Study on the Relationship between Ecological Efficiency and Technological Innovation of Heavy Pollution Industrial Enterprises

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Abstract

Based on the panel data of 16 categories of heavy polluting industrial enterprises from 2004 to 2019, the dynamic relationship between ecological efficiency and technological innovation is empirically analyzed according to pvar2 model. the results show that: (1)Ecological efficiency remained basically stable, and technological innovation grew steadily. (2)There is a two-way causal relationship between ecological efficiency and technological innovation.

Keywords

Heavy Polluting Industrial Enterprises; Ecological Efficienc; Technological Innovation; Dynamic Relationship.

1. Introduction

Over the years, China's heavy polluting industrial enterprises have had an important impact on the development of China's industrial enterprises. The main business income of heavy polluting industrial enterprises accounts for about half of industrial enterprises, but most of the environmental pollution caused by industrial enterprises comes from heavy polluting industrial enterprises, in this extremely mismatched situation, it is particularly important to pay special attention to the economic development of heavy polluting industrial enterprises in the development of green economy in the new era. Innovation is the key means for heavy polluting industrial enterprises to carry out structural adjustment, transformation and upgrading and take the road of sustainable development.

Based on this, this paper evaluates the ecological efficiency and technological innovation of heavy polluting industrial enterprises, and studies the dynamic relationship between them, so that heavy polluting industrial enterprises can achieve economic quality growth while improving economic growth.

2. Index System Construction and Data Source

2.1. Construction of Index System

Based on the principles of comprehensiveness, feasibility and systematicness of the index system, combined with the characteristics and development status of heavy polluting industrial enterprises, Table 1 comprehensive evaluation index system of ecological efficiency and technological innovation of heavy polluting industrial enterprises is constructed.

Table 1. Comprehensive Evaluation Index System of Ecological Efficiency and Technological Innovation of Heavy Polluting Industrial Enterprises

System layer	Criterion layer	Index layer
Ecological efficiency	resource consumption	Investment in fixed assets
		Average number of employees
		Investment in fixed assets
	economic performance	Main business income
		Total profit
	environmental pollution	Wastewater discharge
		Exhaust emission
	circular economy	Fixed waste discharge
		Comprehensive utilization of solid waste
		Treatment capacity of wastewater treatment facilities
Technological innovation	Technological innovation input	Expenditure for new product development
		R & D personnel full time equivalent
		R & D expenditure
	Technological innovation output	Number of R & D projects
		Number of patent applications
		Number of valid patented inventions
		Number of new product development projects
		New product sales revenue

2.2. Data Sources

This paper selects 16 kinds of heavy polluting industrial enterprises as the research object to quantitatively analyze the coupling and coordination effect of ecological efficiency and technological innovation and their dynamic relationship. The index data comes from "China Statistical Yearbook", "China Environmental Statistical Yearbook" and "Statistical Yearbook of Scientific and Technological Activities of Industrial Enterprises", with a time span of 2004-2019.

3. Empirical Analysis

3.1. Comprehensive Development Level Analysis

The weight is determined according to the entropy weight method, and the comprehensive evaluation value of ecological efficiency and technological innovation of heavy pollution industrial enterprises is obtained. It can be concluded that: The comprehensive evaluation value of annual average ecological efficiency of heavy polluting industrial enterprises is relatively stable, but it increases slightly. Besides, the average annual comprehensive evaluation value of technological innovation showed steady growth in other years, with a large growth range, except for a short decline in 2008-2009.Before 2013, the development of technological innovation lagged the score of ecological efficiency, and after 2013, the ecological efficiency lagged the development of technological innovation.

3.2. Dynamic Relationships Analysis

In this paper, pvar2 model is used to combine the advantages of panel data and VAR model. In order to eliminate the pseudo regression problem caused by the non-stationarity of the original sequence, which leads to the invalidity of the analysis results, it is necessary to carry out the stationarity test and cointegration test on the original sequence, followed by Granger causality test, impulse response analysis and analysis of variance.

3.2.1. Stability Test

LLC test, IPS test and PP test were performed on the variables. The results are shown in Table 2, The original sequence of ecological efficiency and technological innovation of heavy polluting industrial enterprises is a non-stationary sequence, but it becomes a stationary sequence after first-order difference, which shows that the original sequence has first-order single integration and can be tested by cointegration.

