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The influence of democracy on emissions and energy efficiency in America: New evidence from quantile regression analysis

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Abstract

This study explores whether the development of democracy can significantly affect CO_2 emissions and the energy efficiencies in the countries. Database reference from Freedom House, Polity IV project and World Development Indicator was applied to analyze the relationship between the democracy development, CO_2 emissions and the energy efficiency of 26 countries in America from the year 1990 to 2013. Empirical result shows that the deepening democracy has a significant impact on the reduction of national CO_2 emissions and brings a positive influence on energy efficiency. The further application of quantile regression also indicates that the influence of democratization on CO_2 emissions and countries' energy efficient scores is significant. The empirical results may reflect the reduction of emission or the improvement of energy efficient outcome from the enhancement of democratic institution.

Keywords

Carbon dioxide emission, energy efficiency, America, democracy, quantile regression

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Introduction

The levels of economic development worldwide are generally promoted, with the strong financial support of economic progress, and the related international environment protection concepts are more and more popular among the countries in the world. As countries put more emphasis on the issues of environmental protection, they also put forward various corresponding solutions. In order to curb the tendency of global warming, UNFCCC (the United Nations Framework Convention on Climate Change) completed Paris Agreement in France, in the year of 2015, setting the target to control the global rise of temperature at a pre-industrial level of 2°C, and in the meanwhile, sparing no effort to make it less than the pre-industrial level of 1.5°C. Paris Agreement came into force in 2016, which symbolized the goal of international greenhouse gas reduction entered a new era. Since then, countries in the world made efforts to gradually reduce their reliance on oil, coal and other fossil fuels to cultivate a low-carbon economic growth mode. In this context, any country that emits greenhouse gases would undertake reduction responsibility of varying degrees. With the increasing costs of energy resources, economic productions with higher energy efficiency have become increasingly prioritized in the world.[1,2] Also, how to adjust the possible impact of emission reduction on economic development becomes an important issue for all the countries.

It is generally believed that political stability and the construction of democratic system have various effects on economy, environment and social benefits in many different aspects, and thus the deepening of economy and democracy is considered the key to economic development.[3–5] The development of democratic system is significantly correlated with education, urbanization, age, income and income inequality of a country.[6–9] What's more, the attitudinal distance between elite and citizen may further affect the process of the energy policy through stealth democracy.[10] There are literature which indicate that the environmental policy and government mechanism of a country could influence the environmental quality to some extent.[11–13] Relevant environmental and economic study show that democratic system development has a substantial influence on national environmental policies.[14–16] Apart from that, Fredriksson et al.[17] and List and Sturm[18] found that the political competition and accountability mechanism in the government would affect a country's policy promotion on pollution prevention or social welfare. Bättig and Bernauer[19] pointed out that as public participation in public affairs improved, social welfare and public goods were attracting increasing consideration in the democratic system. Persson and Tabellini[20] and Fosten et al.[21] believed that the deepening of democracy and the accumulation of tangible capital might have positive effects on the development of economy; besides, Fredriksson and Neumayer[22] pointed out that a country's historical experience and democratic mechanism development would have an important effect on its formulation of current climate policies. Lv[23] found that when a country's income reached a certain level, its democratic mechanism would be correlated with its carbon dioxide emission negatively. Other studies such like Stern,[24] Cirone and Urpelainen,[25] Csereklyei and Stern[26] further discussed the political impact or the correlation between democracy development and energy use.

Though there have been some studies verified the positive effects of social and political mechanisms on the environmental economy from different angles, controversies and disagreements still exist about the impact of democracy on the environment. For instance, Midlarsky,[27] Scruggs,[28] Roberts and Parks[29] believed that there was not

necessarily a positive relationship between democratic system development and environmental quality, while You et al.[30] argued that these differences were caused by the heterogeneity of research objects, and their study showed that there were differences between the deepening of democracy and the carbon dioxide emissions in different countries due to different weights. Joshi and Beck[31] found no evidence of a CO_2 Environmental Kuznets Curves (EKC) for the OECD and non-OECD regions, and empirical results for the impact of political and economic freedom, depending on region. However, the relevant literature showed that very few existing studies involved the correlation between democratic development and energy efficiency. Improving energy efficiency is a significant way to insure the growth of economy while achieving energy conservation and emission reduction. However, most literature focused on the variable factors of energy efficiency, technological progress, structural adjustment, and market reform,[32] and rarely talked about the impact of social and political mechanism on energy efficiency.

