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Nonlinear Relationship of Energy Consumption and FDI Based on Panel Smooth Transition Regression Model

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Abstract. China's economy has achieved rapid development since the reform and opening up, with an average annual growth rate around 10%.At the same time, energy consumption is also rising. This paper investigates the relationship between energy consumption and foreign direct investment(FDI) by adopting a panel data of 30 provinces in China during 1995–2014 to estimate the panel smooth transition regression model(PSTR).It is found that energy consumption and FDI has significant non-linearity relationship. And with the threshold variable industrial structure changes, there is smooth transition between high and low regime. Last of all, reflecting on the defects of the current economic mechanism, we propose some policy implication to achieve the energy-saving goal.

Introduction

According to the 66th edition of 《BP World Energy Statistical Yearbook (2017)》,China accounts for 23% of global energy consumption and 27% of global energy consumption growth [1] .FDI plays an important part of China's economic development and is considered one of the most stable components of capital flows. At the guidance of the performance evaluation mechanism, local governments eased restrictions on FDI and offered many tax incentives to attract foreign capital. Lenard (1984) proposed the "Industrial Escape Hypothesis" and the "Pollution Paradise Hypothesis", arguing that more stringent environmental policies in developed countries have forced the transfer of high-energy-consuming and high-polluting industries in their territories to developing countries. In the meantime, developing economic and attracting FDI will reduce their own requirements both in environmental protection and energy consumption requirements [2] .Therefore., FDI has a great impact on industrial structure, energy consumption and consumption structure. Blackman (1999) analyzed China's FDI policy in the energy field and concluded that FDI is conducive to the improvement of China's energy efficiency [3] .Mielnik and Goldemberg (2002) conducted a statistical regression on the FDI and energy intensity of 20 developing countries. It is found that due to the spillover effect of FDI technology, the increase of FDI can significantly reduce the intensity of energy consumption [4] .Based on the panel data of China's provinces, Li Dong (2008) investigated the impact of industrial structure, opening up, marketization and energy consumption structure on energy efficiency. He pointed out that the role of FDI in promoting China's energy efficiency is not significant [5] . Chor Foon Tang and Bee Wah Tan (2014) analyse the causal relationship among energy consumption, economic growth, relative price, financial development and foreign direct investment in Malaysia using a multivariate framework. They find that energy consumption and economic growth Granger causes each other in the short and long run. In addition, both FDI-led growth and finance-led growth hypotheses are also supported by the findings from this study [6] .Mariem Brahim and Houssem Rachdi (2014) found that only countries with good institutions can exploit the advantages of FDI on growth [7] .Ruguo Fan and Xingyu Meng (2015) constrcted an analytical framework of the impact of FDI technology spillover on energy efficiency. They found that the impact of technology spillover on energy efficiency in China shows significant spatial differences across the country [8] .The current scholars do not make a consistent conclusion on the impact of FDI on energy consumption. Compared with the previous studies on the linear relationship between FDI and energy consumption, this paper uses the threshold regression method to build a non-linear panel data model, that is, to test how FDI affects energy consumption in different regimes, Thus to explore a new perspective for improving energy efficiency.

Data and methodology

Panel Smooth Transition Regression

In this paper, we use panel smooth transition regression (PSTR) model to study. Because the PSTR model could divide the observations into a small number of homogenous regimes with different coefficients in different regimes. Furthermore, when the observations moving from one regime to another, the PSTR model allow the regression coefficients to change gradually. Thus it could avoid the problem of estimation bias due to the neglect of parameter heterogeneity in the panel model. The basic PSTR model with two extreme regimes is defined as follows:

$$y_{it} = \mu_i + \beta_0 x_{it} + \sum_{j=1}^{r} \beta_j x_{it} g_j({q_{it}}^j; \gamma_j, c_j) + \varepsilon_{it}$$

where i =1,⋯,N, is the individual entity, t =1,⋯,T, is time,y_{it} is a scalar,x_{it} is a k-dimensional vector of time-varying exogenous variables,μ represents the fixed individual effect,μ_i is an error term, and $g(q_{it}; \gamma, c)$ is a continuous transition function. Among these,q_{it} is a transition variable and is normalized to be bounded between 0 and 1,γ is a transition speed, and c is a transition threshold value.

