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Research on the Relationship between FDI, Energy Consumption Intensity and Economic Growth Based on Spatial Effect

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Abstract: In order to reveal the driving factors of China ' s economic growth, based on the panel data of 28 provinces from 2010 to 2019, the spatial Durbin model is used to study the relationship between foreign direct investment, energy consumption intensity and economic growth. The results show that energy consumption intensity has a negative impact on the economic growth of the region, and has a positive spillover effect on other adjacent regions. Foreign direct investment has a positive impact on local energy consumption, and has a positive spillover effect on other neighboring regions.

Keywords: FDI, Energy consumption intensity, Economic growth, Spatial Dubin model.

1. Introduction

The study of factors influencing economic growth has always been a hot topic, especially in the light of the global economic downturn. With a relatively high GDP growth rate of around 6%, China remains the locomotive of the world's economic recovery. In particular, the Chinese economy has maintained a steady growth rate since the introduction of the "carbon peaking" and "carbon neutral" targets. Studying the relationship between foreign direct investment, energy consumption and economic growth can be useful in explaining the steady growth of the domestic economy and in finding the impetus for the global economic recovery. In addition, the recently proposed dual domestic and international circulation system, which emphasises the dominance of the major domestic circulation, signals that the circulation of production, distribution, circulation and consumption between multi-dimensional regions will be opened up, and the importance of studying the factors influencing economic growth based on a spatial perspective becomes more prominent.

Economic growth is influenced by a number of factors such as energy consumption and foreign direct investment, and a large number of scholars have made certain research results in this regard. In terms of research on the relationship between energy consumption and economic growth, Ma Qianli and Fu Daishan (2018 studied the relationship between energy consumption, technological progress and economic growth and found that both energy consumption and technological progress play a role in promoting economic growth; Dong Yu (2020)studied the dynamic correlation between China's industrial economic growth and energy consumption and found that there is a two-way impact between economic growth and energy consumption effect. In terms of foreign direct investment and energy consumption, Chen Xingping and Zou Jia (2019)studied the impact of foreign direct investment on energy consumption in Shaanxi Province and found that the growth of both foreign direct investment and the number of domestic investments had a positive effect on energy consumption in Shaanxi Province; in terms of foreign direct investment and economic growth, Zhao Hongzhong and Shi Shasha (2021)studied the impact of FDI on high-quality economic development and found that FDI promoted In terms of FDI and economic growth, Zhao Hongzhong and Shi Shasha (2021)studied the impact of FDI on high-quality economic development and found that FDI promoted high-quality economic development with positive spatial effects.

Most of the existing literature focuses on the relationship between energy consumption and economic growth, foreign direct investment and economic growth and foreign direct investment and energy consumption, but there is a lack of research that integrates the three into a unified system, and there is a lack of research on the relationship based on spatial effects. The innovation of this paper is to incorporate FDI, energy consumption intensity and economic growth into the same system, construct a joint spatial panel data equation and use the spatial Durbin model to study the relationship between the three.

2. Model Construction, Variable Interpretation and Sample Sources

2.1. Model construction and interpretation of variables

In line with the endogenous growth theory, which states that an economy can grow sustainably independently of external forces, the first model of economic growth constructed in this paper integrates the effects of energy consumption intensity, human capital, fixed capital stock and R&D investment on economic growth by:

$$LNGDP_{it}=\alpha_{1it}+\beta_{11}LNEI_{it}+\beta_{12}LNHC_{it}+\beta_{13}LNSA_{it}+\beta_{14}LNR\&D_{it}+\varepsilon_{1it} \quad (1)$$

where the subscripts i and t denote province and time respectively; $LNGDP_{it}$ denotes the logarithm of economic aggregates measured by gross regional product; $LNGDP_{it}$ denotes the logarithm of energy intensity, i.e. the logarithm of energy consumption per unit of GDP; $LNHC_{it}$ is the logarithm of human capital, which is measured using the average years of education of employed persons; $LNSA_{it}$ is the logarithm of fixed capital stock. The calculation of fixed capital stock refers to the calculation method of scholars Zhang Jun and Zhang Yuan (2003); $LNR\&D_{it}$ is the logarithm of scientific research and experimental development input; is the intercept term; and is the residual term.