Although recently, the latest studies such as You et al.[30] and Lv[23] began to explore whether democratic development or the promotion of the per capita income could improve environmental quality or reduce greenhouse gas emissions effectively, Ahlborg et al.[33] and Boräng et al.[34] found that both democracy and institutional quality have significant positive effects on per capita household consumption of electricity; however, there is still no relevant study about whether democracy could change the efficiency of energy significantly.

As mentioned before, this study investigates the relationship between countries' democracy and energy efficiency or greenhouse emissions. The novelty of this paper is trying to explore whether the development of democracy can significantly affect CO_2 emissions and the energy efficiencies in the countries. In this study, the database of World Bank's WDI (World Development Indicator), Freedom House and Polity Index is used to collect and analyze the relative data about energy use, economic and democratic indicators of the Americas while regarding labor, economic output and capital input as explanatory variables to measure their energy efficiency. Besides, it should be noticed that empirical estimates based on traditional regression models could only reflect the functional relationship between explained variables and explanatory variables on an average extent. If the study data are no longer positively distributed, or if we are about to explore the impact of explanatory variables on a certain section of the sample, the estimated results of the methods mentioned above might be biased. Therefore, this study further applies the quantile regression to estimate the impact of democratic development on CO_2 emissions and energy efficiency under different quantiles. The empirical results show that the deepening of national democratic mechanism has a significant impact on the energy efficiency and carbon dioxide emissions of the Americans. And with the deepening of a country's democratic mechanism, its energy efficiency would increase while its carbon dioxide emission would significantly reduce.

The structure of this paper is arranged as follows: the second part introduces the relevant literature, the third part introduces the model of energy efficiency measurement and the model of component regression, the fourth part illustrates the data, the empirical estimation results of the study and in the meantime discusses the impact democracy puts on energy efficiency and carbon dioxide emissions, and last but not least, the final part concludes the full text.

Methods

Emission analysis

To examine how democracy and other factors affect emissions, we have estimated an OLS approach as follows

$$\ln(\mathrm{CO_{2it}}) = \gamma_0 + \gamma_1 Democracy_{it} + \gamma_2 MVA_{it} + \gamma_3 \ln(Capita_{it}) + \gamma_4 Labor_{it} + \gamma_5 X_{it} + \varepsilon_{it} \quad (1)$$

where $\mathrm{CO_{2it}}$ is the amount of emissions of country i at year t, $Democracy_{it}$ is the democracy indicator, and we use two different indices: that is the sum of the Freedom House Political Rights and Civil Liberties Indices and the Polity2 democracy index. MVA_{it} denotes the proportion of a country's manufacturing value added in GDP, $Capita_{it}$ is country's gross capital formation and $Labor_{it}$ is the labor force of country i at year t.

Energy efficiency

In the analysis of the empirical model specification of energy efficiency, this paper follows the theoretical basis of Zhou et al.[35] to set up the empirical model as follows

$$\begin{aligned}\ln(1/\mathrm{E_{it}}) = {} & \beta_0 + \beta_T \ln(K_{it}) + \beta_L \ln(L_{it}) + \beta_T \ln(GDP_{it}) + \beta_{TL} \ln(K_{it}) \ln(L_{it}) \\ & + \beta_{\mathrm{TY}} \ln(K_{it}) \ln(GDP_{it}) + \beta_{LY} \ln(L_{it}) \ln(GDP_{it}) + \mathrm{v_{it}} - \mathrm{u_{it}}\end{aligned} \quad (2)$$

where $\mathrm{E_i}$ is the energy usage of the observed object in each country, K_{it}, L_{it}, GDP_{it} indicate the capital formation, labor input, and gross domestic product, $\mathrm{u_{it}}$ is the inefficient item of the non-negative statistical distribution, and $\mathrm{v_{it}}$ is the error combination of the random production boundary.

