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The Non-Linear Effect of Financial Support on Energy Efficiency: Evidence from China

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Abstract: This study examines the non-linear effect of financial support on energy efficiency for 30 provinces in China, over the period 2003 to 2016. Specifically, we find that technological progress is a key factor in improving energy efficiency, regardless of the transition variable or sample chosen. The non-linear effects of the support of different financial sectors on energy efficiency are different. Banks have the greatest positive impact on energy efficiency, but as economic and financial development levels increase, this impact will diminish. The impact of securities on energy efficiency is contrary to bank support, because as the level of economic and financial development increases, the impact of securities on energy efficiency will shift from negative to positive. The impact of insurance support on energy efficiency is not significant.

Keywords: financial support; technological progress; energy efficiency; PSTR model

1. Introduction

The coupled development of the financial sector and industrial enterprises plays an important role in improving energy efficiency. In China, the emission of energy pollutants is mainly from industrial enterprises, causing economic societal losses and even climate change [1–3]. Increased energy efficiency enables enterprises to achieve greater output with less energy input, thereby reducing pollution emissions and improving air quality [4–6]. The financial sector can reduce the costs of enterprises by providing support to ease the financing constraints of enterprises [7]. Under the background of green development, enterprises have strong incentives to improve their corporate image in order to gain greater advantages in the market [8]. Technological progress is a key element in connecting financial support and energy efficiency.

On the one hand, technological progress is a key element affecting energy efficiency [9,10]. Endogenous growth theories attribute the important driving force of economic growth to innovation activities in various fields, supported by the accumulation of knowledge in the whole society [11,12]. Therefore, in addition to science and technology, such as energy conservation and emission reduction, this paper also considers technological progress to include soft technological progress, such as management system innovation and system innovation. Gerarden et al. suggest that energy-efficient technologies offer considerable promise for reducing the financial costs and environmental damages associated with energy use [13]. Costantini et al. show that the introduction and adoption of green technologies are the most cost effective way to reduce environmental pressure, without compromising economic competitiveness [14]. On the other hand, financial support has a fundamentally important impact on technological progress [15–18]. Based on King and Levine's expansion of the new

Schumpeter growth model, the continuous improvement of the financial system will enable financial intermediaries to obtain more effective project information, so as to better mobilize and use savings, and to invest more funds [19]. In effective projects, this helps firms to diversify risks and promote technological innovation. Amore et al. show that banking development plays a key role in technological progress and that interstate bank deregulation has a significant positive impact on the quantity and quality of innovation activities [20]. Further, Kim and Park suggest that financial development can reduce CO_2 emissions by addressing the role of financial markets in renewable energy [21].

However, there is no consistent conclusion on the relationship between financial support and energy efficiency. This is because the heterogeneity of the sample has not been considered. Further, there is currently no literature that directly studies the relationship between financial support and energy efficiency. There are a large number of studies on the role of financial development and carbon emissions, which note that the focus on the role of increased energy efficiency is to reduce carbon emissions. Katircioğlu and Taşpinar point out that both in the long-term and short-term periods of the Turkish economy, financial development had a positive effect on environmental performance and energy management [22]. Saidi and Mbarek find that financial development decreases carbon emissions, implying that financial development minimizes environmental degradation [23]. However, as noted by several authors, the impact of financial development and carbon emissions might be negative. For example, Shahzad et al. found that in Pakistan, increases in financial development would increase carbon emission by 0.165% [24]. Pata notes that financial development caused increases in CO_2 emissions in Turkey [25].

This paper thus considers the non-linear effect of financial support on energy efficiency. Non-linear effects are widespread in the study of financial problems [26–28]. Most of the current studies use linear models, and the results are inconsistent or even contradictory. The environmental Kuznets curve (EKC) depicts an inverted U shape relationship between economic development and environment pollution. A number of studies have illustrated the existence of a positive correlation between financial development and the development of the economy as a whole. Therefore, we hypothesize that there is a nonlinear relationship between financial support and energy efficiency. There are two important channels, which explain the nexus between financial support and energy efficiency. First, financial support enhances energy consumption, which leads to lower energy efficiency. Second, financial support promotes innovation, application, and promotion of technology, which leads to higher energy efficiency. Shahbaz et al. report that the relationship between energy consumption and financial development can be very complex, because numerous impact channels can exist between them [29].

The focus of this paper is to address the nonlinear effect financial support has on energy efficiency in China, which is both the world's largest energy producer and energy consumer, utilizing data from 30 provinces in China. We expand and supplement the existing literature from the following aspects. Firstly, this paper intends to reveal the nonlinear mechanism of financial support on energy efficiency, which can enrich the theoretical research on energy efficiency. Secondly, this paper aims to measure energy efficiency in China using single factor energy efficiency and total factor energy efficiency. Thirdly, the nonlinear effect of financial support on energy efficiency is tested using the panel smooth transition regression (PSTR) model [30]. Finally, this paper addresses the impact of different levels of financial sector support on energy efficiency.

The paper is structured as follows. The next section (Section 2) introduces the PSTR model and the measurement of energy efficiency. Section 3 tests the nonlinear relationship between financial support and energy efficiency and presents the empirical results of China's 30 provincial states level data from 2003 to 2016. Finally, Section 4 concludes the paper and suggests policy recommendations.

2. Methodology

2.1. Sample and Data Used

This research is conducted in China and focuses on 30 provinces. As the world's largest energy producer and consumer, China has achieved remarkable economic and financial development with its high-input and high-consumption industrial production model [31,32]. However, this extensive economic development model has resulted in huge energy waste and serious environmental problems [33]. Pollution, resources, and environmental issues have become important factors that have constrained the sustainable development of China's economy. Furthermore, China has experienced very uneven regional development. Using China's regions (provinces) as a research sample, we address the impact of sample heterogeneity on the results and their implications for policy recommendations. The data used in this study are obtained from the Wind database (Wind is mainland China's leading financial database and software services provider. Wind has built up a large, complete, and accurate data warehouse focused on financial securities data, covering stocks, funds, bonds, foreign exchange, insurance, futures, financial derivatives, spot trade, macroeconomics, financial news, and other fields). Due to the different economic systems of Hong Kong, Macao and Taiwan, and mainland China, it is difficult to obtain relevant statistics [34]. Considering the integrity of the data, the sample excludes Hong Kong, Macao, and Taiwan. Annual data are used for 30 Chinese provinces during the period of 2003–2016.

According to the economic development and geographical features of China, there are huge differences in the development of the east, central, and west areas. We divided the sample in to three sub-samples [35,36]: the east area, the central area, and the west area. The east area includes 11 provinces (Beijing, Tianjin, Hebei, Liaoning, Shanghai, Jiangsu, Zhejiang, Fujian, Shandong, Guangdong, and Hainan) with the highest level of economic and financial development in China. The central area includes eight provinces (Shanxi, Jilin, Heilongjiang, Anhui, Jiangxi, Henan, Hubei, and Hunan) where the levels of economic and financial development are lower than the east area but superior to the west area. The west area includes 11 provinces (Inner Mongolia, Chongqing, Sichuan, Guizhou, Guangxi, Yunnan, Shaanxi, Gansu, Ningxia, Qinghai, and Xinjiang) with relatively low levels of economic and financial development.

