differences did not lead to the influence of different ecological footprint, energy resource area in affecting factors, the ecological footprint is still a total factor plays the leading role of ecological rate, population and real GDP, There is no obvious negative externality effect of mining activities on the value of regional ecological products, and the regional ecological carrying capacity keeps improving.

Keywords: land use and cover change, three-dimensional ecological footprint, energy resource area, total factor productivity, influencing factors.

1. Introduction

Energy resources area which is important in the development of the national geographic units and this paper focuses on the influence factors of land use and cover change and human ecological occupation and its impact on human sustainable development in cities characterized by energy and resource industries. With the change of the way of energy utilization, and the change of the regional
leading industry, a number of these cities have taken place in transition, there are still some cities belong to the type of energy and mineral resources production and processing core area. The traditional belief is that energy resources industries has certain environmental negative externalities, however, because of the green mine construction, More and more energy and mineral enterprises are taking measures to control the adverse impact on resources and environment. These measures may have a profound impact on the economy, society and environment of the cities they belong to. From an economical point of view, the output value and efficiency characteristics of energy resources market demand and regional green economic development will be taken into account in the industry production, from the social level, regional population change plays an important role in the development of cities and regions. From the perspective of environment, land use and cover change plays an important role in ensuring the sustainable development of cities and regions.

Therefore, this paper mainly did the following job: measured the biological account of three-dimensional ecological footprint changes of the ten cities; Measured the total factor productivity (TFP) of the ten cities; analyzed the influencing factors of 3d ecological footprint and its relationship with regional TFP and industrial industries. Since there are few studies analysis of the perspective that urban development and the correlation effect of natural resources for regional industry characteristics areas. So the contribution of this paper mainly lies in the fact that first we studied the features and characteristics of the land use cover change and industrial structure change in energy resources areas. Second, combined with the city's population and the agricultural production to calculate the three-dimensional ecological footprint, calculated the total factor productivity of the city. Thirdly, this paper analyzed the influencing factors of land use and cover change from the perspectives of population, land, Gross regional product and economic development efficiency, and then obtained the interactive relationship among regional economic growth, industry and human natural imprint, and the influence of regional ecological product value and regional development change on regional ecological carrying capacity.

2. Literature review and research hypothesis

Energy and resource areas play an important role in the national development, their industrial structure, human-land relationship and resource utilization are all paid highly attention. Compared with the general area, there are obvious differences in their development modes. Regional natural resource structure is one of the important factors affecting industrial structure [24]. Ecosystems are related to people's well-being [3]. Land elements are the most direct influencing factors of human activities. Land is the influence of human activities on the natural earth's surface, the most direct signal from a global scale, some study are focus on global land use/land cover change and the impact of ecological system, including influence on runoff, the impact on carbon emissions, the impact on regional climate, etc. [1, 2]. It is generally believed that land use/land cover change is one of the key factors affecting land use/land cover change. It is the pioneer of sustainable development and the core of all related issues. Productive land is a good proxy for natural capital and many of the resource flows and essential life support services that this capital provides [8]. So there is also a close relationship between LUCC and nature resource capital.

As for the relationship of land use cover and regional economy, some studies have focused on the impact of agricultural activities in the Amazon region of South America such as Barbieri Alisson Flávio [5], some studies focused on African areas Qualitative analysis of economic and social influencing factors of land use and cover change, land use intensity and land use type transfer, or the relationship between other driving natural factors, such as Shaokun Liu [4], Xiaowei Shi et al. [12], Yang Yang et al. [22], Yali Li et al. [23]. These researches is less concerned about the land use and land cover (LULC) and its change will be affected by what regional factors or economic development factors. As a matter of fact, human activities are essentially a kind of social activity and have a strong relationship with economy. What kind of policy should be adopted to achieve the goals of sustainable development? It should not only consider the effect of ecological service system. Moreover, the influence of economic and social factors should be considered in a systematical way. For energy and resource concentrated areas, this will
involves resource utilization policy, industrial regional development policy, ecological and environmental protection policy, urban sprawl and other issues. Since REES E W [9] proposed the ecological footprint method to measure the natural imprint of urban economy, the ecological footprint method has been widely used. The ecological footprint method and the improved three-dimensional ecological footprint method are useful for understanding the carrying capacity of a certain resource and to understanding the regional natural resource capitals [10].