Applying the above equation, the energy efficiency value of each country is the dependent variable and discusses the influence of explanatory variables on efficiency values. The empirical model is as follows

$$EE_{it} = \gamma_0 + \gamma_1 Democracy_{it} + \gamma_2 MVA_{it} + \gamma_3 \ln(Capita_{it}) + \gamma_4 Price\ level_{it} + \gamma_5 X_{it} + \varepsilon_i \quad (3)$$

In the above formula, EE_{it} is the estimated value of country i's energy efficiency at year t. $Democracy_{it}$ 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. According to formula (3), we can further analyze the impact of economic development and democratization on national energy efficiency.

Quantile regression

Considering the empirical outcomes may differ in different quantiles, we further employ the quantile approach to examine the effect of democracy on $\mathrm{CO_2}$

emissions and energy efficiency. The quantile estimator is obtained by solving the optimization problem

$$\min_{\beta \epsilon R^k} \left[\sum_{i \epsilon \left\{ i: y_i \geq x_i' \beta \right\}} \theta \left| y_i - x_i' \beta \right| + \sum_{i \epsilon \left\{ i: y_i < x_i' \beta \right\}} (1-\theta) \left| y_i - x_i' \beta \right| \right] \tag{4}$$

For the θ-th quantile ($0<\theta<1$), where y_i is the dependent variable and x_i is a k by 1 vector of the explanatory variables.

Results and discussion

The statistical database economy and energy of each country is cited from World Development Indicator (WDI). The economic variables are the national labor force, capital formation, GDP, manufacturing added value of GDP share, per capital income and price level, energy-related variables for the years of national energy use and CO_2 emissions. Democracy variables refer to the democratic indicators published by Freedom House and Polity IV project over the years. The former measure of democracy provides a subjective classification of countries on a scale of 1 to 7 on civil liberties and political rights separately, with higher ratings signifying less freedom. We combine the two ratings into a single index that varies from 0 to 1 by using the transformation [14- civil liberties- political rights]/12 and the index with a higher value indicating greater democracy. The later one is another measure of democracy that captures 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; and the higher scores indicate more democratic regimes. In this paper, we collect data of 26 countries' CO_2 emissions and the energy use data of 23 countries. By formula (1), we estimate the energy efficiency values of each country from 1990 to 2013. Table 1 summarizes the descriptive statistics and definitions of each variable.

Table 2 summarizes the average energy efficiency of countries in different periods, and we can find some of the countries such as Bahamas, Barbados, Bolivia, Brazil, Chile, Ecuador, Guatemala, Honduras, Mexico, Nicaragua, Panama, Peru, Uruguay and Venezuela, their energy efficiency tends to decrease. The energy efficiency of Belize, Canada, Cuba, Dominican Republic, Jamaica and United State is increasing; the average energy efficiency of Argentina, Colombia and Paraguay is generally unchanged. Uruguay has the highest energy efficiency; Bahamas is the least efficient over the years.

Table 3 shows the result of OLS estimated. First of all, energy efficiency is the dependent variable in columns (1) and (2), empirical evidence shows that a country's deepening of democracy could enhance the national energy efficiency and have a 99% statistically significant level, indicating that when the country implements deepening, democracy institution can further increase the energy efficiency herself; manufacturing factory's added value GDP share has a positive impact on energy performance, and there is a significant negative impact on price levels. In contrast, ln (CO_2_kt) is the explanatory variable in columns (3) and (4), and the results show that democratization has a significant negative impact on the national CO_2 emission level. In addition, the per capita income and labor force are bringing growth of CO_2 emission.

Table 1. Descriptive statistics.

Variable	Definition	Mean	Std. Dev.	Min	Max
Labor force	Total labor force (unit: ten thousand).	142.585	307.932	5.822	15981.582
Capital formation	Gross capital formation (constant 2010 US$, unit: one hundred million dollar).	145.813	5356.717	1.757	33240.900
GDP	GDP at market prices (constant 2010 US$, unit: one hundred million dollar)	6029.468	23919.899	53.438	158029
Energy	Energy use (kg of oil equivalent) per $1000 GDP	104.722	31.995	50.978	19.219
CO_2	CO_2 emissions (unit: 1000 kt)	22.745	94.133	0.165	579.516
MVA	The proportion of a country's manufacturing value added in GDP.	14.639	5.349	3.123	28.359
Capita	GDP per capita (constant 2010 US$, unit: dollar).	8468.090	9391.662	1080.977	49979.541
Price level	Price level ratio of PPP conversion factor (GDP) to market exchange rate	0.541	0.217	0.224	1.253
Freedom house index	Democracy measure that derives from Freedom House.	0.755	0.223	0	1
Polity index	Democracy measure that derives from the Polity IV project (Polity2 Index).	0.858	0.185	0.190	1
Energy efficiency	The estimated energy efficiency of countries by equation (2)	0.907	0.026	0.761	0.951
Countries (N=26)	Argentina, Bahamas, Barbados, Belize, Bolivia, Brazil, Canada, Chile, Colombia, Costa Rica, Cuba, Dominican Republic, Ecuador, Guatemala, Guyana, Honduras, Jamaica, Mexico, Nicaragua, Panama, Paraguay, Peru, Saint Lucia, United States, Uruguay, Venezuela.				