Table 2. Unit Root Test Results

	PP	IPS	LLC	conclusion
e	0.203	0.711	-1.992**	Unstable
	(0.508)	(0.761)	(0.023)	
D.e	-5.587***	-4.309***	-3.783***	stable
	(0.000)	(0.000)	(0.000)	
t	-0.29	1.121	0.726	Unstable
	(0.386)	(0.869)	(0.766)	
D.t	-3.148***	-4.151***	-4.184***	stable
	(0.000)	(0.000)	(0.000)	

Note: ①***P<0.01, ** P<0.05, *P<0.1; the value in brackets is p value, the same below.
② "e" stands for ecological efficiency, "D.e" stands for the first-order difference of ecological efficiency, "t" stands for technological innovation, "D.t" stands for the first-order difference of technological innovation, the same below.

3.2.2. Long-term Cointegration Relationship Test

Kao test and pedroni test whether there is a Long-term cointegration relationship between variables. See Table 3 for the results, it shows that there is a Long-term cointegration relationship between ecological efficiency and technological innovation of heavy pollution industrial enterprises.

Table 3. Cointegration Test Results

Inspection method	Test statistics	Statistic	p-value
Kao	Modified Dickey-Fuller t	0.0845	0.4663
	Dickey-Fuller t	-0.9710	0.1658
	Augmented Dickey-Fuller t	-0.8526	0.1969
pderoni	(panels)Modified Phillips-Perron t	2.5694	0.0051
	(panels)Phillips-Perron t	-7.1469	0.0000
	(panels)Augmented Dickey-Fuller t	-4.4568	0.0000
	(same)Modified variance ratio	-4.5478	0.0000
	(same) Modified Phillips-Perron t	-1.4625	0.0861
	(same)Phillips-Perron t	-8.5404	0.0000
	(same)Augmented Dickey-Fuller t	-6.8962	0.0000

Note: "panels" is the heterogeneity test of "pedroni", and "same" is the homogeneity test of "pedroni".

3.2.3. Granger Causality Test

According to AIC, BIC and hqic information criterion values, it is determined that the optimal lag order is order 3, so it is set as order 3 lag pvar model, Then Granger causality test is carried out on the variables to judge the causality between the variables. The results are shown in Table 4, The results show that: At the significance level of 1%, the original hypothesis was rejected: "t" is not the cause of "e" and "e" is not the cause of "t". This shows that the ecological efficiency of heavy polluting industrial enterprises is an important reason for the development of

technological innovation, and the development of technological innovation promotes the improvement of ecological efficiency. Therefore, there is a two-way causal relationship between ecological efficiency and technological innovation of heavy pollution industrial enterprises.

Table 4. Granger Causality Test Results

Equation	Excluded	chi2	df	Prob > chi2
h_e	h_t	13.207	3	0.004
h_e	ALL	13.207	3	0.004
h_t	h_e	11.549	3	0.009
h_t	ALL	11.549	3	0.009

