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# The effect of democracy on energy efficiency in European countries

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## ABSTRACT

This study explores to what extent the development of democracy affects energy efficiency. This study applies database reference from Freedom House, Polity IV project, International Country Risk Guide (ICRG) and World Development Indicator (WDI) to analyze the relationship between the level of democracy and energy efficiency of 35 countries in Europe from 1990 to 2013. Controlling for manufacturing value-added, price level, and GDP per capita, we find a significant statistical correlation between the level of democracy and the level of energy efficiency in a country. Empirical findings show that a high level of democracy has a significant positive impact on the improvement of national energy efficiency. Further examinations which employ quantile regression estimates indicate that the positive impact of democratic consolidation is stronger when the country is at the stage of relatively low energy efficiency. Empirical research also demonstrates that the consolidation of democratic institutions and economic development has a positive influence on the awareness of environmental conservation, thereby improving the structure of energy consumption and further reinforce the enhancement of energy efficiency.

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## 1. Introduction

Greenhouse gas emissions are the major concerns among the efforts of tackling global climate change. In order to reduce greenhouse gas emissions, the United Nations Framework Convention on Climate Change (the UNFCCC) was launched in Brazil in 1992. In later years, aiming to reduce greenhouse gas emissions, various international regulations were established. As the most high-profile examples, Kyoto Protocol was signed in 1997; the Paris Agreement was passed in the UN Climate Change Conference in 2015 and was signed by the international community in New York in 2016. The two international agreements jointly provide a standardized guideline for

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the improvement of global greenhouse gas emissions and energy use after 2020. Every country that emits greenhouse gases has to shoulder proportional responsibilities of reducing the emissions. Cutting carbon emissions and tackling climate change while ensuring economic prosperity became a priority for every single country and the international community.

In order to ensure the sustainability of economic development, the mitigation of GHG emissions has been the focus of policymakers, as well as researchers in recent decades. The relationship between energy use and economic development or the democracy and economic performance has been extensively examined and discussed in several empirical studies, however, rarely studies discuss the relationship between energy and democracy. The aim of this article is to empirically estimate the influence of democracy in countries' energy efficiency. We focus on the European countries because the current economic and energy data of EU countries are relatively complete, and European energy policy has made efforts to develop coherent strategies for establishing common goals for all countries, including reduction of pollution and increase in the use of renewable energy for sustainability.

The paper is organized as follows. The second part is literature review and the third part introduces the methods of measuring energy efficiency and the econometric models, and further discusses the influence of democracy on energy efficiency. The fourth part explains the research data and the empirical results. And the final part concludes.

## 2. Literature review

Previous studies have revealed the far-reaching and multi-dimensional influence of democracy to a country, not only to the broader social and economic development but also to the micro-level policy-making dynamics of its government. It is generally acknowledged that political stability and the consolidation of democracy affect economy, environment and social benefits in multiple ways, hence the deepening democracy is the key to economic development (Acemoglu & Robinson, 2006; Rodrik, 1999). Researches by Persson and Tabellini (2009) and Fosten et al. (2012) show that the deepening of democracy and the accumulation of tangible capital have a positive effect on economic development. Shi and Pan (2018) found that officials or policy maker make concession in the distribution of aggregate wealth, and such an unequal distribution of aggregate wealth between officials and ordinary members of society is inevitable in economic interactions; the property of equilibriums depends on not only the distribution of economic factors such as aggregate wealth and social costs, but also the group populations (Shi, 2019). The development of democratic institutions has a significant correlation with the status of education, urbanization, age, income and income inequality in a country (Eriksson & Persson, 2003; Farzin & Bond, 2006). Bättig and Bernauer (2009) point out that in a democracy, as the people's level of participation in public affairs rises, issues about social welfare and the supply of public goods increasingly attract the general public's attention. As the democratic contest for power goes on, public opinion has the power to guide the policy-makers' attention to certain social issues. The findings of Fredriksson et al. (2005) as well as List

and Sturm (2006) demonstrates that political competition and accountability mechanism in democracy affect a country's policies on pollution prevention and social welfare.