Data source: World Development Indicators; Freedom House, ICRG, Polity IV project.

Table 2. The average energy efficiency in different periods for each country.

Country	1990–1993	1994–1997	1998–2001	2002–2005	2006–2009	2010–2013	Total
Argentina	0.880	0.886	0.882	0.863	0.868	0.881	0.876
Bahamas	0.825	N.A	N.A	0.870	0.869	N.A	0.860
Barbados	0.900	N.A	N.A	0.884	0.885	N.A	0.888
Belize	0.904	N.A	N.A	0.933	0.930	N.A	0.926
Bolivia	0.941	0.915	0.901	0.909	0.891	0.857	0.902
Brazil	0.924	0.919	0.909	0.905	0.903	0.899	0.909
Canada	N.A	N.A	N.A	N.A	0.895	0.907	0.901
Chile	0.924	0.920	0.910	0.913	0.911	0.899	0.913
Colombia	0.938	0.932	0.933	0.935	0.938	0.938	0.936
Cuba	0.805	0.847	0.853	0.889	0.909	0.912	0.865
Dominican Republic	0.922	0.906	0.896	0.910	0.925	0.933	0.915
Ecuador	0.936	0.925	0.916	0.904	0.892	0.881	0.909
Guatemala	N.A	N.A	0.920	0.920	0.919	0.898	0.913
Honduras	0.926	0.910	0.906	0.901	0.891	0.889	0.904
Jamaica	N.A	N.A	N.A	N.A	0.829	0.878	0.857
Mexico	0.897	0.898	0.904	0.898	0.891	0.889	0.896
Nicaragua	N.A	0.909	0.900	0.901	0.899	0.888	0.899
Panama	0.934	0.919	0.908	0.921	0.925	0.920	0.921
Paraguay	0.899	N.A	N.A	0.908	0.902	0.897	0.900
Peru	0.949	0.943	0.938	0.944	0.936	0.914	0.937
United States	N.A	0.889	0.904	0.918	0.929	0.936	0.920
Uruguay	0.943	0.944	0.941	0.947	0.932	0.928	0.939
Venezuela	0.920	0.904	0.890	0.866	0.899	0.889	0.895
Total	0.913	0.911	0.906	0.907	0.904	0.901	0.907

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

	Energy Efficiency		$\ln(CO_2)$	
Dependent Variable	(1)	(2)	(3)	(4)
Freedom house Index	0.046*** (0.006)	0.050*** (0.006)	−0.458*** (0.097)	−0.401*** (0.100)
MVA	0.001*** (0.0002)	0.001* (0.0003)	0.003 (0.004)	−0.010** (0.005)
ln(capita)	0.001 (0.002)	0.001 (0.002)	0.704*** (0.029)	0.692*** (0.029)
Price level	−0.025** (0.010)	−0.026** (0.010)		
ln(labor force)			1.005*** (0.013)	1.023*** (0.014)
Year dummies	No	Yes	No	Yes
Constant	0.868*** (0.017)	0.863*** (0.018)	−11.038*** (0.207)	−11.017*** (0.225)
N	422	422	565	565
R2	0.156	0.188	0.968	0.969

Note: Standard errors in parentheses, *$p < 0.1$, **$p < 0.05$, ***$p < 0.01$.

Table 4. OLS estimations with other democracy index.

