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Energy and Environment

Impact of Environmental Stringency on Energy Efficiency

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This paper investigates the impact of environment policy stringency on energy efficiency by using the unbalanced data of 23 countries from 1990 to 2015. The regression results show that increased stringency of environmental policy implementation has a negative impact on energy intensity, as well as a lagging effect. This finding illustrates that strict environmental protection policies can effectively reduce unit resource energy consumption, reduce resource waste, and promote energy efficiency.

I. Introduction

A key factor affecting economic development, the level and efficiency of energy use have always attracted scholars' attention (Iyke et al., 2021). Greenhouse gas emissions caused by the use of fossil fuel are also forcing countries to improve their energy efficiency (Chang et al., 2018). Improvements in energy efficiency mean that less energy is used to achieve more tasks, reducing energy waste. For example, the International Energy Agency has illustrated that improving energy efficiency in buildings, industrial processes, and transportation can reduce world energy demand by one-third by 2050 and help control global greenhouse gas emissions.[1]

Previous studies (e.g., Cagatay & Mihci, 2006) show that strict environmental policies can have an impact on a country's trade patterns. Wolde-Rufael & Weldemeskel (2020) found an inverted-U relation between the stringency of environmental policies and carbon dioxide emissions. However, the literature rarely discusses the relation between environmental policy and energy efficiency. Therefore, this paper aims to analyze the impact of stringent environmental policies on energy efficiency through panel data from 23 countries. Theoretically, restricting carbon dioxide emissions in the production of enterprises through strict environmental policies can force enterprises to reduce energy waste in the production process, improve green innovation, and thus improve energy efficiency.

Our empirical estimations reveal that an increase in the strictness of environmental policies will have a positive effect on energy efficiency, and this effect has a certain lag. At the same time, considering that energy efficiency could have an certain inertial effect, we use the dynamic difference generalized method of moments (GMM) model for estimation and find the regression results are consistent with the original conclusions. The regression results show that the government's implementation of stringent environmental protection policies can promote the improvement of energy use efficiency to a certain extent and reduce resource waste.

II. Data and Methods

A. Dependent Variable

Most of the literature regards energy intensity as a proxy variable to measure energy efficiency (Chang et al., 2018). High energy intensity means that the cost of converting energy into the corresponding gross domestic product (GDP) is high. On the contrary, lower energy intensity means a lower cost of converting energy into the corresponding GDP, which means higher energy efficiency. Energy intensity is the ratio of energy use to the GDP. Therefore, the government's goal is to reduce energy intensity, improve energy efficiency, and reduce resource waste and greenhouse gas emissions. We therefore follow Chang et al. (2018), who use energy intensity as a proxy variable to measure energy efficiency. Figure 1 shows the energy intensity of the sample countries from 1990 to 2015.

B. Independent Variables

We use the environmental policy stringency index as a proxy variable for the independent variables. Establishment of the environmental policy stringency index (*EPS*) aims to provide countries with a comparable indicator of the intensity of the implementation of their environmental policies. The index scores selected climate and air pollution environmental policies to measure the strictness of their implementation. The higher the index, the more stringent the environmental policies implemented by the country (Botta & Koźluk, 2014). For the remaining independent variables,

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1 See https://www.scidev.net/global/news/invest-in-clean-technology-says-iea-report/#comments.

Table 1. Descriptive Statistics

Variable	N	Mean	SD	Min	Max
EPS	569	1.577	0.966	0.208	4.133
EI	569	1.738	0.643	0.686	3.703
HCI	569	1.063	0.219	0.397	1.384
EFI	569	7.337	0.897	3.690	8.760
FDI	552	23.213	1.787	14.509	27.322
CO_2	568	22.421	1.41	19.44	26.452

This table shows descriptive statistics of the variables. The statistics are observations (N), mean (Mean), standard deviation (SD), minimum (Min), and maximum (Max). The sample covers 23 countries over the period from 1990 to 2015.

this paper uses foreign direct investment (*FDI*), the carbon dioxide damage value (*CO_2*), an economic freedom index (*EFI*), and a human capital index (*HCI*). The variables mentioned are all converted to their natural logarithmic values.