More specifically, various researches demonstrate that democracy also has an impact to environment and environmental policy-making. The environmental quality of a country is closely linked to the environmental policy and governmental decision-making mechanism (Bernauer & Koubi, 2009; Fankhauser et al., 2015; Libman, 2013; Povitkina et al., 2015). The studies on environment and economy shows that the development of democratic system has a substantial impact on national environmental policies, or can even bring significant changes to the environmental status of the country (Barrett & Graddy, 2000; Cirone & Urpelainen, 2013; Congleton, 1992; Didia, 1997; Torras & Boyce, 1998). Fredriksson and Neumayer (2013) point out that historical experience and the development of democratic mechanism in a country have an important influence to the formulation of current climate policies of the country. Lv (2017) discussed the relationship between democracy and economic performance, the author found that when the national income of a country reaches a certain level, the level of democratic consolidation is negatively correlated with the level of carbon dioxide emission. The research by Ramalho et al. (2018) concludes that the effect of development on the energy mix depends on the level of democracy. Neagu and Teodoru (2019) examine the long-term relationship between economic complexity, energy consumption structure, and greenhouse gas emission. The empirical results indicate a long-term equilibrium relationship between economic complexity, energy consumption structure and greenhouse gas emission. Less democratic countries depart faster from the hydro source and rely more on oil and gas, while more democratic societies have more variety at the upper rungs.

Although some existing studies have examined the positive influence that social and political mechanisms bring to the environment and economy from different perspectives, there are still persisting debate and disagreement. For example, researches by Midlarsky (1998), Scruggs (1998), as well as Roberts and Parks (2007) provide different accounts and suggest that the development of democratic institutions does not necessarily have positive correlation to environmental quality. According to You et al. (2015), this divergence can be attributed to the heterogeneity of the research objects, and their study shows that there are differences between the deepening of democracy and the carbon dioxide emissions in different countries due to the different weights.

We believe that the existing literature has not paid sufficient attention to the correlation between democratic development and energy efficiency. Improving the efficiency of energy is a significant way to promote economic growth and advance towards the goals of achieving energy security and emission reduction. Most of the literature focuses on the variable factors of energy efficiency, technological progress, structural adjustment, and market reform (Lin & Li, 2014), while the analysis about the influence of social and political mechanism on energy efficiency has been absent.

Although the latest researches, such as You et al. (2015) and Lv (2017), began to explore whether the development of democracy or the promotion of the per capita income can effectively improve environmental quality or greenhouse gas emissions, Ahlborg et al. (2015) and Borång et al. (2016) found that both democracy per se and the quality of democratic institutions have significant positive effects on per capita

household consumption of electricity, and Adom et al. (2018) concluded that potential CO2 emissions improve efficiency and democracy significantly reduces both emissions only in the transport sector, there is still no related research about whether democracy can significantly change the national energy efficiency.

The aim of this study is to reveal the relationship between the development of democracy and national energy efficiency. Firstly, this paper is based on the energy usage efficiency assessment model of Zhou et al. (2012), and takes the labor, economic output and other variables as explanatory variables to measure energy efficiency of each country. Secondly, the empirical estimation based on the traditional regression model can only reflect the function relationship between explanatory variables and the dependent variable on average. If the research data is not a normal distribution, or explore the effect of explanatory variables on a selected sample, the estimated results obtained by the regression method may be biased. According to the quantile regression model of Koenker and Bassett (1978), this paper is probes into the influence of democratic development on energy efficiency under the different degree. The empirical results show that there is a significant statistical correlation between democratization and the energy efficiency. The application of quantile regression estimates furtherly indicates that the deepening of democratization brings a positive effect on energy efficiency, especially in the process of improvement from lower energy efficiency.

### 3. Methodology

#### 3.1. The assessment of energy efficiency

Based on the parametric frontier approach of energy efficiency performance, Zhou et al. (2012) and Chou et al. (2019) derived the estimator of total factor energy productive efficiency through stochastic frontier production function. This paper follows the theory of Zhou et al. (2012). The setup of estimator model setup is shown in equation (1):

$$\ln(1/E_{it}) = \beta_0 + \beta_K \ln(K_{it}) + \beta_L \ln(L_{it}) + \beta_Y \ln(GDP_{it}) + \beta_{KL} \ln(K_{it}) \ln(L_{it}) + \beta_{KY} \ln(K_{it}) \ln(GDP_{it}) + \beta_{LY} \ln(L_{it}) \ln(GDP_{it}) + v_{it} - u_{it} \quad (1)$$

In this formula, E represents energy use of the research object;  $K_{it}$ ,  $L_{it}$ ,  $GDP_{it}$  indicate the capital formation, labor force, and gross domestic product,  $u_i$  represents an inefficient item of non-negative statistical distribution;  $v_i$  represents the combined errors at stochastic production frontier.