When technological progress has become the mainstream of social development, researches on technological progress and its far-reaching impact is of great significance for people to better understand the influencing factors of regional development. Related literatures such as Miao, C.L. [16] argue that technologies from different sources will have different impacts on economic activities. For example, Bengoa and Roman [17], Wang Shengyun et al. [18] measured the welfare efficiency and ecological efficiency of economic growth. From the methodology Farrell [12] applied data envelopment analysis (DEA) to the study of input factors and their interaction, and proposed the data envelopment analysis model to handle technological efficiency. Charnes et al. [13], and Simar & Wilson [14, 15] all make efforts to improve the DEA analysis method and apply it to energy efficiency, economic development efficiency, industrial development efficiency, resource input-output efficiency and so on. In this study, the DEA method and the stochastic Frontier Function Analysis method (SFA) are used to measure the total factor productivity of 10 cities from 2009 to 2019 in order to find the technological progress impact.

To summarize, this study took the leading industry of energy resources city in China as samples, using land inputs variable as the breakthrough point, applying of three-dimensional ecological footprint method and the rate of total factor of ecological measure method to characterize the status of land, total factor productivity and related resources of the research city. And using three dimensions of the ecological footprint of biological account refers to land use cover change in the interaction relationship between human activities. The systematic analysis is used to analyse the influencing factors is of reference significance for understanding and evaluating the influencing factors of regional sustainable development from the micro scale and have reasonable reference meaning to formulating rational energy, industry and regional development policies.

According to the above research purposes and literature review, based on theory of environmental Kuznets curve, which believes that the impact of industrialization on the environment has a trend of rising and decreasing trend at different developing stage, this paper proposed the following three hypothesis:

Hypothesis 1: Ecological footprint is a significant confirmation of human occupation of resources. The biological account in ecological footprint measures the mark of human activities in non-built-up areas, and the correlation between the scope of non-built-up areas and human activities can directly reflect the ecological environment nature resources capital carrying capacity of the whole regions.

Hypothesis 2: Different population sizes and different lands input factors in different regions will have different impacts on the ecological footprint occupation and ecological product value of these cities.

Hypothesis 3: The improvement of regional total factor productivity will reduce human's dependence on natural resources and reduce the occupation of regional and urban ecological footprint.

3. Empirical process of influencing factors of land use and cover change and results

3.1 Study design

Based on research hypothesis 1, Since the biological account of three-dimensional ecological footprint is closely related to land use and cover change, that it can be regarded as one of the measurement standards of land use and cover change. In addition, three-dimensional ecological footprint can better reflect the carrying capacity of regional resources and environment from multiple dimensions. At the same time, three-dimensional ecological footprints are closely related to land classes variation, and the three-dimensional ecological footprints of different accounts can show the changes of each land class variation. Therefore, this study designed and calculated the biological account of the three-dimensional ecological footprint of the study city, and the calculation process referring to the design ideas of Niccoliucci V et al., and some scholars’ previous studies and revised it for actual.
on research hypothesis 2.3, the study takes the local permanent population, capital stock, energy consumption and lands input as input variables, and local real GDP as output variable. DEA method is used to estimate the change of total factor productivity of these study cities. The study shows that there are obvious urban differences in total factor productivity among the studied cities, which is closely related to urban industrial structure, population scale and urban construction situation. These difference will be used to further explain the mechanism of related to local land use and cover changes.

Table 1 shows the descriptive statistical analysis of HLM regression. Panel data of Yinchuan and other cities arranged from year 2009 to 2019 are used for analysis. Variables include three dimensional ecological footprint biological account, local real GDP, local nominal GDP, lands areas and scale efficiency. Cities are divided into four categories based on population size.