The data on energy intensity (*EI*) are from the bp Statistical Review of World Energy, and the environmental policy stringency index (*EPS*) is obtained from Organisation for Economic Co-operation and Development statistics. Data on the remaining independent variables are from the World Bank and the Penn World Table databases. We thus obtain unbalanced panel data covering 23 countries from 1990 to 2015.[2]

C. Methods

Following the classic literature on energy efficiency and the stringency of environmental policies, this paper uses the panel data method. First, it uses fixed effects to test the impact of environmental policy stringency on energy efficiency. At the same time, considering potential endogeneity and possible deviation estimates, this paper introduces the differential GMM method to conduct a robustness test. The estimated equation is as follows:

$$EI_{i,t} = \beta EPS_{i,t} + \beta_1 X_{i,t} + \mu_i + \eta_t + \varepsilon_{i,t} \tag{1}$$

where, for country i and period t, $EI_{i,t}$ represents the dependent variable for energy efficiency; $EPS_{i,t}$ denotes the independent variable, which is the environment policy stringency index; $X_{i,t}$ corresponds to a set of remaining independent explanatory variables; μ_t corresponds to a set of remaining independent explanatory variables; η_t is a time-specific effect; and $\varepsilon_{i,t}$ is an error term.

III. Results and Discussion

A. Data Description

Table 1 displays the statistical information of the variables. It shows that, for energy intensity (*EI*), the standard deviation is 0.643, the maximum is 3.703, and the minimum is 0.686, which indicates differences in energy efficiency among the sample countries. For the environmental policy stringency index (*EPS*), the minimum value is 0.208, the maximum value is 4.133, and the standard deviation is 0.966. This result shows that the strictness of the implementation of environmental protection policies in various countries is quite different. The reason for this could be the different economic conditions of the various countries, leading to different government attitudes toward environmental protection.

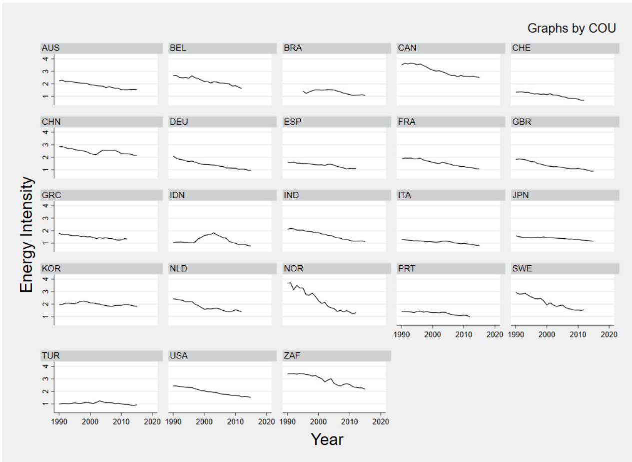

Figure 1. Energy Intensity of sample countries

This figure shows the dynamics of energy intensity across the 23 countries in our sample. Sample countries include Australia (AUS), Belgium (BEL), Brazil (BRA), Canada (CAN), Switzerland (CHE), China (CHN), Germany (DEU), Spain (ESP), France (FRA), United Kingdom (GBR), Greece (GRC), Indonesia (IDN), India (IND), Italy (ITA), Japan (JPN)), Korea (KOR), Netherlands (NLD), Norway (NOR), Portugal (PRT), Sweden (SWE), Turkey (TUR), United States (USA), and South Africa (ZAF). The sample period is from 1990 to 2015.

B. Regression Results

Table 2 shows the regression results for the influence of environment policy stringency on energy intensity. The dependent variables in the first to third columns correspond to the current value, the one-period-lagged value, and the

2 The sample countries include Australia (AUS), Belgium (BEL), Brazil (BRA), Canada (CAN), Switzerland (CHE), China (CHN), Germany (DEU), Spain (ESP), France (FRA), United Kingdom (GBR), Greece (GRC), Indonesia (IDN), India (IND), Italy (ITA), Japan (JPN)), Korea (KOR), Netherlands (NLD), Norway (NOR), Portugal (PRT), Sweden (SWE), Turkey (TUR), United States (USA), and South Africa (ZAF).