The energy efficiency of nations derived from above-mentioned estimator is taken as the dependent variables. And this paper discusses the influence of the explanatory variables on the efficiency value. The setup of empirical model is as follows:

$$EE_{it} = \gamma_0 + \gamma_1 Democracy_{it} + \gamma_2 MVA_{it} + \gamma_3 \ln(Capita_{it}) + \gamma_4 Price\ level_{it} + \gamma_5 X_{it} + \varepsilon_i \quad (2)$$

In equation (2),  $EE_{it}$  represents the estimated value of energy efficiency in equation (1),  $Democracy_{it}$  is the democracy indicator, and we use three different indices: that is

the sum of the Freedom House Political Rights and Civil Liberties Indices, Polity IV project and International Country Risk Guide (ICRG).  $MVA_{it}$  denotes the proportion of a country’s manufacturing value added in GDP,  $Capita_{it}$  is country’s gross capital formation, and  $Price\ level_{it}$  is the ratio of PPP conversion factor (GDP) to the market exchange rate in each country. Based on this equation we can further analyze the impact of economic development and democratization on the energy efficiency of all countries.

**3.2. Quantile regression**

Consider the empirical outcomes may differ in different quantiles, we also apply the quantile regression. For the dependent variable  $Y$  with probability distribution function

$$F(y) = \text{Prob}(Y \leq y) \tag{3}$$

We can define the  $\tau$  – th quantile of  $Y$  as the following inverse function

$$Q(\tau) = \inf\{y : F(y) \geq \tau\} \tag{4}$$

Where  $0 < \tau < 1$ , and the case of median is  $Q(1/2)$ . Next, we define a random variable  $Y$  as a vector space  $\{y_1, \dots, y_n\}$ , and thus the sample median is the value that minimizes the sum of absolute deviations, as follows:

$$\min_{\vartheta \in R} \sum_{i=1}^n |y_i - \vartheta| \tag{5}$$

In other words, the general  $\tau$  – th sample quantile  $\vartheta(\tau)$ , which is similar to  $Q(\tau)$ , can be formulated as the solution of the optimization problem.

$$\min_{\vartheta \in R} \sum_{i=1}^n \rho_{\tau}(y_i - \vartheta) \tag{6}$$

Where  $\rho_{\tau}(z) = z(\tau - I(z < 0))$ ,  $0 < \tau < 1$ . Here  $I(\cdot)$  denotes the indicator function. However, the linear conditional quantile function  $Q(\tau|X = x) = x'\beta(\tau)$  can be estimated by solving

$$\beta(\tau) = \arg \min_{\beta \in R^D} \sum_{i=1}^n \rho_{\tau}(y_i - x'\beta) \tag{7}$$

for any quantile  $\tau \in (0, 1)$ .

The quantity  $\hat{\beta}(\tau)$  is called the  $\tau$  – th regression quantile. For example, the case  $\tau = 1/2$ , which minimizes the sum of absolute residual, corresponds to the median regression.

#### 4. Database, results and discussion

The data used in our study are drawn from various databases, the democracy measures are deriving from the Freedom House, Polity IV database and the International Country Risk Guide (ICRG). The first measure of democracy provides an assessment annually to report the current state of civil and political rights on a scale from 1 (most free) to 7 (least free). States where the average for political and civil liberties differed from 1.0 to 2.5 are considered “free”. States with values from 3.0 to 5.5 are considered “partly free” and those with values between 5.5 and 7.0 are considered “not free”. Follow the definition of Rodrik (1999, 2003), we combine the two rating into a single index that varies from 0 to 1 by using the transformation  $[(14 - \text{civil liberties} - \text{political rights})/12]$  and the index with a higher value indicating greater democracy.

The second one is another measure of democracy and used data series in political science research, contains coded annual information on the level of democracy for most independent states with greater than 500,000 total population and covers the years since 1800. We capture the regime authority spectrum on a 21 point scale ranging from  $-10$  (fully non-democratic) to  $+10$  (fully democratic). We transform the second measure into an index which varies from 0 to 1; higher scores indicate more democratic regimes. Finally, the third measurement comprises 22 variables in three subcategories of risk: political, financial, and economic to evaluate national political and economic situation. ICRG disclosures a scale of 1 to 6 on countries’ democratic accountability, with higher ratings signifying higher democracy. We transform the measure into the index that varies from 0 to 1 which uses the transformation  $\text{democratic accountability} / 6$ . Consider the data integrity of the energy and economic indicators in each country, the relevant data in this paper are drawn from the World Bank’s World Development Indicator (WDI), which aggregates the statistics of the 35 countries in Europe from 1990 to 2013. Table 1 shows the descriptive statistics for our variable.