At this stage, studies have shown that foreign direct investment has a significant impact on energy consumption . In addition, there is already a consensus among academics that the industrial structure of different regions has a significant impact on energy consumption, so the second model constructed in this paper is

$$LNEI_{it}=\alpha_{2it}+\beta_{21}LNFDI_{it}+\beta_{22}LNISA_{it}+\varepsilon_{2it} \quad (2)$$

Where $LNGDP_{it}$ is the logarithm of foreign direct investment; $LNSA_{it}$ is the logarithm of the industrial structure of each region, which is expressed as the product of the weights of different industries in each region and the share of value added of each industry in GDP; is the intercept term of model 2; and is the residual term of model 2

2.2. Sample source

The sample data for this paper is obtained from the China Statistical Yearbook, China Population Statistical Yearbook, China Labour Statistical Yearbook and the National Statistical Bulletin of Science and Technology Funding Inputs. Due to missing data, this paper selects data from 28 provinces from 2010-2019 after excluding Tibet, Qinghai, Hainan, Hong Kong, Macau and Taiwan. As indicators for individual provinces are missing in some years, the missing values were filled in using interpolation. To eliminate heteroskedasticity, all data are logarithmised in this paper. The data were processed and analysed using GeoDa1.18 and STATA16.0.

3. Empirical Analysis

3.1. Spatial autocorrelation analysis

3.1.1. Global spatial autocorrelation analysis

According to the first law of geography, geographical things or attributes are correlated with each other in terms of their spatial distribution, and verification of this correlation requires the use of the Moran index. For the analysis of global spatial autocorrelation, the global Moran index, which describes the average degree of correlation of all spatial units with other surrounding areas throughout the region, is usually used:

$$\text{Global Moran'I}=\frac{n}{S}\times\frac{\sum_{i=1}^{n}\sum_{i=1}^{n}w_{ij}(x_i-\bar{x})(x_j-\bar{x})}{\sum_{i=1}^{n}(y_i-\bar{y})^2} \quad (3)$$

$$S=\sum_{i=1}^{n}\sum_{j=1}^{n}w_{ij}$$

where n is the total number of spatial units; xi and xj denote the attribute values of the ith spatial unit and the jth spatial unit respectively; is the average of all spatial unit attributes; and is the spatial weight. The global Moran index has a range of [-1,1], and values greater than zero and less than zero indicate that the attributes of cells are clustered in space due to similarity and dissimilarity, respectively, with larger values indicating higher clustering due to similarity and smaller values indicating higher clustering due to dissimilarity.

This paper uses GeoDa1.18 software to construct a spatial weight matrix and calculate the global Moran index for the three indicators LNFDI, LNEI and LNGDP from 2010-2019 to determine whether there is spatial autocorrelation or spatial dependence of the indicators. The spatial weight matrix was adopted as the 0-1 matrix of the Queen neighbourhood after standardisation.

The data in Table 1 show that the Moran indices of the three variables of foreign direct investment, energy consumption and economic growth in 28 provinces of China from 2010-2019 are all positive and pass the 5% significance level test, indicating that all three variables are spatially clustered in all years due to similarity, i.e. all have significant global spatial autocorrelation.