3.2.4. Impulse Response Analysis

Figure 1 shows the impulse response results of ecological efficiency and technological innovation of heavy polluting industrial enterprises The ecological efficiency of heavy polluting industrial enterprises has a Long-term positive impact on themselves and a short-term negative impact on technological innovation. An impact on ecological efficiency will bring significant positive impact to itself within 10 lag periods, and the impact degree will decrease with the change of lag periods; Lag phase 1 has a significant negative impact on technological innovation, and the impact reaches the maximum. Lag phase 2 has no significant impact on technological innovation. Technological innovation of heavy polluting industrial enterprises has a Long-term significant negative impact on ecological efficiency and a Long-term significant positive impact on themselves. It has an impact on technological innovation. The lag period of 10 has a significant negative impact on ecological efficiency, and the impact effect tends to be stable; Within the lag period of 6, it has a significant positive impact on itself, and from the seventh period, it has no significant impact on itself.
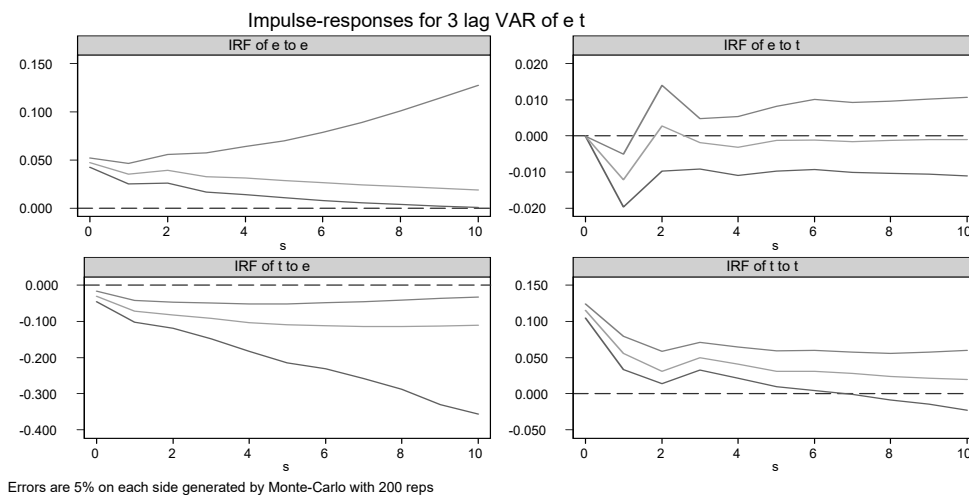
Figure 1. Impulse Response Results of Ecological Efficiency and Technological Innovation of Heavy Polluting Industrial Enterprises

3.2.5. Analysis of Variance

According to Table 5, The ecological efficiency of heavy polluting industrial enterprises was 100% affected by their own fluctuation impact in phase 1. The impact of technological innovation on ecological efficiency began to appear in phase 2. The impact intensity on ecological efficiency was 4.1%, and the impact was weak. After that, the impact intensity continued to decline to, gradually showing a steady development trend, this shows that the impact of technological innovation on ecological efficiency is lagging, Long-term and sustainable. In the variance decomposition of technological innovation, the impact of ecological efficiency on technological

innovation appeared in phase 3, the impact intensity was 6.6%, and then the impact intensity continued to rise until phase 10, the impact intensity increased to 79.1%, the impact intensity was large, and there was no stable impact trend, This shows that the impact of ecological efficiency on technological innovation is timely, effective and sustainable, and increases with the increase of lag periods.

It can be seen from the above that the ecological efficiency of heavy polluting industrial enterprises is not highly dependent on technological innovation in the early stage, which is basically affected by their own development, This is because ecological efficiency mainly depends on economic and environmental impacts in the early stage, and technological innovation cannot change in a short time, Therefore, the impact of technological innovation on ecological efficiency lags behind, and the impact of ecological efficiency on technological innovation can be presented in time.

Table 5. Variance Decomposition of Ecological Efficiency and Technological Innovation of Heavy Pollution Industrial Enterprises

Period	Variance decomposition of ecological efficiency		Variance decomposition of technological innovation	
	e	t	e	t
1	1.000	0.000	0.066	0.934
2	0.959	0.041	0.270	0.730
3	0.970	0.030	0.426	0.574
4	0.975	0.025	0.517	0.483
5	0.977	0.023	0.599	0.401
6	0.979	0.021	0.663	0.337
7	0.981	0.019	0.708	0.292
8	0.982	0.018	0.743	0.257
9	0.982	0.018	0.770	0.230
10	0.983	0.017	0.791	0.209

4. Conclusion

By constructing the evaluation index system of ecological efficiency and technological innovation of heavy polluting industrial enterprises, this paper empirically analyzes the dynamic relationship between ecological efficiency and technological innovation of heavy polluting industrial enterprises from 2004 to 2019,The results show that: (1) The comprehensive score of ecological efficiency of heavy polluting industrial enterprises was relatively stable, and the comprehensive score of technological innovation increased steadily. Before 2013, technological innovation lagged ecological efficiency, and after 2013, ecological efficiency lagged technological innovation. (2) Ecological efficiency and technological innovation are mutually causal, and they promote each other and develop together. Among them, the impact of technological innovation on ecological efficiency lags, and the impact of ecological efficiency on technological innovation can be presented in time.

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