2.2. The PSTR Model

To address the nonlinear effect of financial support on energy efficiency we specify the following PSTR model. The PSTR model can accurately describe the transition between the linear model and the asymmetric model in the process of energy efficiency by selecting different transition variables or transfer functions [30]. The basic expression equation form of the panel smooth transition model is:

$$y_{i,t} = \beta_0 x_{i,t} + \sum_{j=1}^{r} \beta_j x_{i,t} g_j\left(q_{i,t}^{(j)}; \gamma_j; c_j\right) + \mu_i + \varepsilon_t \quad (1)$$

For, $i = 1, 2, \cdots, N; t = 1, 2, \cdots, T$. y_{it} is the dependent variable, and x_{it} is the explanatory variables that changes over time. μ_i indicates the vector of the individual fixed effects and ε_t is a random disturbance. β_0 and β_j indicate respectively the parameter vector of the linear model and the non-linear model. $g_j\left(q_{i,t}^{(j)}; \gamma_j; c_j\right)$ is the function of transition which depends on the transition variable of transition $q_{i,t}^{(j)}$ to the parameter of threshold c_j and to the smooth transition parameter γ_j allows the system to transition gradually. The transition function is set in the form of a logistic function in Equation (2):

$$g_j\left(q_{i,t}^{(j)}; \gamma_j; c_j\right) = \left[1 + \exp\left(-\gamma_j \prod_{k=1}^{m_j} \left(q_{i,t}^{(j)} - c_{j,k}\right)\right)\right]^{-1} \quad (2)$$

where $\gamma_j > 0, c_{j,1} \leq c_{j,2} \leq \cdots \leq c_{j,m_j}$ and c_j is a vector of level parameter. γ_j represents the supposed positive smooth parameter.

2.3. Energy Efficiency

Energy efficiency measures can be divided into two categories: single factor energy efficiency and total factor energy efficiency. The single factor energy efficiency indicator, that is, the energy intensity, refers to increasing energy consumption per unit of GDP, which is energy consumption per unit of output value—one of the important indicators reflecting energy efficiency. The energy intensity indicator is simple and easy to understand, easy to use, can be used to conduct country-specific comparative studies, and is widely used in policy as it is relatively easy to calculate and comparable with country characteristics. The total factor energy efficiency considers the interaction and substitution between energy and capital and labor and other production factors, which is more in line with the actual production process than the single factor energy efficiency, and thus is more widely used [37,38]. In order to eliminate the impact of energy efficiency measured by different methods on the results, this paper uses both methods to measure energy efficiency.

Calculating energy efficiency requires calculating energy consumption. According to statistics, the proportion of global coal in energy consumption is around 28%, while the proportion of China's consumption has always remained above 60%, while China's oil, natural gas, hydropower, nuclear energy, and other energy consumption are at a very low level [39]. Since the reform and opening up, China's coal-based energy consumption structure has not changed. This is determined by China's energy distribution pattern of rich coal, lean oil, and low natural gas. Therefore, considering the special circumstances of China, the calculation of energy consumption is based on the consumption of coal, oil, and natural gas.

We can calculate carbon emissions through data on energy consumption. The coal, oil, and natural gas consumption data of all provinces is derived from the Wind database. The energy consumption of coal, oil, and natural gas in each province is converted into a standard coal calculation. The estimated formula for obtaining carbon emissions is:

$$CE = e\sum_{i=1} \eta_i \times \alpha_i \tag{3}$$

In formula (3), CE is carbon dioxide emissions, e is the total energy consumption, η_i refers to the energy structure, and α_i refers to the carbon emission factor for energy consumption. The energy consumption carbon footprint of each energy source are collected from various official websites and shown in Table 1.

Table 1. Carbon emission factors for energy consumption.

Data Sources	Carbon emission Factor for Coal Consumption (t(C)/t)	Carbon Emission Factor for Oil Consumption (t(C)/t)	Carbon Emission Factor for Natural Gas Consumption (t(C)/t)
Energy Information Administration—EIA	0.702	0.478	0.389
The Institute of Energy Economics, Japan	0.756	0.586	0.449
Chinese Committee for WCRP	0.726	0.583	0.409
Energy Research Institute National Development and Reform Commission	0.7476	0.5825	0.4435
Average	0.7329	0.5574	0.4426

Common methods for measuring efficiency are parametric and non-parametric methods. The parametric method needs to construct a specific optimal production preamble function to make the efficiency calculation of the decision-making unit. The non-parametric method does not require too many assumptions and directly uses the linear programming method to construct the optimal production frontier. DEA (Data envelopment analysis) is recognized in the literature as a powerful method, more suitable for performance measurement activities than traditional econometric methods such as regression analysis and simple ratio analysis [40,41]. Therefore, the calculation using DEA does not need to set various assumptions in advance, and does not need to look for the specific function form of the production frontier.

The Malmquist index is:

$$M_i^t(x_{t+1}, y_{t+1}, x_t, y_t) = \left[\frac{D_i^t(x_{t+1}, y_{t+1})}{D_i^t(x_t, y_t)} \times \frac{D_i^{t+1}(x_{t+1}, y_{t+1})}{D_i^{t+1}(x_t, y_t)}\right]^{1/2} \quad (4)$$

The index reflects the improvement of total factor productivity for each decision-making unit from period t to $t+1$ under fixed-scale remuneration. If the index is greater than 1, it indicates that the efficiency has risen, and vice versa.

The Malmquist index can be decomposed into the technical efficiency change index (TEC) and technological progress index (TP):

$$\begin{aligned} M_i^t(x_{t+1}, y_{t+1}, x_t, y_t) &= \frac{D_i^{t+1}(x_{t+1}, y_{t+1})}{D_i^t(x_t, y_t)} \times \left[\frac{D_i^t(x_{t+1}, y_{t+1})}{D_i^{t+1}(x_{t+1}, y_{t+1})} \times \frac{D_i^t(x_t, y_t)}{D_i^{t+1}(x_t, y_t)}\right]^{1/2} \\ &= TEC \times TP \end{aligned} \quad (5)$$

According to the index construction and decomposition process, as long as the "input–output" indicators are selected, the energy efficiency can be measured and decomposed into TEC and TP. M_0 indicates the change of energy efficiency of each province from t to t + 1. D_0^t and D_0^{t+1} represents the distance functions of the t period and the t + 1 period, respectively. If $M_0 > 1$, this indicates that energy efficiency has improved, and vice versa [42]. In order to show energy efficiency more clearly, this paper uses Equation (6) to calculate the energy efficiency based on 2002, that is, the energy efficiency of all provinces in 2002 was 1.

$$EE_i^t = M_i^t \times EE_i^{t-1} \quad (6)$$

This article analyses China's provinces' total factor energy efficiency from the perspective of factor input and output. Input indicators include energy input, labor input, and capital investment. Output indicators include expected economic output and unanticipated environmental pollution indicators. Among them, the input indicators are the total energy consumption of provinces converted to standard coal, the labor force is the number of employees at the end of the year in each province, and the capital investment is the fixed capital stock of each province. The output indicator is the GDP and carbon dioxide emissions of each province.