	Energy efficiency		ln(CO_2)	
Dependent Variable	(1)	(2)	(3)	(4)
Polity index	0.054***	0.059***	−0.710***	−0.648***
	(0.007)	(0.007)	(0.109	(0.113)
MVA	0.001*	−0.0001	−0.006	−0.014***
	(0.0003)	(0.0003)	(0.005)	(0.005)
ln(capita)	0.003	0.002	0.763***	0.767***
	(0.002)	(0.002)	(0.032)	(0.032)
Price level	−0.015	−0.007		
	(0.010)	(0.011)		
ln(labor force)			0.969***	0.979***
			(0.017)	(0.018)
Year dummies	No	Yes	No	Yes
Constant	0.838***	0.850***	−10.638***	−10.650
	(0.017)	(0.019)	(0.237)	(0.256)
N	388	388	469	469
R2	0.166	0.216	0.954	0.956

Note: Standard errors in parentheses, *$p < 0.1$, **$p < 0.05$, ***$p < 0.01$.

To investigate the robustness of our findings, we explore whether the effect of democracy on energy efficiency or CO_2 emissions is driven by the choice of democracy measures. Table 4 lists separate regressions for an alternative index of democracy (polity index), and the sign and significance of the estimated outcome of democracy are similar to those results in Table 3. Comparing Tables 3 and 4, we can find the empirical results all indicate that the deepening democracy has a significant impact on the reduction of national CO_2 emissions and brings a positive influence on energy efficiency.

Tables 3 and 4 show the average influence of explanatory variables on dependent variables under OLS estimation, in order to further explore why the deepening of democracy affects a country's energy efficiency as it is at a relatively low or relatively high level. Tables 5 and 6 apply quantile regression to assess democratic mechanism's impact on different CO_2 emission levels and different energy efficiency. Empirical outcome shows that under all quantiles, democratization has a significant effect on the reduction of all countries' CO_2 emissions and has a positive effect on energy efficiency. The empirical results in Table 5 show that the higher a country's energy efficiency goes, the smaller the positive effect of democratization have on energy efficiency, which means the development and deepening of democratic mechanism have a positive effect on a country's energy efficiency improvement when its energy efficiency is relatively low. The estimation results of Table 6 show that the development of democratization at different quantile levels has a significant effect on the reduction of a country's CO_2 emission.

Results of the study are further explained in Figures 1 and 2. The horizontal axis represents the different components of energy efficiency in Figure 1 and CO_2 emissions in Figure 2, while the vertical axis represents the degree of democratization's impact. The horizontal dotted line represents the coefficient estimation value obtained in the regression analysis by applying formula (3) or formula (1), i.e. the average impact of the explanatory

Table 5. Quantile regression result 1.

Dependent Variable	Energy efficiency									
	(1) Q0.1		(2) Q0.3		(3) Q0.5		(4) Q0.7		(5) Q0.9	
Freedom	0.070***		0.066***		0.045***		0.033***		0.012	
House index	(0.022)		(0.007)		(0.008)		(0.009)		(0.008)	
Polity index		0.083***		0.076***		0.071***		0.048***		0.017
		(0.020)		(0.010)		(0.004)		(0.009)		(0.012)
MVA	0.001	0.001	0.001**	−0.0002	0.00001	−0.001***	−0.0001	−0.0003	0.001***	0.0004
	(0.001)	(0.001)	(0.0003)	(0.001)	(0.0004)	(0.0002)	(0.0004)	(0.0004)	(0.0002)	(0.0003)
ln(capita)	−0.010	−0..005	0.002	−0.0005	0.002	0.001	0.005*	0.007***	−0.002	−0.004
	(0.007)	(0.008)	(0.002)	(0.004)	(0.003)	(0.001)	(0.003)	(0.002)	(0.002)	(0.003)
Price level	0.010	0.020	−0.038**	−0.0001	−0.032**	−0.009	−0.033**	−0.030**	0.010	0.023
	(0.007)	(0.042)	(0.011)	(0.020)	(0.014)	(0.006)	(0.013)	(0.012)	(0.010)	(0.014)
Year dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Constant	0.862***	0.814***	0.848***	0.862***	0.878***	0.865***	0.879***	0.850***	0.934***	0.948***
	(0.070)	(0.085)	(0.019)	(0.035)	(0.024)	(0.012)	(0.023)	(0.021)	(0.020)	(0.028)
N	422	407	422	407	422	407	422	407	422	407
R2	0.205	0.227	0.146	0.185	0.126	0.167	0.098	0.126	0.058	0.064

Note: Standard errors in parentheses, *$p < 0.1$, **$p < 0.05$, ***$p < 0.01$.