Table 2 estimates the energy efficiency values of the samples according to equation (1), and varies the energy efficiency in different regions. From this table, we can see that the energy efficiency of southern Europe is the highest, followed by Central Europe and the lowest in Eastern Europe. In addition, it is found that the regional energy efficiency is generally increasing year by year. Table 3 takes the efficiency value as the dependent variable and discusses the effects of the explanatory variables. First, the estimated combinations show that democratization has a positive impact on the country’s energy efficiency. Take the estimate (4) for example, the estimated result shows that the Freedom House index each enter with positive coefficients that significant at 99 percent confident levels, respectively, indicate that when the country implements deepening democracy institution can furtherly increase the energy efficiency herself. In other variables, the empirical evidence shows that the higher the proportion of manufacturing in a country’s GDP (MVA) is, the greater the contribution of industrial production to GDP, and has a negative impact on energy efficiency. The outcome indicates that when a country’s manufacturing sector contributes more to its economic activities, it means that the more dependent its production is on energy consumption, which in turn has a negative effect on energy efficiency. Besides, the

**Table 1.** Descriptive statistics.

Variable	Definition	Mean	Std. Dev.	Min	Max
Labor Force	Total labor force (unit: ten thousand).	983.938	137.287	15.328	7707.350
Capital Formation	Gross capital formation (constant 2010 US\$, unit: on hundred million dollar).	1212.682	1709.642	77.328	7329.624
GDP	GDP at market prices (constant 2010 US\$, unit: on hundred million dollar)	5629.275	8183.469	34.514	35772.300
Energy	Energy use (kg of oil equivalent) per \$1000 GDP	143.790	79.697	57.288	607.909
MVA	The proportion of a country's manufacturing value added in GDP.	17.806	5.384	5.058	33.901
Capita	GDP per capita (constant 2010 US\$, unit: dollar).	30658	22784	946	110001
Price Level	Price level ratio of PPP conversion factor (GDP) to the market exchange rate	0.863	0.359	0.152	1.678
Freedom House Index	Democracy measure that derives from Freedom House.	0.901	0.192	0	1
ICRG Index	Democracy measure that derives from the International Country Risk Guide.	0.901	0.169	0	1
Polity Index	Democracy measure that derives from the Polity IV project.	0.949	0.137	0	1
Energy Efficiency	The estimated energy emission efficiency in equation (1)	0.643	0.201	0.141	0.981
Countries (N = 35)	Albania, Austria, Belarus, Belgium, Croatia, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Moldova, Netherlands, Norway, Poland, Portugal, Romania, Russia, Serbia, Slovakia, Slovenia, Spain, Sweden, Switzerland, Ukraine, United Kingdom.				

Data Source: World Development Indicators; Freedom House, ICRG, Polity IV project.  
Source: this study.

**Table 2.** The average of energy efficiency in different period each region in European countries.

Regions	1990-1993	1994-1997	1998-2001	2002-2005	2006-2009	2010-2013
North	0.569	0.538	0.499	0.502	0.501	0.518
East	N.A	N.A	0.366	0.412	0.478	0.487
Center	0.739	0.635	0.661	0.653	0.686	0.708
West	0.627	0.624	0.623	0.617	0.649	0.686
South	0.749	0.787	0.778	0.784	0.833	0.859
Total	0.654	0.653	0.615	0.614	0.654	0.676

Source: this study.

**Table 3.** OLS estimations using WDI data (1990-2013).

Dependent Variable	Energy Efficiency			
	(1)	(2)	(3)	(4)
Freedom House Index	0.270*** (0.039)	0.267*** (0.040)	0.219*** (0.053)	0.219*** (0.053)
MVA			-0.007*** (0.001)	-0.008*** (0.002)
ln(Capita)			0.045*** (0.018)	0.080*** (0.020)
Price Level			-0.135*** (0.045)	-0.263*** (0.056)
Year Dummies	No	Yes	No	Yes
Constant	0.404*** (0.036)	0.428*** (0.073)	0.248* (0.130)	0.137 (0.147)
N	669	669	669	669
R square	0.067	0.080	0.110	0.136

Standard errors in parentheses.