Table 2 below summarizes the descriptive statistics for all variables used in this study. For each variable, we present the average value, median, standard deviation, minimum, and maximum values. Descriptive statistics are presented to describe the basic characteristics of data used in this study concerning 30 provinces of China over the period from 2003 to 2016.

The MaxDEA software was used to measure the energy efficiency [43], and the overall results of energy efficiency are shown in Table 3 and Figure 1. From the perspective of the provinces, the energy efficiency in the east is much higher than that in the central and west regions. The average energy efficiency in the east region from 2003 to 2016 was 1.7727, while the energy efficiency in the central and west regions was 1.0502 and 1.0312, respectively. Among all the provinces, Guangdong's energy efficiency improvement is the most obvious, reaching 4.734 in 2016. Heilongjiang's energy efficiency decline is the most obvious, only 0.344 in 2016. From the overall situation, the energy efficiency in the east has improved gradually since 2013. The overall trend in the central and west regions is relatively consistent. From 2003 to 2008, the energy efficiency in the central and western regions has slowly declined. Beginning in 2009, energy efficiency in the central and west regions has slowly increased. By 2016, the energy efficiency in the central and western regions was 1.405 and 1.274, respectively.

Table 2. Descriptive statistics for input–output indexes of energy efficiency.

Sample		Input			Desirable Output	Undesirable Output
		Total Number of Employees (Ten Thousand)	Total Energy consumption (10,000 Tons of Standard Coal)	Total Investment in Fixed Assets of Industry (Billion Yuan)	Gross Domestic Product in the Region (Billion Yuan)	Carbon Dioxide Emissions (Tons)
Whole	Mean	468.31	11,960.99	9245.97	14,447.14	7455.07
	Std. Dev.	316.14	7883.32	9195.82	13,919.62	5234.63
	Min	42.67	683.74	255.62	390.2	390.41
	Max	1973.28	38,899.25	53,322.94	80,854.91	25,050.65
East	Mean	669.09	16,163.55	12,535.14	23,023.99	8144.79
	Std. Dev.	368.51	9505.17	11,056.87	17,405.11	5564.97
	Min	191.20	3214.97	921.30	2578.03	1397.52
	Max	1973.28	38,899.25	53,322.94	80,854.91	22,522.79
Central	Mean	426.57	10,870.06	8862.14	11,773.34	8549.60
	Std. Dev.	110.13	4207.13	7190.20	7196.08	3838.82
	Min	262.02	3426.00	969.03	2662.08	3379.71
	Max	719.32	19,863.00	30,011.65	32,665.38	20,263.36
West	Mean	281.67	8323.46	6032.74	7523.11	5815.66
	Std. Dev.	160.71	4730.50	5856.48	6475.57	5026.05
	Min	42.67	1122.70	255.62	390.20	431.34
	Max	846.25	20,575.00	28,811.95	32,934.54	25,050.65

Table 3. Energy efficiency in different regions in China from 2003 to 2016.

	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
Beijing (E)	1.047	1.108	1.122	1.149	1.215	1.222	1.354	1.363	1.343	1.344	1.383	1.365	1.362	1.315
Tianjin (E)	1.077	1.046	0.987	1.018	1.078	1.272	1.624	2.059	2.191	2.229	2.569	2.744	2.964	3.059
Hebei (E)	0.968	0.974	1.027	1.141	1.171	1.226	1.501	1.550	1.451	1.617	1.801	2.011	2.197	2.229
Liaoning (E)	0.981	1.073	1.163	1.305	1.408	1.548	1.727	1.871	1.781	2.000	2.190	2.072	1.682	1.793
Shanghai (E)	0.986	1.024	1.041	1.047	1.086	1.117	1.150	1.099	1.172	1.240	1.282	1.248	1.155	1.027
Jiangsu (E)	1.294	1.295	1.278	1.394	1.536	1.786	2.136	2.574	2.999	3.349	3.952	4.265	4.465	4.492
Zhejiang (E)	1.165	1.241	1.277	1.378	1.493	1.560	1.813	1.967	2.247	2.530	2.613	2.723	2.680	2.596
Fujian (E)	1.010	1.034	1.044	1.073	1.158	1.233	1.424	1.619	2.169	2.375	2.563	2.684	2.802	2.813
Shandong (E)	1.277	1.337	1.485	1.580	1.645	1.882	2.225	2.490	2.621	2.834	3.114	3.245	3.420	3.496
Guangdong (E)	1.077	1.125	1.137	1.163	1.252	1.418	1.730	2.363	3.724	3.828	5.018	5.078	4.931	4.734
Hainan (E)	0.946	0.871	0.806	0.734	0.661	0.610	0.629	0.597	0.560	0.599	0.668	0.725	0.765	0.755
Shanxi (C)	0.826	0.686	0.605	0.573	0.522	0.462	0.521	0.455	0.396	0.407	0.423	0.420	0.421	0.403
Jilin (C)	0.878	0.788	0.803	0.871	0.926	0.991	1.107	1.137	0.922	1.019	1.046	1.079	1.157	1.200
Heilongjiang (C)	0.897	0.781	0.683	0.630	0.583	0.504	0.499	0.441	0.385	0.390	0.405	0.366	0.353	0.344
Anhui (C)	0.978	0.981	1.047	1.192	1.369	1.518	1.824	2.058	1.965	2.223	2.549	2.876	3.057	3.201
Jiangxi (C)	1.099	1.121	1.148	1.178	1.230	1.412	1.671	1.835	1.725	1.899	2.121	2.266	2.402	2.524
Henan (C)	0.917	0.809	0.784	0.795	0.807	0.849	0.984	1.039	1.013	1.053	1.235	1.247	1.271	1.263
Hubei (C)	0.931	0.865	0.797	0.771	0.659	0.627	0.660	0.679	0.695	0.739	0.816	0.832	0.854	0.862
Hunan (C)	0.945	0.891	0.894	0.863	0.829	0.816	0.902	0.924	0.922	0.971	1.103	1.178	1.316	1.446
Inner Mongolia (W)	0.970	1.054	1.159	1.196	1.214	1.131	1.302	1.319	1.249	1.299	1.490	1.758	1.356	1.465
Guangxi (W)	0.932	0.835	0.826	0.804	0.817	0.849	1.083	1.339	1.673	2.021	2.257	2.338	2.437	2.900
Chongqing (W)	1.098	1.159	1.214	1.316	1.446	1.562	1.906	2.148	2.272	2.333	2.546	2.597	2.563	2.463
Sichuan (W)	1.010	0.965	1.007	0.993	1.023	1.079	1.502	1.598	1.461	1.554	1.807	1.735	1.615	1.551
Guizhou (W)	0.935	0.849	0.776	0.708	0.630	0.532	0.529	0.479	0.433	0.424	0.413	0.405	0.416	0.451
Yunnan (W)	0.973	0.904	1.001	1.019	1.034	0.982	1.055	1.014	0.956	0.971	1.004	0.948	0.905	0.915
Shaanxi (W)	0.940	0.847	0.772	0.732	0.712	0.667	0.690	0.652	0.615	0.654	0.753	0.792	0.816	0.858
Gansu (W)	0.915	0.794	0.730	0.660	0.598	0.533	0.539	0.493	0.459	0.481	0.536	0.555	0.580	0.581
Qinghai (W)	0.981	0.934	0.921	0.937	0.888	0.789	0.902	0.849	0.896	1.018	1.181	1.217	1.247	1.402
Ningxia (W)	0.944	0.868	0.848	0.786	0.716	0.674	0.707	0.697	0.630	0.705	0.797	0.887	0.942	0.910
Xinjiang (W)	0.934	0.842	0.778	0.720	0.670	0.595	0.608	0.511	0.468	0.449	0.441	0.443	0.493	0.517