Table 1. Global spatial autocorrelation analysis of variables

Indicators	LNFDI		EI		LNGDP	
Year	Moran'I	P-value	Moran'I	P-value	Moran'I	P-value
2010	0.3130	0.007	0.3423	0.003	0.2527	0.015
2011	0.3249	0.004	0.4083	0.001	0.2906	0.009
2012	0.3713	0.002	0.4251	0.001	0.3117	0.002
2013	0.3678	0.005	0.3326	0.005	0.2374	0.018
2014	0.3811	0.003	0.4046	0.003	0.3120	0.005
2015	0.2646	0.013	0.3720	0.001	0.2603	0.012
2016	0.2961	0.015	0.4017	0.002	0.3546	0.002
2017	0.5381	0.001	0.4412	0.001	0.3880	0.001
2018	0.5403	0.001	0.4575	0.001	0.3801	0.002
2019	0.3516	0.003	0.4952	0.001	0.4075	0.002

3.1.2. Local spatial autocorrelation analysis

Local spatial autocorrelation is primarily used to explore the spatial location of agglomeration centres, i.e. which specific units in a region show characteristics of agglomeration due to similarity or dissimilarity. The local Moran index is calculated by the formula:

$$\text{Local Moran'I}=\frac{(x_i-\bar{x})}{S^2}\sum_{j=1}^{n}w_{ij}(x_i-\bar{x}) \quad (4)$$

The value of local Moran index ranges from [-1,1], a positive value indicates that the spatial unit is clustered with neighbouring spatial units due to similarity, i.e. high-high clustering or low-low clustering; a negative value indicates that the spatial unit is clustered with neighbouring spatial units due to dissimilarity, i.e. low-high clustering or high-low clustering.

Using GeoDa1.18 software, local spatial autocorrelation analysis was conducted on foreign direct investment, energy consumption intensity and economic growth variables for 28 provinces in China, and LISA cluster analysis was performed with data from 2010 and 2019, and the results are shown in Tables 2 and 3.

The results of the LISA cluster analysis in 2010 show that for foreign direct investment, Gansu and Yunnan provinces show LL-type clustering, i.e. low foreign direct investment utilisation regions and are surrounded by other low foreign direct investment utilisation regions. For energy consumption, Inner Mongolia, Heilongjiang and Liaoning are HH-type clusters, where provinces with high energy consumption per unit of GDP are surrounded by other provinces with high energy consumption per unit of GDP; Zhejiang, Fujian, Jiangxi and Anhui are LL-type clusters, where provinces with low energy consumption per unit of GDP are surrounded by other provinces with low energy consumption per unit of GDP. For economic growth, Anhui, Shandong, Jiangsu and Shanghai are HH-type clusters, with high economic growth provinces surrounded by other high economic growth provinces; Inner Mongolia is HL-type clusters, with high economic growth provinces surrounded by other low economic growth provinces.

The results of the 2019 LISA cluster analysis show that for FDI, Jiangxi, Zhejiang and Hubei are HH-type clusters, with high FDI utilising provinces surrounded by other high FDI utilising provinces; Xinjiang is LL-type, with low FDI utilising provinces surrounded by other low FDI utilising provinces; and Sichuan is HL-type, with high FDI utilising provinces surrounded by other low F For energy consumption, Inner Mongolia, Jilin, and China For energy consumption, Inner Mongolia, Jilin, Liaoning, Gansu and Ningxia are of type HH, with provinces with high energy consumption per unit of GDP surrounded by other provinces with high energy consumption per unit of GDP; Zhejiang and Jiangxi are of type LL, with provinces with low energy consumption per unit of GDP surrounded by other provinces with low energy consumption per unit of GDP. For economic growth, Shandong, Jiangsu, Anhui, Zhejiang, Fujian and Shanghai are HH-type, with high economic growth provinces surrounded by other high economic growth provinces; Jiangxi is LH-type, with low economic growth provinces surrounded by other high economic growth provinces; and Inner Mongolia, Gansu and Ningxia are LL-type, with low economic growth provinces surrounded by other low economic growth provinces.