\*p < .1, \*\*p < 0.05, \*\*\*p < 0.01.

Source: this study.



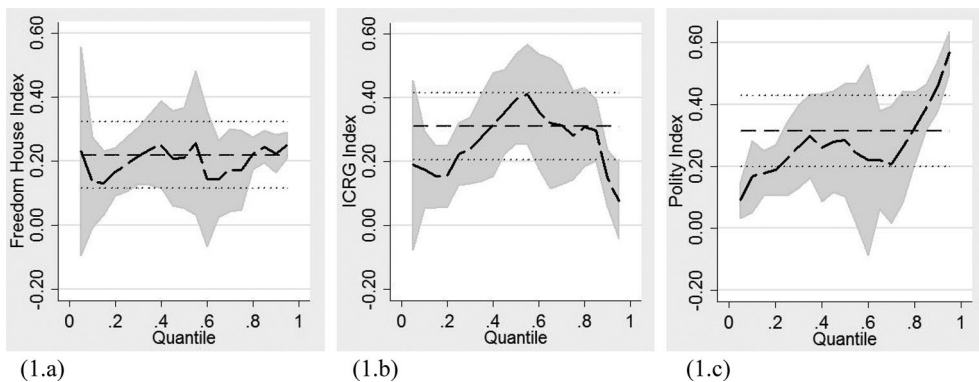
**Table 4.** Quantile regression results.

Dependent Variable	Energy Efficiency				
	(1) Q <sub>0.1</sub>	(2) Q <sub>0.3</sub>	(3) Q <sub>0.5</sub>	(4) Q <sub>0.7</sub>	(5) Q <sub>0.9</sub>
Freedom House Index	0.132*	0.179***	0.223*	0.162**	0.214***
MVA	-0.002	-0.006***	-0.009**	-0.017***	-0.007***
ln(Capita)	0.085*	0.081***	0.103**	0.171***	0.022**
Price Level	-0.236*	-0.239***	-0.256*	-0.415***	-0.111***
Year Dummies	Yes	Yes	Yes	Yes	Yes
Constant	-0.161	-0.018	-0.111	0.309	0.667***
N	669	669	669	669	669
R square	0.126	0.119	0.077	0.120	0.094

Standard errors in parentheses.

\* $p < .1$ , \*\* $p < 0.05$ , \*\*\* $p < 0.01$ .

Source: this study.



**Figure 1.** OLS and quantile regression results using energy efficiency as the dependent variable. Source: this study.

per capita income has a positive impact on energy efficiency, and the price level has a negative impact on the explanatory variables.

Table 3 is the OLS result which is the average effect of explanatory variables on dependent variables, however, the usual regressions focus on the mean, and the result obtained from OLS regression may be biased due to neglect the distributional heterogeneity. Table 4 applies the quantile regression to estimate sample which is by quantile 0.1-0.9 in a period of 1990 and 2013. The purpose of applying quantile regression because the methodology is able to describe the entire conditional distribution of the dependent variable and distinguish the energy efficiency quantile from the concept of sample distribution and to analyze the impact of deepening democracy on energy efficiency in a country when energy efficiency is lower or higher. Demonstration shows that democratization has a significant effect on improving energy efficiency under all quantile. We further illustrate in Figure 1a, in which the horizontal axis represents the different quantile of the energy efficiency value, the vertical axis represents the effect of democratization degree and the horizontal dashed lines are expressed as coefficient estimates, which are estimated from equation (2) in Table 3. The figure

**Table 5.** Robust analysis, alternative measures of democracy.

Dependent Variable	Energy Efficiency			
	(1)	(2)	(3)	(4)
ICRG Index	0.310*** (0.054)	0.314*** (0.054)		
Polity Index			0.313*** (0.059)	0.315*** (0.060)
MVA	-0.006*** (0.054)	-0.007*** (0.001)	-0.007*** (0.001)	-0.007*** (0.001)
ln(Capita)	0.059*** (0.016)	0.095*** (0.018)	0.038** (0.015)	0.057*** (0.018)
Price Level	-0.168*** (0.044)	-0.302*** (0.055)	-0.061 (0.041)	-0.132** (0.053)
Year Dummies	No	Yes	No	Yes
Constant	0.404*** (0.036)	-0.078 (0.141)	0.160 (0.118)	0.084 (0.136)
N	680	638	680	638
R square	0.143	0.171	0.169	0.184

Standard errors in parentheses.