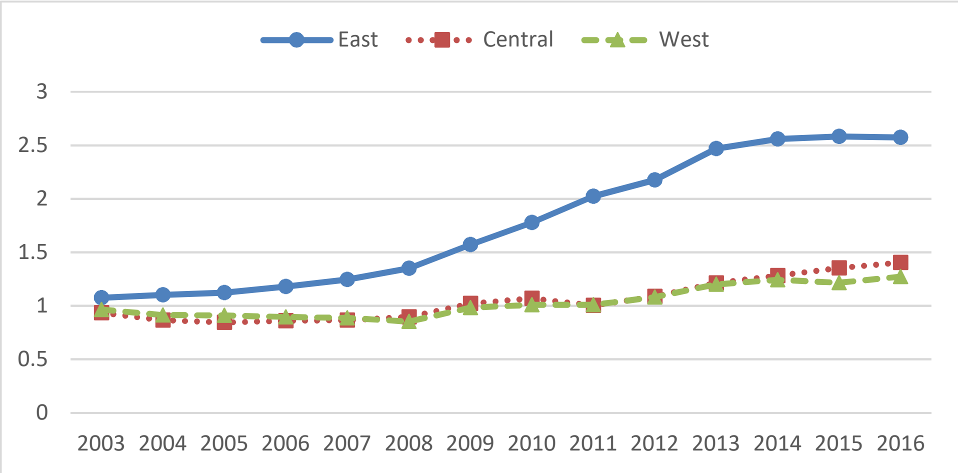


Figure 1. China's regional average energy efficiency.

2.4. Variables Definition

Financial support is mainly considered from the perspectives of banking, securities, and insurance. Financial support is measured by the ratio of total bank loans to GDP, the ratio of total market capitalization of listed companies to GDP, and the depth of insurance. In order to correctly identify the impact of financial support and technological progress on the energy efficiency, this paper improves the accuracy of empirical results by setting control variables. Government intervention capacity (GOV) is an effective remedy to compensate for market failures, and plays an important role in the loss of efficiency in the energy industry. This indicator is calculated by the annual fiscal expenditure of the provinces in China as a percentage of the province's GDP. The large inflow of foreign direct investment (FDI) capital not only brings sufficient capital for economic development, but also provides research and development funds for energy technology improvement. This indicator is calculated by the proportion of the actual use of foreign capital in the provinces of China to the province's GDP. The energy consumption structure (ESC) has a major impact on energy efficiency. In areas such as coal, petrochemical, and other consumer structures, the emission of carbon and other pollutants is higher, which is not conducive to regional environmental quality improvement and increased energy efficiency. This indicator is calculated by the proportion of coal consumption in each province in China accounting for the total energy consumption of the province. The energy consumption intensity of different industries is quite different. The more the energy-consuming industry in a certain region accounts for a greater proportion of the national economy of the whole region, the more difficult it is to improve energy efficiency. This indicator is calculated by the ratio of the tertiary industry output value in each province of China to the province's GDP. The descriptive statistic of the data are given in Table 4.

The heterogeneity between regions is mainly reflected in the difference in economic and financial development levels. Therefore, this paper selects the level of economic development (EDL) and the level of financial development (FIN) as transfer variables to study the non-linear effects of financial support on energy efficiency. The level of economic development is measured by GDP per capita, and the level of financial development is measured by the sum of bank, securities, and insurance support.

To investigate the impact of financial support on energy efficiency, we will specify the following two models. In this model, EDL is the first transition variable, and FIN is the second transition variable. Hence, the two empirical model can be written as follows:

$$\begin{aligned} \mathrm{EE}_{i,t} = \mu_i + \alpha_0 TP_{i,t} + \alpha_1 LOAN_{i,t} + \alpha_2 STOCK_{i,t} + \alpha_3 INSURE_{i,t} + \alpha_4 X_{i,t} + \\ \sum_{j=1}^{r} (\beta_0 TECH_{i,t} + \beta_1 LOAN_{i,t} + \beta_2 STOCK_{i,t} + \beta_3 INSURE_{i,t}) g_j \left(EDL_{i,t}^{(j)}; \gamma_j; c_j \right) + \varepsilon_t \end{aligned} \quad (7)$$

$$\mathrm{EE}_{i,t} = \mu_i + \alpha_0 TP_{i,t} + \alpha_1 LOAN_{i,t} + \alpha_2 STOCK_{i,t} + \alpha_3 INSURE_{i,t} + \alpha_4 X_{i,t} + \sum_{j=1}^{r} (\beta_0 TECH_{i,t} + \beta_1 LOAN_{i,t} + \beta_2 STOCK_{i,t} + \beta_3 INSURE_{i,t}) g_j \left(FIN_{i,t}^{(j)}; \gamma_j; c_j \right) + \varepsilon_t \quad (8)$$

In the nonlinear model described above, $i = 1, \ldots, N$ and $t = 1, \ldots, T$ where N and T denote the cross-section and time dimensions of the panel, respectively, $\mathrm{EE}_{i,t}$ is the energy efficiency, $X_{i,t}$ is a vector of control variables, μ_i is included in the model specification to reflect fixed individual-effects, and ε_t is the error term.

Table 4. Descriptive statistic of the data.