Table 2. LISA cluster analysis for 2010 variables

类型	LNFDI	EI	LNGDP
HH (High-High Aggregation Zone)		neimenggu**, heilongjiang*, liaoning*	anhui**, shandong*, jiangsu*, shanghai*
LH (Low-High Aggregation Zone)			jiangxi*
LL (Low-Low Aggregation Zone)	gansu*, yunnan*	zhejiang**, fujian**, jiangxi*, anhui*	
HL (High-Low Aggregation Zone)			neimenggu*

***, ** and * represent 0.1% significance level, 1% significance level and 5% significance level respectively

Table 3. LISA cluster analysis for 2019 variables

TYPE	LNFDI	EI	LNGDP
HH (High-High Aggregation Zone)	Jiangxi*,Zhejiang*,Hubei*	Neimengu***, Jilin*, Liaoning*, Gansu**, Ningxia*	Shandong*, Jiangsu*, Anhui**, Zhejiang*, Fujian*, Shanghai*
LH (Low-High Aggregation Zone)			Jiangxi**
LL (Low-Low Aggregation Zone)	Xinjiang*	Zhejiang*, Jiangxi**	Neimenggu**, Gansu*, Ningxia*
HL (High-Low Aggregation Zone)	Sichuan**		

***, ** and * represent 0.1% significance level, 1% significance level and 5% significance level respectively

3.2. Study on the relationship between foreign direct investment, energy consumption and economic growth based on the spatial Durbin model

3.2.1. Energy consumption and economic growth

In order to choose the best regression model, this paper firstly conducted a fixed effects regression on model 1 and judged whether it was suitable to use a fixed effects model or a mixed effects model through the F-test. The regression results showed that the variables included in the model passed the significance test, and the F-test result of the model was F(28, 257) = 152.84, with a significance of 0.000, so the original hypothesis should be rejected and the fixed effects The fixed effect model is more appropriate. The Hausman test of the fixed effects model and the random effects model showed that chi2(4) = -153.23, so the original hypothesis should be rejected and the fixed effects model should be used. The results of the spatial panel Durbin model with fixed effects are shown in Table 4.

The spatial Durbin model with fixed effects shows that the regression coefficient of LNEI is negative, indicating that energy consumption intensity has a negative impact on economic growth, i.e. the higher the energy consumption per unit of GDP, the lower the economic growth rate. rho indicates that the spatial autocorrelation coefficient of the model is positive and passes the significance test. Further decomposition of the spatial effects of the model, analysis of the direct effect found that the coefficient of the independent variable energy consumption intensity was negative and passed the significance test, indicating that energy consumption intensity has a negative impact on the economic growth of the region; analysis of the indirect effect found that the coefficient of energy consumption intensity was positive and passed the significance test, indicating a positive spillover effect on the economic growth of other neighbouring regions; analysis of the total effect found that the coefficient of energy consumption intensity was negative and passed the significance test; analysis of the total effect The coefficient of energy consumption intensity was found to be negative and passed the significance test, indicating that energy consumption intensity has a negative impact on the economic growth of all regions.

Table 4. Model 1 Spatial panel Durbin model with fixed effects

LNGDP	Coef.	Std. Err.	P>|z|		Coef.	Std. Err.	P>|z|
Mian				LR_Direct			
LNEI	-.8133618	.0186087	0.000	LNEI	-.7974252	.0204515	0.000
LNHC	.3912897	.212973	0.066	LNHC	.4241994	.199548	0.034
LNSA	.1678696	.0449488	0.000	LNSA	.1898539	.0461471	0.000
LNRD	.1150788	.0341064	0.001	LNRD	.1102199	.0319808	0.001
Wx				LR_indirect			
LNEI	.4770536	.0740377	0.000	LNEI	.1931386	.0605238	0.001
LNHC	.1482734	.2944583	0.615	LNHC	.5423392	.3978199	0.173
LNSA	.0554476	.0820563	0.499	LNSA	.2169935	.1429747	0.129
LNRD	-.0679149	.0676717	0.316	LNRD	-.0320553	.1013032	0.752
				LR_Total			
Spatial				LNEI	-.6042866	.0710951	0.000
rho	.4410682	.0744723	0.000	LNHC	.9665386	.421492	0.022
Variance				LNSA	.4068474	.1661985	0.014
Sigma2_e	.0033063	.0002815	0.000	LNRD	.0781645	.1118293	0.485