Table 6. Quantile regression result 2.

Dependent Variable	ln(CO_2)									
	(1) Q0.1		(2) Q0.3		(3) Q0.5		(4) Q0.7		(5) Q0.9	
Freedom	−0.746***		−0.728***		−0.337***		−0.217***		−0.102**	
House index	(0.076)		(0.092)		(0.119)		(0.077)		(0.052)	
Polity index		−1.100***		−0.726***		−0.449***		−0.324***		−0.275***
		(0.089)		(0.211)		(0.108)		(0.109)		(0.038)
MVA	−0.007	0.010*	−0.005	−0.020**	−0.002	−0.011**	−0.011***	−0.017***	−0.023***	−0.016***
	(0.006)	(0.006)	(0.005)	(0.010)	(0.006)	(0.005)	(0.004)	(0.006)	(0.003)	(0.003)
ln(capita)	0.681***	0.633***	0.654***	0.570***	0.727***	0.725****	0.677***	0.831***	0.647***	0.783***
	(0.032)	(0.038)	(0.028)	(0.062)	(0.035)	(0.030)	(0.024)	(0.033)	(0.017)	(0.014)
ln(labor force)	0.942***	0.967***	0.950***	0.945***	1.070***	1.074***	1.088***	0.957***	1.037***	0.966***
	(0.016)	(0.024)	(0.016)	(0.041)	(0.017)	(0.017)	(0.011)	(0.019	(0.007)	(0.007)
Year dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Constant	−10.164***	−10.033***	−9.707***	−8.635***	−12.184***	−11.879***	−11.773***	−10.936***	−10.311***	−10.392***
	(0.236)	(0.230)	(0.216)	(0.436)	(0.267)	(0.238)	(0.197)	(0.313)	(0.148)	(0.116)
N	565	469	565	469	565	469	565	469	565	469
R2	0.826	0.741	0.809	0.742	0.825	0.781	0.845	0.827	0.870	0.872

Note: Standard errors in parentheses, *$p < 0.1$, **$p < 0.05$, ***$p < 0.01$.

variables has on the explained variables, and the oblique line represents the estimated value of the component regression at each component level. Figure 1 shows that before a country's energy efficiency reaches the value of 0.4, the influence of democratization on its energy efficiency is greater than average, which means that the development and deepening of democratic mechanism have a positive effect on a country's energy efficiency improvement when its energy efficiency is relatively low. In other words, democratization has a strong positive effect on energy efficiency when it processes from the lower value to a higher value, and energy efficiency could be improved by deepening democratization. In the meanwhile, Figure 2 shows that the development of democratic mechanism has an inhibitory effect on the emission of national greenhouse gases such as CO_2.

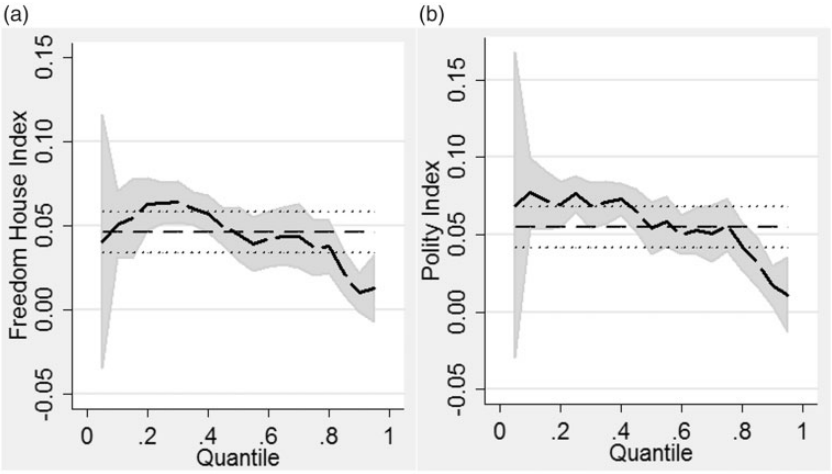

Figure 1. The influence of democratization under different energy efficient score.