Variables	Descriptive	Mean	Std. Dev	Min	Max
EE	Energy efficiency	1.3085	0.0973	0.3435	5.0785
TP	Technical progress	1.0356	0.0962	0.6730	1.3410
LOAN	Total loans/GDP	1.1517	0.3992	0.5372	2.5847
STOCK	Total market capitalization/GDP	0.5875	1.4016	0.0578	18.6363
INSURE	Insurance penetration	2.7021	1.0134	0.4467	7.3900
GOV	Local government expenditure on science and technology	0.2043	0.0921	0.0792	0.6274
FDI	Foreign direct investment	0.3637	0.2823	0.0058	1.2999
ESC	Coal consumption/energy consumption	0.6847	0.2618	0.0870	1.4495
IS	Share of service sector/GDP	0.4160	0.0861	0.2860	0.8023
EDL	GDP per capita	3.3431	2.2906	0.3701	11.8198
FIN	LOAN + STOCK + INSURE	4.4412	2.3808	1.4358	26.1564

3. Empirical Analysis

3.1. Results of Pre-Tests

Before testing the PSTR model, some pre-tests were undertaken. The first one tested for stationarity of all variables used. The second tested the linearity or homogeneity and the third test was done to identify the number of transition functions. Table 5 presents the results of the panel unit root test. Table 6 below summarizes the results of the test of linearity based on the statistics of Lagrange multiplier Wald test (LM), Fisher test (LMF), and the likelihood ratio test (LRT).

The procedures of PSTR specification rely on the assumption that all variables in the model are I(0) process. To test for stationarity, we used the Levin–Lin–Chu (LLC) test and the Fisher-augmented Dickey–Fuller (Fisher-ADF) test [44,45]. Results displayed in Table 5 indicate that the LLC and Fisher-ADF tests rejected the null hypothesis (non-stationarity) at both the 1% and 5% significance level for all variables used in this study. The results in Table 5 show that our data are stationary and suitable for the next step of analysis. From these results, we can conclude that all data are I(0) process.

Table 5. Panel unit root test.

Variables	LLC	Fisher-ADF
EE	−3.6816 (0.000)	155.95 (0.000)
TP	−3.8328 (0.000)	155.73 (0.000)
LOAN	−7.0140 (0.000)	144.40 (0.000)
STOCK	−13.6992 (0.000)	197.67 (0.000)
INSURE	−4.3744 (0.000)	128.53 (0.000)
GOV	−5.893 (0.000)	106.10 (0.000)
FDI	−5.0639 (0.000)	128.06 (0.000)
ESC	−9.5078 (0.000)	153.92 (0.000)
IS	−3.4194 (0.000)	68.64 (0.208)
EDL	−5.6636 (0.000)	100.85 (0.001)
FIN	−4.3613 (0.000)	112.99 (0.000)

Note: p-statistics are shown in parentheses.

Table 6. Linearity test.

Transition Variable	Sample	H_0: r = 0; H_1: r = 1			H_0: r = 1; H_1: r = 2		
		LM	LM_F	LRT	LM	LM_F	LRT
EDL	Whole	82.619 (0.000)	11.827 (0.000)	92.843 (0.000)	11.261 (0.187)	1.219 (0.287)	11.426 (0.179)
	East	30.145 (0.000)	4.107 (0.000)	33.548 (0.000)	11.580 (0.171)	1.128 (0.350)	12.038 (0.150)
	Central	28.605 (0.000)	4.116 (0.000)	33.030 (0.000)	5.410 (0.248)	1.233 (0.296)	5.445 (0.245)
	West	103.182 (0.000)	34.263 (0.000)	170.739 (0.000)	11.305 (0.255)	1.021 (0.427)	11.741 (0.228)
FIN	Whole	117.072 (0.000)	18.454 (0.000)	137.238 (0.000)	17.614 (0.244)	2.003 (0.456)	17.994 (0.214)
	East	43.632 (0.000)	6.671 (0.000)	51.302 (0.000)	10.738 (0.217)	1.115 (0.358)	11.130 (0.194)
	Central	16.279 (0.039)	2.041 (0.049)	17.591 (0.025)	15.953 (0.043)	1.661 (0.121)	17.210 (0.121)
	West	44.804 (0.000)	6.924 (0.000)	52.947 (0.000)	11.243 (0.211)	1.051 (0.403)	10.842 (0.188)

Note: p-statistics are shown in parentheses.

The objective of this empirical study was to confirm that there is a non-linear relationship. To this end, we conducted a test of linearity against the PSTR model [30]. The null hypothesis was H0: $\beta_1 = 0$ and the alternative was H1: $\beta_1 \neq 0$. However, the test was nonstandard since, under H0, the PSTR model contained unidentified nuisance parameters. The transition function was replaced by its first order Taylor expansion round $\gamma = 0$. The null hypothesis of this test became H0: $\gamma = 0$. This null hypothesis could be conveniently tested by the Wald and likelihood ratio tests. The test can be written in the Equation (9) as:

$$LM = \frac{TN(SSR_0 - SSR_1)}{SSR_0}, LM_F = \frac{(SSR_0 - SSR_1)/mk}{SSR_1/(TN - N - mk)}, LRT = -2\log\frac{SSR_1}{SSR_0} \quad (9)$$

where SSR_0 is the panel sum of squared residuals under H0 and SSR_1 is the panel sum of squared residuals under H1. LMF is assumed to follow Fisher distribution with mk and $TN - N - mk$ degrees of freedom $\left(F(mk, TN - N - mk)\right)$. Under the null hypothesis, all linearity tests follow a chi-2 distribution with k degrees of freedom $\left(\chi^2(k)\right)$.

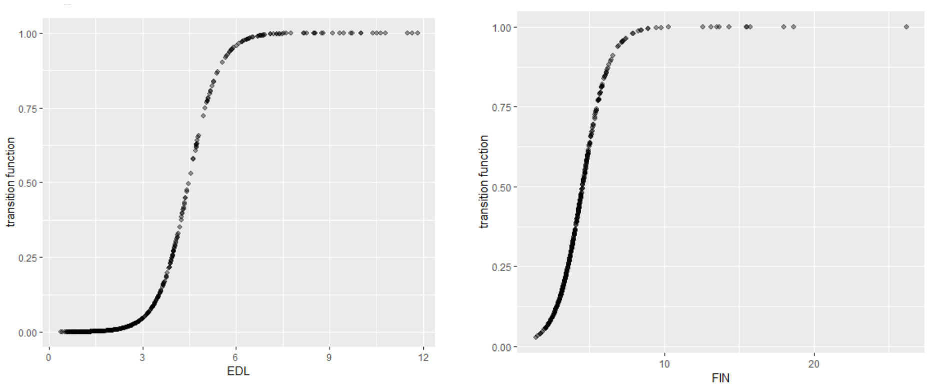
If the non-linearity test rejects the original hypothesis, further surplus non-linearity tests (H0: r = 1; H1: r = 2) are required, which means the test has one or two transition functions. At this point, the smoothing parameter for the second transition function is expanded into a first-order Taylor linear expression at 0, and an auxiliary regression equation is constructed. Using a method similar to a linearity test, the LM, LMF, and LRT statistics are calculated. If H0 is still rejected, then the remaining non-linearity test is continued until H0 cannot be rejected. Finally, the number of optimal transition functions r for the model can be obtained.