Table 1. Eigenvalues of HLM regression variables

| Variable | Obs | Mean   | Std. Dev. | Min  | Max  |
|----------|-----|--------|-----------|------|------|
| ef3d     | 110 | 6.150727 | 1.01919  | 4.127868 | 7.646883 |
| ip       | 110 | 2.7    | 0.7845995 | 1    | 4    |
| realgdp  | 110 | 7.198384 | 1.157705 | 5.225155 | 9.859392 |
| land     | 110 | 9.448637 | 0.9855921 | 7.783724 | 10.6613 |
| incrs    | 110 | -0.0628283 | 0.0473741 | -0.17304 | 0 |
| gdp      | 110 | 7.345362 | 1.132486 | 5.225155 | 10.07021 |

3.2 Null model results

According to the size of urban population, these 10 cities are divided into four groups: 1. Guangzhou; 2. Dongguan, Ganzhou; 3. Yinchuan, Wuzhong, Yulin, Shaoguan, Qingyuan, Yan’an; 4. Shizuishan. Ip Group1 for Guangzhou city $u_1$ is 0.0502136 and $u_0$ is 0.0702613; Ip Group2 for Dongguan city and Ganzhou city $u_1$ is 0.04064 and $u_0$ is 0.6378765; Ip Group3 for Yulin city, Shao guan city, Qingyuan city and Yanan city $u_1$ is 0.0502136 and $u_0$ is 0.4851803; Ip Group4 for Shizuishan city $u_1$ is 0.0145514 and $u_0$ is 0.2229575, where $u_1$ represents the slope and $u_0$ represents the intercept, which indicate the rationality of grouping.

And there are four model underlying HLM, respectively are model 1 (null model), model 2(random intercept and fixed slope), model 3(Random intercept and random slope) and model 4 (full model). we compare the results of the full models.

3.3 Regression results analysis

For the estimation of the model Akaike information criterion, the reduction of Akaike information value can improve the model was better fitted. The AIC criterion in this study respectively is 293.2603, -155.8727, -164.1787 and -169.1141 under the null model, random intercept model, random intercept slope model and full model. The results show that the multilayer linear model has a better fitness than the general linear regression model and is more suitable for this study. The estimation results and fitting test results of the random intercept model, the random intercept slope model and the full model are reported respectively.

The full model fitting results are as follows:

\[ ef3d_y = \beta_0 + \beta_1 land_y + \beta_2 rea\log dp_y + e_y \]  \hfill (1)
\[ \beta_0 = \gamma_{00} + \gamma_{01} \ln crs_y + \mu_{0j} \]  \hfill (2)
\[ \beta_1 = \gamma_{10} + \gamma_{11} \ln crs_y + \mu_{1j} \]  \hfill (3)
\[ ef3d_y = \gamma_{00} + \gamma_{01} \ln crs_y + \mu_{0j} + \gamma_{10} land_y + \gamma_{11} \ln crs_y land_y + \mu_{1j} land_y + \beta_2 rea\log dp_y + e_y \]  \hfill (4)
Full model indicates three-dimensional urban ecological footprint of research city is affected by the land inputs and real GDP. There are different influences due to different population groups bring the intercept and slope change. In this model lands input is the transmission elements which bring between-group variance among different groups. Land input in the grouping variable is affected by the city scale efficiency of total factor productivity. Effects of land elements and total factor productivity on the biological accounts of three-dimensional ecological footprints in urban groups of different population sizes estimated by random intercept model, the random intercept slope model and the complete model are reported respectively.

3.3.1 Random intercept and fixed slope model and Random intercept and random slope model

The estimations of the random intercept model and the random intercept slope model are model 3 and mode 4 respectively. Table 2 shows the regression results of the random intercept model and the random intercept slope model. The regression results shows that the coefficients of land and real GDP are both positive. The coefficient of land random intercept model is 1.068521, and the coefficient of random intercept slope model is 1.066046. There is no obvious difference between the two slope. The coefficient of the random intercept model of real GDP is 0.0680272, and the coefficient of the random intercept slope model is 0.122755. It shows that the effect of GDP is enhanced when the slope of the land varied following with the size of the population in different cities. The random intercept model and the random intercept slope model show that the increase of real GDP and the increase of land input will lead to the increase of the biological account of three-dimensional ecological footprint, and thus indicating the deepening of human's occupation of natural resources.