The most common conversion function is a logic function:

$$g(q_{it}; \gamma, c) = (1 + \exp(-\gamma \prod_{j=1}^{m} (q_{it} - c_j))^{-1}$$

（i =1,...,N ， t=1,...,T,$\gamma > 0$， $c_1 \le c_2 \le \cdots \le c_m$）

where c=(c1,⋯,cm) is an m-dimensional vector of location parameters and the slope parameter γ determines the smoothness of the transitions. The restrictionsγ N 0 and $c_1 \leqslant c_2 \leqslant \cdots \le c_m$ are imposed for identification purposes. In practice it is usually sufficient to consider m=1 and m=2,as these values allow for commonly encountered types of variation in the parameters. For m=1,the type of transition function is logistic, and m= 2 means that the transition function is exponential.

Data and Descriptions of Variables

In order to explore t the relationship between energy consumption and foreign direct investment, this study calculates these primary variables: the explained variable energy consumption intensity (ENR),the core explanatory variable FDI, the control variables industrial structure (STR),the economic growth (GDP) and the urbanization rate (URB).And select the industrial structure (STR) as the threshold variable to analyze the Impact of FDI on Energy consumption in different threshold regions. The empirical model adopted in this study can be presented as follows:

$$ENR_{it} = \mu_i + \beta_0 FDI_{it} + \beta_1 STR_{it} + \beta_2 GDP_{it} + \beta_3 URB_{it} + \sum_{j=1}^{r} \beta_j x_{it} g_j({q_{it}}^j; \gamma_j, c_j) + \varepsilon_{it}$$

This paper selects the panel data of 30 provinces in our country from 1995 to 2014 for empirical research.

ENR: Energy consumption intensity, represents the ratio of provincial energy consumption to provincial GDP. The unit is tons / ten thousand yuan. Data is from the China Energy Statistics Yearbook.

FDI: The level of foreign direct investment, represents the provincial share of nationwide foreign direct investment. Data is from China's economic and social development statistics database.

STR: The Industrial Structure, represents the provincial share of nationwide tertiary industry GDP. Data is from the iFinD database.

GDP: Per capita GDP, represents the level of economic growth. The unit is million / person. Data is from the iFinD database.

URB: Urbanization, represents the provincial share of nationwide urban population. Data is from the National Bureau of Statistics.

Empirical Analysis

Descriptive Statistics of the Data

Table 1 Descriptive statistics

	Minimum	Maximum	Average	Standard deviation
ENR	0.00031	7.81856	1.71072	1.15414
FDI	0.27665	0.77948	0.40010	0.07509
STR	0.00013	0.32008	0.04815	0.06410
GDP	0.18260	10.52313	2.09380	1.94714
URB	0.20390	0.89600	0.45844	0.16019

Empirical Test

Linear Test

The preliminary work of estimating the PSTR model requires a non-linear test of the panel data to determine if it is necessary to use the nonlinear model. Therefore, the null hypothesis of the test is that the model is a linear model (H0:r=0).That is, there is only one mechanism in the system. In this case, a linear model should be used. The alternative assumption is that the model is a non-linear model (H1:r=1).There are at least two mechanisms in the system, and it is indeed necessary to use a non-linear model. This article selects LM,LMF and LRT three statistics to test whether there is a real nonlinear relationship between energy consumption intensity and FDI. From Table 2,the LM,LMF and LRT results clearly reject the null hypothesis of the linear model. The test results provide sufficient evidence for the non-linear results between energy consumption intensity and FDI.