The model's non-linearity test and residual nonlinear test results are shown in Table 6.

The Table 6 results show that there are non-linear effects of financial support on energy efficiency, and one transfer function. We can see the three statistics of the nonlinear test LM, LMF, and LRT are significant at the 1% level, thus strongly rejecting the number of transition functions as being equal to the null hypothesis of 0, that is, the number of transfer functions should be at least 1, there is a nonlinear transition mechanism, and the PSTR model should be used for estimation. In the remaining non-linear tests, the LM, LMF, and LRT statistics in all models are not significant, which means the number of transfer functions should be considered to be 1. Therefore, the number of the transfer functions r are all determined to be 1.

3.2. PSTR Estimates of Economic Development

To further examine the impact of financial support and technological progress on energy efficiency, this paper uses the interactions of technological progress and financial support as explanatory variables to verify the non-linear effects of financial support on energy efficiency through technological progress. Figure 2 presents the smooth transfer function when EDL and FIN are transfer variables. Tables 7 and 8 present the estimation of the PSTR model for the whole sample of 30 provinces of China and the three sub-samples of the east, central, and west regions during the period of 2003–2016, with economic development level as the transition variable. Tables 9 and 10 present the estimation of the PSTR model for the whole sample of 30 provinces of China and the three sub-samples of the east, central, and west regions during the period of 2003–2016, with financial development level as the transition variable.



(**a**) EDL as transition variable (**b**) FIN as transition variable

Figure 2. Estimated transition function of the panel smooth transition model.

Table 7. Coefficient estimation of the panel smooth transition regression (PSTR) model: economic development (EDL).

Variable	Whole		East		Central		West	
	Linear	**Nonlinear**	**Linear**	**Nonlinear**	**Linear**	**Nonlinear**	**Linear**	**Nonlinear**
TP	0.6526 ***	0.1206 **	0.4478 ***	0.3906 ***	0.7021 ***	0.3373 **	0.3716 **	0.4768 **
	(9.3042)	(2.187)	(7.1)	(2.6215)	(7.0485)	(2.3422)	(2.5383)	(2.3581)
LOAN	0.4956 **	−0.2354 *	1.056 ***	−1.004 **	0.23 *	1.213 **	0.3462 ***	0.5185 ***
	(2.5157)	(−1.6724)	(2.9797)	(−2.1066)	(1.6674)	(2.5537)	(3.7704)	(3.0198)
STOCK	−0.019 *	0.0132	0.2153 ***	−0.2385 ***	0.0603 *	0.1152	−0.0157	0.7325 ***
	(−1.7546)	(0.3286)	(2.8722)	(−3.3157)	(1.6917)	(0.2934)	(−0.3667)	(3.1051)
INSURE	0.0039	−0.0293	0.0869	−0.0961 *	−0.0972 ***	0.0937	0.0316	−0.1549 **
	(0.1222)	(−0.5393)	(1.6029)	(−1.8055)	(−3.4406)	(1.2115)	(0.7412)	(−2.415)
GOV	−0.5069 **	1.002	2.216 *	−1.546	2.591 ***	−3.34 *	−1.176 ***	0.0974
	(−2.4283)	(0.9882)	(1.8956)	(−0.9923)	(3.2943)	(−1.7387)	(−3.2158)	(0.1662)
FDI	0.0034	−0.2101	−0.0488	−0.0066	−0.1248	0.5978	0.2128	−0.1388
	(0.0322)	(−1.129)	(−0.2797)	(−0.0298)	(−0.5799)	(1.0486)	(1.1206)	(−0.3777)
ESC	0.342	−0.6467	1.63 **	−2.902 ***	0.1439	−0.3267	0.2238	0.2519 *
	(0.9735)	(−1.3532)	(1.9893)	(−3.4049)	(0.5599)	(−1.0335)	(1.3401)	(1.8387)
IS	−0.0223 **	0.0167	−0.0985 ***	0.072 ***	0.0001	−0.0346 **	−0.0061	−0.0278 *
	(−2.085)	(0.8497)	(−3.9903)	(2.8876)	(0.0138)	(−2.3093)	(−0.7404)	(−1.9536)
c	4.495		4.394		4.31		2.966	
γ	2.533		3.0460		1.533		3.004	
Number of observations	420		154		112		154	

Note: t-statistics are shown in parentheses below the estimated coefficients. *, **, and *** denote statistical significance at the 10%, 5%, and 1% levels, respectively.

Under different regimes of economic development and financial development, financial support has a non-linear impact on energy efficiency. Whether EDL or FIN is used as a transition variable, most of the non-linear effects of financial support on energy efficiency have passed the significance test. Taking the east, central, and west regions as a sub-sample, the results are still valid. It can be seen that the non-linear effects of financial support on energy efficiency are widespread.

Table 8. Interaction coefficient estimation of the PSTR model: EDL.

Variable	Whole		East		Central		West	
	Linear	Nonlinear	Linear	Nonlinear	Linear	Nonlinear	Linear	Nonlinear
TP × LOAN	0.5787 *** (12.7383)	−0.1489 ** (−2.117)	0.5304 *** (4.1405)	−0.086 * (−1.7156)	0.7167 *** (9.9404)	−0.0351 (−0.1185)	0.42 *** (6.422)	0.2846 *** (3.3267)
TP × STOCK	−0.0624 * (−1.9388)	0.0671 * (1.8495)	−0.1199 ** (−1.9611)	0.1205 * (1.7579)	−0.0258 (−0.61)	−0.2638 ** (−2.297)	0.0024 (1.0802)	−0.2281 (−1.0565)
TP × INSURE	0.0076 (0.1766)	0.0735 (0.718)	0.0095 (0.4418)	0.077 (1.5599)	0.0058 (0.2431)	−0.0306 (−0.3852)	0.0248 (1.1058)	−0.0747 *** (−3.619)
GOV	−0.2139 * (−1.6578)	-	3.316 * (1.8756)	-	1.034 (1.5655)	-	−1.059 *** (−4.3207)	-
FDI	−0.1761 (−0.9442)	-	−0.237 (−1.6177)	-	0.1178 (0.5036)	-	−0.1824 (−1.2071)	-
ESC	0.2299 (1.0963)	-	1.001 * (1.817)	-	−0.0811 (−0.3704)	-	0.1011 (0.6822)	-
IS	−0.0201 *** (−3.0403)	-	−0.0592 ** (−2.5057)	-	−0.0111 *** (-4.0862)	-	−0.0079 (−1.4921)	-
c	4.868		4.7810		4.31		2.964	
γ	1.608		2.705		1.327		5.909	
Number of observations	420		154		112		154	

Note: t-statistics are shown in parentheses below the estimated coefficients. *, **, and *** denote statistical significance at the 10%, 5%, and 1% levels, respectively.