\[
ef3d_{ij} = \beta_0 + \beta_1 land_{ij} + \beta_2 realgdp_{ij} + \mu_{ij} + \epsilon_{ij}
\] (model 3)

\[
ef3d_{ij} = \beta_0 + \beta_1 land_{ij} + \beta_2 realgdp_{ij} + \mu_{ij} + \mu_{ij} land_{ij} + \epsilon_{ij}
\] (model 4)

| Table 2. Regression results (1). |
|----------------------------------|
| **Random intercept and fixed slope model** | **Random intercept and random slope model** |
| ef3d | Estimate | ef3d | Estimate |
| land | 1.068521*** | land | 1.066046*** |
| | (-0.0129211) | | (-0.0389942) |
| realgdp | 0.0680272*** | realgdp | 0.122755*** |
| | (-0.0169601) | | (-0.018311) |
| _cons | -4.395902*** | _cons | -4.76729*** |
| | (-0.2132267) | | (-0.4137256) |
| ip: | Var(_cons) | Var(_cons) | Var(land) | (-0.003477) |
| | 0.0414733 | (-0.0307632) |
| Var(Residual) | 0.0110621 | Var(_cons) | 0.4064371 |
| | (-0.0015214) | | (-0.3458117) |
| AIC | -155.8727 | Var(Residual) | 0.0086817 |
| | (-0.0012179) | | (-0.0012179) |
| AIC | -164.1787 |

(Standard errors in parentheses:* p<0.05,** p<0.01,*** p<0.001)
3.3.2 Regression results of the full model

The full model regression results in Table 3-left column show that the increase of total factor productivity will reduce the occupation of natural resources by human activities, while the increase of real GDP and land input will increase the occupation of natural resources by human activities. The interaction term indicates that the improvement of technical efficiency will strengthen the positive effect of land input on EF3D, and has a significant moderating effect. At the same time, by comparing the random intercept fixed slope model, intercept and random slope model and the full model, we can also find that, in a situation of different city group, because of the inter-group difference of the land input factors influence degree, the influence of real GDP are enhanced. That is to say, on a premise of considering the groups of different population sizes, due to the inter-group difference in the influence degree of land input factors, the impact of real GDP on three-dimensional ecological footprint has a significant strengthening trend. This indicates that the mediating effect of land input and the moderating effect of total factor productivity have an intensification difference on the positive impact intensity of real GDP towards three-dimensional ecological footprint. Robustness test results show in Table 3 right column are all significant at the 1% level, indicating the robustness of the relationship among variables.

Table 3. Regression results (2).

|                | ef3d(1)   | Coef.(1) | ef3d(2)   | Coef.(2) |
|----------------|-----------|----------|-----------|----------|
| lncrs          | -12.01274** | (-5.249063) | -12.01274*** | (-4.632525) |
| realgdp        | 0.1018642*** | (-0.0253987) | 0.1018642*** | (-0.0392958) |
| land           | 1.115881*** | (-0.0358677) | 1.115881*** | (-0.0470166) |
| c.lncrs#c.land | 1.291742**  | (-0.5327014) | 1.291742*** | (-0.4546412) |
| _cons          | -5.056307*** | (-0.4387745) | -5.056307*** | (-0.3842426) |
| ip             |           |          |           |          |
| Var(lnd)       | 0.0017711  | (-0.0019607) | 0.0017711  | (-0.0010279) |
| Var(_cons)     | 0.2244214  | (-0.2205939) | 0.2244214  | (-0.1728338) |
| Var(Residual)  | 0.0008242  | (-0.0011775) | 0.0008242  | (-0.0032408) |
| AIC            | -169.1141  |          |           |          |

(Standard errors in parentheses:* p<0.05,** p<0.01,*** p<0.001)