Table 2 Linear test

Wald Tests (LM):	W =	100.007	pvalue = 0.000
Fisher Tests (LMF):	F =	9.301	pvalue = 0.000
LRT Tests (LRT):	LRT =	109.401	pvalue = 0.000

Sequence Homology Test

In this paper, we use the sequence homogeneity test to determine the value of m in a logic function. In fact, assuming that m = 1 and m = 2 are sufficient for the research problem, m = 1 is monotonically increasing for two regimes and m = 2 is for the three regimes to be symmetric or exponential. Therefore, two values already take into account the parameters of all models that are commonly encountered. When denying H2 hypothesis is strong, then m = 2,otherwise choose m = 1.As can be seen from Table 3,in the model, m = 1 is optimal for our model.

Table 3 Sequence homology test

Select m=2 if the rejection of H02 is the strongest one,otherwise select m=1.		
H03:B3=0	F3 =0.936	pvalue = 0.510
H02:B2=0|B3=0	F2 =2.477	pvalue = 0.004
H01:B1=0|B2=B3=0	F1 =5.530	pvalue = 0.000

Residual Nonlinear Effects Test

On the basis of passing the non-linear test, the "residual non-linear effect test" needs to be further carried out. The hypothesis of this test is that there is only one transition function (H0:r=1).The alternative hypothesis includes at least two transition functions (H1:r=2).If we reject the null hypothesis again, we continue to test H0: r = 2 and H1: r = 3 until we can not reject the null hypothesis and then determine the optimal number of transition functions. From Table 4,we know that r = 1 is optimal for our model.

Table 4.Residual nonlinear effects test

H0: PSTR with r = 1 against H1: PSTR with at least r = 2		
Wald Tests (LM)	W=4.927	pvalue = 0.295
Fisher Tests (LMF)	F=1.155	pvalue = 0.330
LRT Tests (LRT)	LRT=4.948	pvalue = 0.293

Estimation Results and Analysis

Parameter Estimation

As can be seen from Table 5,most of the variables in the model are statistically significant, and the transition function is a monotonically increasing transition function for the energy intensity of consumption. In this paper, the value of position parameter c of non-linear transformation of PSTR model is 37.18%,that is, the threshold value of model is 37.18%.The value of the smoothed parameter γ between the low system and the high system is 22.9489,indicating that the conversion function g (qit; γ,c) is slowly converted from 0 to 1,that is, the model transitions from low to high is smooth. Figure 1 plots the smooth transition function graph.

Table 5 Parameter estimation results

parameter	c	β_0	β_1	β_2	β_3
estimated value	0.3718	-2.6514**	-8.7574***	-0.6229***	-1.9903**
T value		-1.9644	-4.4959	-9.3014	-2.0742
parameter	γ	β_0^1	β_1^1	β_2^1	β_3^1
estimated value	22.9489	8.1222***	0.8839	0.6218***	-1.0145
T value		4.7997	0.5190	8.4953	-0.8239

Note:*** 1% significance level.

** 5% significance level.

* 10% significance level.