\* $p < .1$ , \*\* $p < 0.05$ , \*\*\* $p < 0.01$ .

Source: this study.

shows that when a country's energy efficiency is at 0.4 quantile before and after the 0.6 quantile, the democracy has a positive effect on the improvement of energy efficiency in the country and the degree of influence increases with the increase of the quantile.

To investigate the robustness of our findings, we explore whether the effect of democracy on energy efficiency is driven by other indexes of democracy measures. Tables 5 and 6 list regression results and quantile regression outcomes for the alternative index of democracy (ICRG index and Polity index), the sign and significance of the estimated outcomes of democracy index are similar to those results in Tables 3 and 4. Figure 1b and c depicts the impact of democratization on energy efficiency under the quantile regression in Table 6. It is found that most coefficient of the democratic index has positive and significant influence by comparing Table 4 with Table 6. In addition, the influence of democratization is stronger when the countries' energy efficiency improve before 0.4 quantile. Comparing the Figure 1a to c, it can be found that all democratic indicators have a positive impact on the country's energy efficiency. The positive impact of democratization on energy efficiency is stronger when a country is in a process where energy efficiency is promoted from a low state (lower quantile). In other words, when the country is at a low energy efficiency stage, energy efficiency can be improved through deepening democracy.

All the above estimation shows that the deepening of democratization has a significant positive impact on the energy efficiency of most countries under average (OLS) or different quantile regressions. Considering the time-series nature of some of the variables in the empirical analysis, could the estimative results above show that there is an autocorrelation between the explanatory variables and the dependent variables? To further verify whether our estimation results affect the significance of the explanatory variables due to autocorrelation, the Prais-Winsten approach (PW) and Cochrane-Orcutt approach (CO) of Feasible Generalized Least Square (FGLS) are applied in this paper. Firstly, we set the mean value of time series of the estimated

**Table 6.** Robust analysis, quantile regression results.

Dependent Variable	Energy Efficiency				
	(1) Q <sub>0.1</sub>	(2) Q <sub>0.3</sub>	(3) Q <sub>0.5</sub>	(4) Q <sub>0.7</sub>	(5) Q <sub>0.9</sub>
ICRG Index	0.174*** (0.058)	0.221*** (0.065)	0.338*** (0.097)	0.246*** (0.068)	0.128** (0.054)
Polity Index	0.130** (0.057)		0.153 (0.125)		0.217*** (0.075)
MVA	-0.001 (0.003)	-0.005** (0.002)	-0.008*** (0.003)	-0.134*** (0.002)	-0.015*** (0.002)
ln(Capita)	0.091** (0.043)	0.063** (0.029)	0.110*** (0.033)	0.184*** (0.020)	0.126*** (0.020)
Price Level	-0.253* (0.139)	-0.240*** (0.076)	-0.329*** (0.098)	-0.425*** (0.060)	-0.275*** (0.064)
Year Dummies	Yes	Yes	Yes	Yes	Yes
Constant	-0.239 (0.296)	-0.121 (0.189)	-0.246 (0.251)	-0.582*** (0.163)	-0.103 (0.171)
N	680	680	680	680	680
R square	0.136	0.132	0.105	0.146	0.097
					0.535*** (0.047)
					-0.005*** (0.001)
					0.066*** (0.011)
					-0.052 (0.037)
					Yes
					0.378*** (0.105)
					680
					0.135

Standard errors in parentheses.  
\*p<.1, \*\*p<0.05, \*\*\*p<0.01.  
Source: this study.

**Table 7.** Robust analysis, autoregressive estimation.

Dependent Variable Approach	Energy Efficiency					
	PW (1)	CO (2)	PW (3)	CO (4)	PW (5)	CO (6)
Freedom House Index	0.623** (0.262)	0.629** (0.268)				
ICRG Index			-0.518* (0.247)	-0.577 (0.366)		
Polity Index					0.829** (0.406)	0.891* (0.424)
MVA	-0.001 (0.006)	0.001 (0.006)	-0.013*** (0.005)	-0.014** (0.006)	-0.005 (0.005)	-0.003 (0.006)
ln(Capita)	0.003 (0.041)	-0.002 (0.045)	0.163** (0.059)	0.186** (0.070)	0.004 (0.043)	-0.010 (0.048)
Price Level	0.074* (0.039)	0.072 (0.041)	0.036 (0.044)	0.040 (0.045)	0.094** (0.042)	0.087* (0.043)
Year	Yes	Yes	Yes	Yes	Yes	Yes
Constant	-6.639 (3.642)	-7.591 (4.841)	-2.858 (3.268)	-1.292 (4.981)	-5.883 (3.646)	-7.605 (4.430)
N	24	23	24	23	24	23
$\rho$	0.751	0.768	0.745	0.791	0.692	0.664
Durbin-Watson statistic	1.876	1.921	1.757	1.576	1.892	1.849
R square	0.974	0.618	0.973	0.602	0.973	0.613

Standard errors in parentheses.