Table 2. Regression Results

VARIABLES	(1) *EI*	(2) $EI_{(t+1)}$	(3) $EI_{(t+2)}$	(4) *EI*
L. dependent variable				1.352***
				(8.709)
EPS	-0.128**	-0.117**	-0.096*	-0.179*
	(-2.319)	(-2.210)	(-1.910)	(-1.696)
FDI	-0.031	-0.034*	-0.029*	-0.080**
	(-1.608)	(-1.747)	(-1.869)	(-2.088)
CO2	-0.200	-0.220	-0.205	0.417**
	(-1.294)	(-1.430)	(-1.453)	(2.540)
EFI	0.166	0.157	0.136	-0.071
	(1.481)	(1.444)	(1.315)	(-0.986)
HCI	-0.269	-0.239	-0.202	-0.562
	(-1.089)	(-1.050)	(-0.896)	(-1.435)
Observations	551	528	505	496
R-squared	0.622	0.622	0.641	
AR(1) (p-value)				0.001
AR(2) (p-value)				0.942
Sargan(p-value)				0.980

This table shows the regression results. Robust t-statistics and z-statistics in parentheses. *** p<0.01, ** p<0.05, * p<0.1. AR(1) and AR(2) denote the p-value for the Arellano-Bond test of first-order and second-order autocorrelations, respectively. Sargan represents the p-value of the over-identification test.

two-period-lagged value of energy intensity, respectively. The regression coefficients of the first to third columns are -0.128, -0.117, and -0.096, respectively, and significantly negative at the 5% and 10% levels. The regression results show that an increase in the stringency of environmental policies will have a negative effect on energy intensity, which is also lagging, with a significant negative impact on energy intensity in the later period.

In recent years, people have become gradually more worried about the impact of greenhouse gas emissions on the global environment. Countries have thus begun to implement more stringent environmental protection policies aimed at reducing pollution costs. With the implementation of stringent environmental protection policies, the level of green innovation has improved, with further improvements in energy efficiency and in reducing energy intensity (Galeotti et al., 2020). Subsequently, to ensure the reliability of the regression results and considering that energy intensity could be affected by inertia in the previous period, this paper introduces a dynamic differential GMM model to test the impact of environmental policies on energy intensity. The regression results are shown in column (4) of Table 2.

Column (4) in Table 2 shows that, when the lag period of the dependent variable is included in the independent variable, its regression coefficient is 1.352, significant at the 1% level, which demonstrates that a dynamic difference GMM is reasonable as a robustness test. In column (4), the regression coefficient of the strictness of environmental policy (*EPS*) is -0.179, significant at the 10% level, which is consistent with the fixed effects regression results and confirms the reliability of the original conclusions. Our empirical results are basically consistent with the conclusions of Martínez-Zarzoso et al. (2019).

IV. Conclusion

Porter and van der Linde (1995) pointed out that, when the government has the ability to design more complete and stringent external environmental policies, it will effectively promote competition among enterprises and improve their research and development and innovation capabilities. With continuous improvements in economic development, the goal of green development has been unanimously recognized throughout the world. Countries have implemented more stringent environmental protection policies to reduce greenhouse gas emissions and are trying to reduce environmental pollution. These policies have promoted the development of green innovative technologies to a certain extent and reduced energy waste.

This paper attempts to empirically examine the impact of strict environment policies on energy efficiency through data from 23 countries from 1990 to 2015. The regression results show that an increase in the strictness of environmental policies will have a negative effect on energy intensity, which illustrates that the implementation of strict environmental policies can promote green innovation capabilities, reduce the energy consumption per unit of the GDP, and improve energy efficiency. Martínez-Zarzoso et al. (2019) point out that strict environmental regulations and policies can effectively improve the clean production process, reduce the environmental costs of unit production, and improve energy efficiency, consistent with our conclusions.

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