3.3.3 Robustness test of model

Bootstrap method and substitution variable method were used to test the robustness of the full model. The Z value of Bootstrap method was 14.64, and P>Z was significant at the level of 0.05%. Bootstrap Std.err is 0.0095521 indicates that model relationship is stable under the sample. In addition, for the final form estimate of the model, real GDP is replaced by nominal GDP, and the results are basically the same as the original results (Table 4), indicating the robustness of the model.
Table 4. Test results of substitution variable method.

| Variable | Coefficient | Standard Error |
|----------|-------------|----------------|
| GDP      | 0.09204*    | (-0.0542767)   |
| Lncrs    | -12.27842** | (-5.364671)    |
| c.Lncrs#c.land | 1.327302*** | (-0.5179832)   |
| _cons    | -4.984711***| (-0.4885845)   |

(ip:)

| Variable | Coefficient | Standard Error |
|----------|-------------|----------------|
| Var(land) | 0.0012055 | (-0.0008573)   |
| Var(_cons) | 0.1635858 | (-0.1460749)   |
| Var(Residual) | 0.0079013 | (-0.0026253)   |

(Standard errors in parentheses: * p<0.05, ** p<0.01, *** p<0.001)

4. Conclusions and policy recommendations

Based on empirical evidence and hypothesis of environmental kuznets, this paper applied the improved three-dimensional ecological footprint method and multiple linear regression analysis for the empirical analysis. This paper further improved prior research of Dongguan city’s land use cover and trend of the ecological footprint and total factor productivity evaluation, and further explores cities of different urban population scales, The hierarchical difference of influencing factors of its ecological footprint. This paper measured the three-dimensional ecological footprint and total factor productivity, and constructed a multi-layer linear model to verify the three hypotheses previously proposed. The study shows that total factor productivity plays an important role in regional and urban sustainable development. From the evidences of 10 cities of China, it can be seen that when GDP growth to a certain stage, China has entered a new stage of sustainable development, green development concept of the ecological environment improvement and transformation and upgrading of traditional industries, bring a change to ecological footprint, which means compare with before it has a positive impact, the original population and land use model bring a negative effect for ecological footprint and for regional development. However, with the changes brought by industry and new development concept, some interactive transmission effect has been produced to reverse the original trend. This study quantitatively analyzes the different characteristics and influencing factors of ecological footprint and ecological product value of cities characterized by land, natural resources and their derived industries, and their different effects on urban and regional development. The study also shows that the multi-layer linear regression model has obvious advantages in solving the transmission mechanism of resources, economy and environment. In this study, multiple linear model, a general linear regression model fitting effect is much better. It can describe and reflect the different population size of the three-dimensional urban ecological footprint of the differences between groups, and when the slope of land inputs varies, the conductive follow-up effect and the impact of total factor productivity in three-dimensional urban ecological footprint have obvious differences between groups. It shows that land, population and technology factors have different impacts on three-dimensional ecological footprint. This plays an important role in formulating and evaluating the effect of policy implementation and formulating differentiated and targeted development plans.
The depth and size of three-dimensional ecological footprint is an objective standard to reflect whether ecological product value can meet the demand of future and current ecological carrying capacity and human life’s need for the environment. It has a same mean that whether local ecological account can satisfy people pursuit for the value of ecological products. In the study, most cities have a positive development trend of ecological footprint. And these cities are mostly belong to energy resources city, mining land proportion is higher than the national average. It also reflects the Yinchuan, Yan’an, Shizuishan, Ganzhou, Qingyuan, Yulin such kind of resource-based industries as the leading industry of local has not so much inverse refect to local ecological footprint. Local resources and environment protection appears positive momentum, The economic and ecological achievements of green mine construction can be evaluated through this aspect. These positive changes are of great significance for us to continue to implement the concepts of sustainable development and green development, and to properly handle the relationship between population, resources, environment and economic development.

The implications of this study suggest that the increase of TFP plays an important role in the value of ecological products and the improvement of ecological footprint, and China should continue to improve TFP at both the urban and industrial levels, especially to evaluate the benefits of technology and economies of scale. At the same time, the research also shows that the urban population size has an impact on the three-dimensional ecological footprint, and a reasonable urban population size is of great significance to achieve sustainable development.

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