Table 9. Coefficient estimation of the PSTR model: financial development (FIN).

Variable	Whole		East		Central		West	
	Linear	Nonlinear	Linear	Nonlinear	Linear	Nonlinear	Linear	Nonlinear
TP	0.6989 *** (7.7785)	0.2462 * (1.7867)	0.6711 * (1.8899)	0.4405 * (1.8649)	0.3434 * (1.8071)	0.9524 ** (2.2993)	0.3014 ** (2.4286)	0.723 * (1.9166)
LOAN	0.3552 ** (1.9944)	−0.3525 ** (−2.1237)	0.8923 ** (1.7918)	−0.7632 * (−1.6518)	1.095 (1.4793)	−2.862 ** (−1.9971)	−0.0323 (−0.0449)	1.551 ** (2.1715)
STOCK	−0.184 * (−1.8394)	0.1972 * (1.8879)	−0.3205 * (−1.6964)	0.3252 * (1.7073)	−1.133 *** (−3.1648)	1.207 * (1.8244)	0.1149 (0.1529)	0.6069 (0.6355)
INSURE	−0.0629 (−0.9782)	−0.0776 (−0.796)	−0.0776 (−0.4759)	−0.0134 (−0.0698)	−0.4207 ** (−2.0492)	−0.0922 (−0.2519)	0.6948 (0.6122)	−0.3434 (−0.3246)
GOV	−0.025 (−0.0716)	−0.0566 (−0.0784)	3.064 * (1.7321)	−1.19 (−0.365)	−13.78 (−1.5325)	27.27 (1.545)	−0.4789 (−0.2)	0.2189 (0.0563)
FDI	−0.0924 (−0.6375)	−0.634 ** (−2.0146)	0.5982 (0.5433)	−1.177 (−0.9124)	−1.793 *** (−3.1966)	2.989 ** (2.1675)	−0.5564 (−0.7527)	0.2436 (0.1974)
ESC	0.05 (0.2269)	−0.1516 (−0.5181)	3.032 (0.9434)	−4.29 * (−1.6559)	−2.332 *** (−3.0721)	4.028 *** (3.2484)	−0.5276 (−0.7376)	0.8585 (1.0738)
IS	−0.0139 * (−1.847)	0.0224 (1.3088)	−0.1121 * (−1.7138)	0.0895 (1.4234)	−0.0144 (−0.7736)	0.0224 (0.6116)	0.1308 (0.7832)	−0.228 (−1.3793)
c	4.989		3.9067		3.65		3.162	
γ	1.82		0.8968		0.6236		0.3328	
Number of observations	420		154		112		154	

Note: t-statistics are shown in parentheses below the estimated coefficients. *, **, and *** denote statistical significance at the 10%, 5%, and 1% levels, respectively.

The impact of different financial sector support on energy efficiency is different. Table 7 indicates that the threshold EDL for the whole sample is 4.495, 4.394 for the east region, 4.31 for the central region, and 2.966 for the west region. The results show that the positional parameter of the whole sample is 4.495, which means that the value of its per capita GDP variable is 4.495, which indicates that the energy efficiency is affected by the different effects of financial support. When the per capita GDP value is lower than 4.495, the PSTR model tends towards the low regime, and the maximum value of bank support for energy efficiency promotion is 0.4956. When the per capita GDP value is greater than 4.495, the PSTR model tends towards the high regime, and the effect of bank support on energy efficiency eventually weakens to 0.2602 through the smooth transfer function. This means that the increase in per capita GDP will decrease the impact of bank support on energy efficiency. When the PSTR model tends towards the low regime, the maximum value of the securities support for energy efficiency promotion is −0.019. When the PSTR model tends towards the high regime, the impact of the securities support on energy efficiency increases to −0.0058 through the smooth transfer function. The increase in per capita GDP will increase the impact of securities support on energy efficiency. The impact of the insurance support on energy efficiency is not significant. There are similar conclusions in the east, central, and west regions.

Table 10. Interaction coefficient estimation of the PSTR model: FIN.

Variable	Whole		East		Central		West	
	Linear	Nonlinear	Linear	Nonlinear	Linear	Nonlinear	Linear	Nonlinear
TP × LOAN	0.6144 *** (8.7721)	−0.1238 * (−1.7288)	0.7474 *** (5.83)	−0.2358 ** (−2.3323)	1.301 *** (3.587)	−1.21 *** (−3.975)	0.4933 *** (7.23)	−0.0186 (−0.0922)
TP × STOCK	−0.2791 * (−1.8022)	0.2959 * (1.833)	−0.657 ** (−1.9121)	0.677 * (1.9113)	−0.8006 *** (−2.754)	1.353 *** (3.6099)	−0.1145 *** (−3.7321)	0.4725 (1.0477)
TP × INSURE	0.039 ** (2.5397)	0.0075 (0.3036)	0.0477 ** (2.1855)	0.0158 (0.5003)	0.0502 (0.4976)	0.0249 (0.2171)	0.0458 (1.0566)	−0.0903 *** (−3.142)
GOV	−0.4026 * (−1.6609)	-	1.654 * (1.934)	-	0.6179 (0.9393)	-	−0.7115 *** (−4.6443)	-
FDI	−0.3057 ** (−2.2813)	-	−0.3722 ** (−2.3497)	-	0.1 (0.3526)	-	−0.3519 (−1.5267)	-
ESC	0.2453 (1.2586)	-	0.4885 (0.8321)	-	0.0708 (0.3969)	-	0.1211 (1.1339)	-
IS	−0.0156 ** (−2.6652)	-	−0.0494 ** (−2.3452)	-	−0.0068 ** (−2.5013)	-	−0.0071 (−0.878)	-
c	4.213		4.035		3.251		5.858	
γ	1.354		1.973		0.5452		1.377	
Number of observations	420		154		112		154	

Note: t-statistics are shown in parentheses below the estimated coefficients. *, **, and *** denote statistical significance at the 10%, 5%, and 1% levels, respectively.