\* $p < .1$ , \*\* $p < 0.05$ , \*\*\* $p < 0.01$ .

Source: this study.

variables in the 24 years (1990-2013) according to the study period, and set the model as follows:

$$y_t - \rho y_{t-1} = (1 - \rho)\beta_1 + \beta_2(x_{t2} - \rho x_{t-1,2}) + \dots + \beta_K(x_{tK} - \rho x_{t-1,K}) + \varepsilon_t \quad (8)$$

$$y_t - \rho y_{t-1} = (1 - \rho)\beta_1 + \beta_2(x_{t2} - \rho x_{t-1,2}) + \dots + \beta_K(x_{tK} - \rho x_{t-1,K}) + \varepsilon_t - \rho \varepsilon_{t-1} \quad (9)$$

In this model,  $\rho$  is the first-order autocorrelation coefficient, and Equation (8) represents PW estimation, Equation (9) represents CO estimation. The difference between these two is that the first sample is deleted in CO estimation. We can find the statistics of Durbin-Watson close to 2, imply nonexistence of autocorrelation in the estimation in Table 7, though the statistical significance of the explanatory variables is relatively reduced considering the autocorrelation, the impact of democratization on a country's energy efficiency is still significantly positive, which indicates that democratization still has a positive effect on a country's energy efficiency when taking autocorrelation into consideration.

Why can democracy improve energy efficiency? We think there are some reasons as follows. First, the improvement of energy efficiency may be related to the establishment of the legal system by the deepening of democracy. The study of Sunde et al. (2008) found evidence for a significant interaction effect between democracy and equality in determining the quality of growth-promoting institutions like rule of law. Democracy is associated with better rule of law when inequality is lower. When the deepening of democracy makes the legal system more complete, the society can further strengthen the government to carry out pollution prevention policy or

internalizes external costs such as environmental pollution, energy waste and so on, and promotion of energy use at the environmental level, thereby enhancing a country's energy efficiency. Second, economic growth may enhance people's living standards, and thus promote public awareness of environmental protection. In an early study of the link between economic growth and democratization, Barro (1999) argued that there is only a very weak evidence that democracy can drive economic growth. But the actual causal relationship should be due to growth, democracy for the fruit. And the democratic politics established without economic development cannot lead to long-term and stable economic growth in the country.

After consulting relevant democratic and energy economic literature, Ahlborg et al. (2015) speculated that the development of democratic institutions would affect the supply of national public finances and thus affect household electricity (energy) consumption. Boräng et al. (2016) concluded that democratization has positive effects on the provision of electricity to the general population only when there is a certain level of corruption control in place. Lv (2017) found that democratization had a significant reduction in greenhouse gas emissions for a country only when national average income was raised to a specific level. These studies show that the deepening of democracy has a significant impact on national energy consumption or emissions. In other words, the development of national energy policies, the consequent emissions, and consumption of socio-economic activities may change due to the development of regional democratic mechanisms. The empirical results in our study also show that the degree of democratization influence is different when the national energy efficiency is at different levels. Compare with Lv (2017), the study concluded that democracy can improve the environmental quality but only if a country has already reached a certain development level, that is, democratization implied to worsen environmental quality in poorer countries, while richer countries, democracy has a positive effect on environmental quality. In this study, we do not find similar outcome but found that the significantly positive impact of democratization on energy efficiency is stronger in the process of improvement from lower energy efficiency. We believe that democratization affects the legal system and economic development. On one hand, the legal system will improve the environmental quality of the administration of the government. On the other hand, economic development can lead to the improvement of people's living standards but also inspires the rise of environmental protection awareness, thereby affecting the use of energy and enhancing energy efficiency. In a word, when a country or regional economy is at a lower level of energy efficiency, they can improve the energy efficiency by reforming the legal system through democratic deepening or promoting economic development.