3.2.2. Foreign direct investment and energy consumption

Similarly, a fixed effects regression was run on model 2 in order to choose between a fixed effects model and a mixed effects model. The regression results showed that the key variable LNFDI included in the model passed the significance test and the F-test result for the model was F(28, 259) = 20.06, with a significance of 0.000 and a significant fixed effect. The Hausman test of the fixed effect model and the random effect model showed chi2(2) = 322.08, with a significance of 0.000, indicating that the Hausman test result was significant and the original hypothesis should be rejected and the fixed effect was more reasonable. The results of the spatial panel Durbin model with fixed effect for model 2 are shown in Table 5.

The results of the spatial panel Durbin model with fixed effects show that the coefficient of LNFDI is positive, indicating that foreign direct investment has a positive impact on energy consumption intensity. rho indicates that the autocorrelation coefficient of the spatial model is positive and passes the significance test. The spatial effects of the model were further decomposed and the direct effect was found to be positive and passed the significance test, indicating that foreign direct investment has a positive impact on the energy consumption intensity of the region; the indirect effect was found to be positive and passed the significance test, indicating that foreign direct investment has a positive impact on the energy consumption intensity of other neighbouring regions; the total effect was analysed and the coefficient of LNFDI was positive and passed the significance test. The coefficient of LNFDI was found to be positive and passed the significance test, indicating that FDI has a positive impact on the energy consumption intensity of all regions.

Table 5. Model 2 Spatial panel Durbin model with fixed effects

LNEI	Coef.	Std. Err.	P>|z|		Coef.	Std. Err.	P>|z|
Mian				LR_Direct			
LNFDI	.0607368	.0181332	0.001	LNFDI	.0735582	.0202278	0.000
LNISA	.1508917	.0487707	0.002	LNISA	.1196625	.0475793	0.012
Wx				LR_indirect			
LNFDI	.0322845	.0282004	0.252	LNFDI	.1397592	.054369	0.010
LNISA	-.2537497	.0957034	0.008	LNISA	-.3378199	.1837657	0.066
Spatial				LR_Total			
rho	.559578	.0491593	0.000	LNFDI	.2133174	.065939	0.001
Variance				LNISA	-.2181574	.1993876	0.274
Sigma2_e	.041607	.0035298	0.000				

4. Conclusions and Insights

This paper empirically investigates the relationship between foreign direct investment, energy consumption intensity and economic growth using a spatial Durbin model and coupling degree analysis based on panel data from 2010-2019 for 28 provinces in China, and the research findings and insights obtained are as follows:

(1) The results of the spatial Durbin model of energy consumption and economic growth show that energy

consumption has a negative impact on the economic growth of the region, but has a positive spillover effect on other adjacent regions. At this stage, China's economic development should not rely solely on the expansion of the production capacity of high-energy-consuming enterprises, but should also focus on controlling energy consumption, vigorously develop high-tech industries, improve the quality of economic development and firmly achieve the goal of "double carbon".

(2) The results of the spatial Durbin model of foreign direct investment and energy consumption intensity show that foreign direct investment has a positive impact on the energy consumption intensity of the region, and also has a positive spillover effect on the energy consumption intensity of other neighbouring regions. Since higher energy consumption intensity values indicate higher energy consumption per unit of GDP, China should pay attention to guiding the flow of foreign direct investment and increase investment in high-tech industries, while continuing to vigorously promote supply-side structural reform and eliminate backward production capacity to achieve low-carbon and high-quality economic development.

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