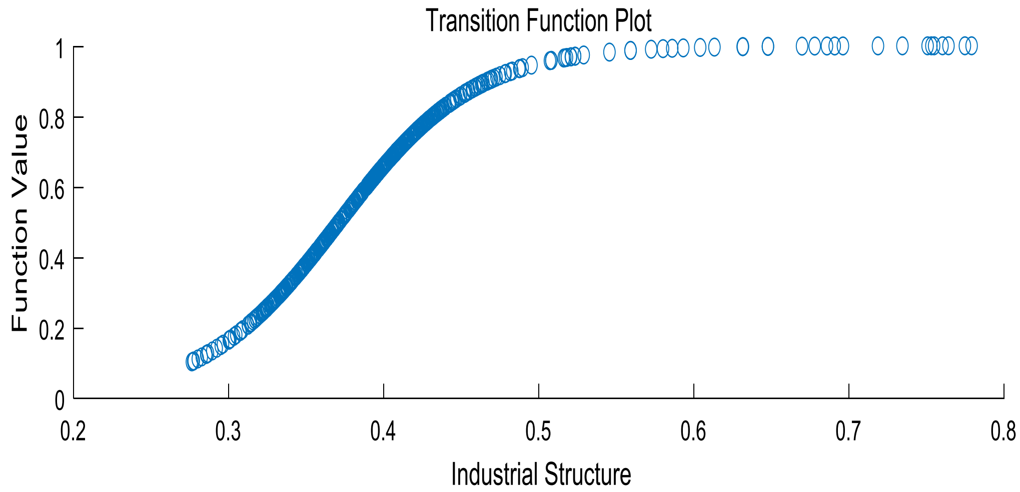

Figure 1. Smooth transition function

Result Analysis

From Table 6,in the low regime (c≤37.18%),the coefficient of FDI's impact on energy consumption intensity is -2.6514,indicating that in the industrial structure with the lower proportion of the tertiary industry, FDI has significant energy consumption intensity Negative impact. In areas where the industrial structure is lagging behind and where labor-intensive industries are dominant, the capital and technology content are relatively low while the provinces can effectively reduce the energy consumption in the region by attracting foreign direct investment to bring in advanced technologies, abundant capital and management concepts Consumption intensity, that is, FDI can improve the region's energy efficiency through technology spillover effects. However, with the advancement of the industrial structure, FDI has gradually inhibited the improvement of energy consumption efficiency. When the proportion of the tertiary industry in the national economy gradually increases, the impact of FDI on the intensity of energy consumption changes from negative to positive by the function of a smooth transfer function. In the high regime (c≥37.18%),the impact coefficient reached 5.4708.Means that with the optimization and upgrading of industrial structure, FDI is increasingly detrimental to energy efficiency. Although FDI is conducive to the increase of China's economic scale, in the long run, it will have less effect on upgrading our country's cutting-edge technologies. At the same time, under the incentive mechanism of pursuing political achievements, governments across the country have had a phenomenon of "race" on the issue of energy consumption, lowering the threshold for entry of FDI and stagnating in the extensive mode of development.

Then, consider the impact of control variables on energy intensity. For the level of industrial structure, the proportion of the tertiary industry structure has a significant negative effect on the energy consumption intensity in the low institutional area (c≤37.18%),negative effect in the high institutional area (c≥37.18%),but not significant This reflects that the optimization and upgrading of industrial structure has reduced the intensity of energy consumption in our country, especially in the low regime where the industrial structure lagged behind. For economic growth, the impact of GDP per capita on energy intensity has a significant negative effect in both low and high regime. When STR is less than 37.18%,the coefficient of per capita GDP on energy consumption intensity is -0.6229 when STR is less than 37.18%.When STR is higher than 37.18%,the coefficient of per capita GDP on energy intensity declines to -0.0011 This shows that with the optimization of industrial structure and industrial technology, the strength of the economy's demand for energy is declining. For the rate of urbanization, the impact of urbanization rate on the intensity of energy consumption is negative but not significant enough in the low and high regimes.

Table 6. Influence Coefficients of PSTR Model

Transition variables:STR Explained variables:ENR		
FDI	β0	-2.6514(-)
	β0+β1	5.4708(+)
STR	β0	-8.7574(-)
	β0+β1	-7.8735(-)
GDP	β0	-0.6229(-)
	β0+β1	-0.0011(-)
URB	β0	-1.9903(-)
	β0+β1	-3.0048(-)

Conclusion and Policy Implications

Although FDI can reduce the intensity of energy consumption when the industrial structure is lagging behind, the excessive introduction of FDI also has more side effects. On the one hand, the backward economic sectors within the less developed countries have long been attached to the advanced economic sectors, which is not conducive to the healthy economic development of the host countries. On the other hand, large-scale introduction of FDI will also bring risks to China's financial security and industrial security. In various regions of China, a differentiated strategy of attracting foreign investment should be implemented, focusing on improving the absorptive capacity of technology so as to increase the positive spillover effect of FDI on energy efficiency.

Morever, it is essential to promote the optimization and upgrading of industrial structure. China is in a period of rapid economic development. It has obtained a good space for development in terms of self-organization of the market or the guidance from the state in its industrialization. According to the previous industrial structure level and energy consumption, it is a long-term plan to make technological progress and optimize the industrial structure as the main driving force to improve energy efficiency.

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