Table 9 indicates that the threshold FIN for the whole sample is 4.989, 3.9067 for the east region, 3.65 for the central region, and 3.162 for the west region. The results show that the positional parameter of the whole sample is 4.989, which means that the threshold of FIN variable is 4.495. When the FIN value is lower than 4.989, the PSTR model tends towards the low regime, and the maximum value of bank support for energy efficiency promotion is 0.3552 When the per capita GDP value is greater than 4.989, the PSTR model tends towards the high regime, and the effect of bank support on energy efficiency eventually weakens to 0.0027 through the smooth transfer function. This means that the increase in the level of financial development will decrease the impact of bank support on energy efficiency. When the PSTR model tends towards the low regime, the maximum value of securities support for energy efficiency promotion is −0.184. When the PSTR model tends towards the high regime, the impact of the securities support on energy efficiency increases to 0.0132 through the smooth transfer function. The increase in level of financial development will increase the impact of securities support on energy efficiency. The impact of the insurance support on energy efficiency is not significant. There are similar conclusions in the east, central, and west regions.

Financial support has different impacts on energy efficiency in different regions when the level of economic development is used as a transition variable. For the east region, when per capita GDP is below the threshold of 4.394, financial support has a positive impact on energy efficiency. When per capita GDP is above the threshold of 4.394, bank support for energy efficiency will be greatly reduced (from 1.056 to 0.052), while securities support (−0.07) and insurance support (−0.009) on the contrary will have a negative impact on energy efficiency. For the central region, the higher the level of economic development, the more obvious the role of bank support (from 0.23 to 1.443) and securities support (from 0.0603 to 0.1755) in promoting energy efficiency. When the economic development level is at a low regime, insurance support (−0.0937) has a negative impact on energy efficiency. When the economic development level is at a high regime the negative impact of insurance support (0.0035) on energy efficiency will be greatly diminished. For the west region, the higher the level of economic development, the more obvious the role of bank support (from 0.3462 to 0.8647) in promoting energy efficiency. When the economic development level is at a low regime, securities support (−0.0157) has a negative impact on energy efficiency, and insurance support (0.0316) has a positive impact on energy efficiency. When the development level is at a high regime, the impact of securities support (from −0.0157 to 0.7168) on energy efficiency shifts from negative to positive, while the impact of insurance support (from 0.0316 to −0.1233) on energy efficiency shifts from positive to negative.

3.3. PSTR Estimates of Financial Development

Considering the level of financial development as a transition variable, for the east region, when FIN is below the threshold of 3.9067, bank support (0.8923) has a positive impact on energy efficiency, but securities support (−0.3205) has a negative impact on energy efficiency. When FIN is above the threshold of 3.9067, bank support (from 0.8923 to 0.1291) for energy efficiency will be greatly reduced, while securities support (from −0.3205 to 0.0007) will have a positive impact on energy efficiency. For the central region, as the level of financial development increases, the impact of bank support (from 1.095 to −1.767) on energy efficiency shifts from positive to negative, while the impact of securities support (from −1.133 to 0.074) on energy efficiency shifts from negative to positive, and the negative impact of insurance support on energy efficiency will increase. For the west region, when the financial development level is at a low regime, the impact of financial support on energy efficiency has not passed significance testing. Further, when the financial development level is at a high regime, only bank support has a positive impact on energy efficiency.

Technological progress always has a positive impact on energy efficiency. It can be seen from Table 7 that the higher level of economic development, the more obvious the improvement regarding energy efficiency resulting from technological progress. However, the impact of technological progress on energy efficiency will vary from region to region When the economic development level is at a low regime, technological progress has the greatest impact on energy efficiency in the central region, at 0.7021, with minimal impact on energy efficiency in the west region, only 0.3716. When the economic development level is at a high regime, the impact of technological progress on energy efficiency in the east, central, and west regions reached 0.8383, 1.0394, and 0.8484, respectively. From Table 9, similar conclusions can be drawn. When the financial development level is at a low regime, technological progress has the greatest impact on energy efficiency in the east region, at 0.6711, with minimal impact on energy efficiency in the west region, only 0.3014. When the financial development level is at a high regime, the impact of technological progress on energy efficiency in the east, central, and west regions reached 1.1167, 1.2958, and 1.0244, respectively. The difference in the impact of technological progress on energy efficiency between different regions has decreased.

Financial support has a non-linear effect on energy efficiency through technological progress. The empirical results of interactions between financial support and technological progress are shown in Tables 8 and 10. Most of the impact of the interaction between bank support and technological progress in different regions on energy efficiency has passed the significance test. Whether in the full sample or in the three sub-samples of east, central, and west, there are similar conclusions. When the economic and financial development level is at a low regime, bank support will have a positive impact on energy efficiency through technological progress. When the economic and financial development level is at a high regime, the positive impact of bank support on energy efficiency through technological progress will decline. For securities support, whether in the full sample or in the three sub-samples of east, central, and west, there are similar conclusions. When the economic and financial development level is at a low regime, securities support will have a negative impact on energy efficiency through technological progress. When the economic and financial development level is at high regime, the impact of securities support on energy efficiency through technological advancement will shift from negative to positive. The impact of the interaction between insurance support and the effect technological progress in different regions on energy efficiency has not passed the significance test. This shows that overall financial support, bank support, and securities support will have a non-linear impact on energy efficiency through technological progress.

4. Conclusions

In this paper, we use the DEA–Malmquist model to measure the energy efficiency for 30 provinces from China over the period of 2003 to 2016. The data were sub-divided into the east, central, and west sub-samples to study the nonlinear relationship between financial support and energy efficiency. We used the PSTR to conduct an empirical test. The main conclusions drawn from this analysis are as follows.

Technological progress is the main factor in improving energy efficiency. In order to cope with increasingly serious environmental pressure, attention should be paid to technological innovation and research and development. In short, technological progress is the main way to improve energy efficiency, reduce energy consumption, and achieve sustainable economic development.

In the financial sector, banks have the greatest impact on energy efficiency. When the economic and financial development is at a high regime, the positive impact of bank support on energy efficiency will be weakened. Banks have always been in the main position in China's financial system. When the market mechanism has not been established, the bank-led indirect financing model is conducive to ensuring enterprises improve energy efficiency. However, with the improvement of economic and financial levels and the continuous improvement of the market, the effect of banks on the improvement of the energy efficiency of enterprises has declined. This is mainly because the investment targets of the Chinese banking sector are guided by the government, and the state-owned industrial enterprises with lower energy efficiency are more likely to receive relevant financing services. Therefore, banks should consider the impact of corporate environmental protection factors when selecting investment targets.

When economic and financial development are at a high regime, securities support will have a positive impact on energy efficiency. This shows that when economic and financial development is at a low level, the imperfect development of the capital market will reduce energy efficiency, but with the development of the economic and financial environments, the securities market plays a positive role in improving energy efficiency. This shows that the capital market and direct financing are of great significance to the improvement of energy efficiency. Therefore, attention should be paid to the development of capital markets and the direct financing ability of enterprises.

The impact of insurance support on energy efficiency is not significant. This shows that China's insurance market has not yet formed a good relationship with enterprise development. At present, insurance is mainly for individuals and property. In the future, the scope of insurance services should be expanded, and insurance products be related to enterprise R and D to increase the willingness of enterprises to invest in R and D.

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