The next question is whether the relationship between democracy and energy efficiency holds up in a panel setting, so the impact of democratization on energy efficiency was further discussed by applying panel data analysis. As regarding whether the democratization will significantly influence the country's development, it is found that the individual features of regions will weaken the influence of democratization. For example, Acemoglu et al. (2005, 2008) used about 150 countries' democratized index in the Polity IV and Freedom House, OLS estimates and found that democratic indicators and economic growth are significantly associated with each other under

**Table 8.** Robust analysis, fixed effect.

Dependent Variable	Energy Efficiency					
	(1)	(2)	(3)	(4)	(5)	(6)
Freedom House Index	0.162** (0.064)	0.216*** (0.061)				
ICRG Index			0.097*** (0.031)	0.109*** (0.031)		
Polity Index					0.351*** (0.120)	0.362*** (0.125)
MVA	-0.002 (0.001)	-0.002* (0.001)	-0.001 (0.001)	-0.002* (0.001)	-0.003** (0.001)	-0.003*** (0.001)
ln(Capita)	0.152*** (0.017)	0.214*** (0.021)	0.164*** (0.015)	0.229*** (0.020)	0.144*** (0.015)	0.189*** (0.021)
Price Level	0.020 (0.013)	0.006 (0.027)	0.015 (0.013)	0.006 (0.027)	0.033*** (0.013)	0.012 (0.031)
Year Dummies	No	Yes	No	Yes	No	Yes
Country Dummies	Yes	Yes	Yes	Yes	Yes	Yes
Constant	-1.002*** (0.156)	-1.586*** (0.209)	-1.067 (0.150)	-1.636*** (0.204)	-1.090*** (0.163)	-1.477*** (0.210)
N	669	669	680	680	638	638
R square	0.045	0.050	0.060	0.060	0.105	0.101

Standard errors in parentheses.

\* $p < .1$ , \*\* $p < 0.05$ , \*\*\* $p < 0.01$ .

Source: this study.

OLS estimation. However, there is no significant relationship between democracy and economic growth in the fixed effect. According to Acemoglu et al. (2003, 2005, 2008) and Rodrik (2003), they concluded that there will be a miscalculation about the democratic indicator and economic growth when factors like cultural, ethical, geographical, environmental of different countries were neglected. We curious that whether the influence of democratization on national energy efficiency will be weakened when we consider the fixed effect. In order to verify the relationship between the democratic indicator and energy efficiency, the fixed effect estimation was conducted and shown in Table 8.

The findings are quite consistent where democracy index is concerned, all the fixed effect estimates of the coefficient on democracy are positive and statistically significant at the 95 percent level or better; the results indicate that the outcomes with the fixed effect regression are also strong. The outcomes quite persuasive evidence that the democratic development is associated with higher energy efficiency for countries. A closer look at the range of panel estimates for the coefficient on democracy index is 0.097-0.362, with the fixed effect regressions providing somewhat lower estimates if we compare with OLS estimations in Tables 3 and 5.

## 5. Conclusion

This study discusses whether democratic development can significantly change energy efficiency. We analyzed the link between the democratic development and energy efficiency of 35 countries in Europe between 1990 and 2013 which applied the database from Freedom House, Polity IV project, ICRG, and WDI. The empirical finding shows that the deepening of democracy has the positive influence on the energy efficiency improvement of the country. The further application of quantile regression

estimates indicates that the positive impact of democratization on energy efficiency is stronger in the process of improvement from lower energy efficiency.

We believed that the deepening of democracy promotes the institutionalization of law and improves energy efficiency. In addition, economic development probably can promote environmental protection awareness of people while improving people's living standards, and then improve energy efficiency. The FGLS and the fixed effect regression also indicate that democracy has a significant positive effect on the energy efficiency even we consider the autocorrelation and panel data analysis. Such findings suggested that factors such as time trends, cultural, ethnic or geographical differences do not change the statistically significant of democratic deepening on a country's energy efficiency.

Although this paper shows that democratization has a significant impact on national energy efficiency, there are still some deficiencies in this study. For example, we don't know exactly how the legal, social, or political mechanisms that democratization has spawned will affect the energy use and environmental quality of a country. These also require further study and discussion. Secondly, whether the empirical results are suitable for specific geographical areas such as Africa or the Middle East also needs to be further analyzed. In future studies, we will explore questions in this direction.

### Disclosure statement

No potential conflict of interest was reported by the author(s).

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