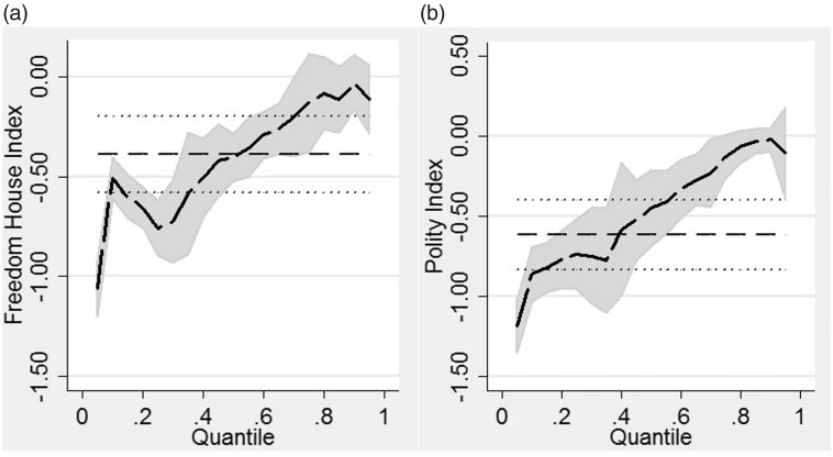

Figure 2. The influence of democratization under different CO_2 emission level.

Why the deepening of democracy or the development of democratic mechanism can raise the energy efficiency and reduce greenhouse gas emissions? It probably has something to do with the associated legal norms which come along with the development of democratic mechanism. Previous literature points out that democracy and equality have obvious interaction effects on determining the quality of a growth-promoting system such as a legal system.[36] When the deepening of democracy strengthens the legal system, it could further consolidate the good effects of pollution prevention and energy utilization with regard to the environment, and then enhance a country's energy efficiency. In other words, 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 and decreases the greenhouse emissions. What's more, recently study also found that democratization could significantly reduce a country's greenhouse gas emission only when its average national income rises to a certain level.[23] Comparing with Lv,[23] 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 in richer countries, democracy has a positive effect on environmental quality. In other words, it might be the economic growth that raises both the per capita income and the living standard of people, which in turn raise their awareness of environmental protection, thereby enhancing the efficiency of energy use and lowering the greenhouse gas emissions. The empirical results in this paper also show that the impact of democratization is different in terms of different levels of national energy efficiency. And the positive impact democratization has on energy efficiency is greater when the energy efficiency evolves from a low level to a higher level. We believe that democratization affects the development of legal system and economy, the former improves the quality of environment by improving the policy system, and the latter raises living standard of people while enhancing their awareness of environmental protection, thereby affecting energy use and promoting energy efficiency.

Finally, Tables 7 and 8 list the robust check about the autoregressive and the panel data analysis. Considering that our original empirical results may face the concern of autocorrelation, Table 7 applied the Prais–Winsten approach (PW) and Cochrane–Orcutt approach (CO) of Feasible Generalized Least Square (FGLS) to test whether our estimation results affect the significance of the explanatory variables due to autocorrelation. Firstly, we set the mean value of time series of the estimated variables in the 24 years (1990–2013) according to the study period, and set the model as follows

$$y_t - \rho y_{t-1} = (1-\rho)\beta_1 + \beta_2(x_{t2} - \rho x_{t-1,2}) + \ldots + \beta_K(x_{tK} - \rho x_{t-1,K}) + \varepsilon_t \quad (5)$$

$$y_t - \rho y_{t-1} = (1-\rho)\beta_1 + \beta_2(x_{t2} - \rho x_{t-1,2}) + \ldots + \beta_K(x_{tK} - \rho x_{t-1,K}) + \varepsilon_t - \rho\varepsilon_{t-1} \quad (6)$$

In this model, ρ is the first-order autocorrelation coefficient, and equation (5) represents the PW estimation, and equation (6) represents the 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, implying nonexistence of autocorrelation in the estimation. The results of Table 7 indicate that the impact of democratization on a country's energy

Table 7. Robust analysis, autoregressive estimation.

Dependent variable	Energy Efficiency				ln(CO_2)			
Approach	(1) PW	(2) CO	(3) PW	(4) CO	(5) PW	(6) CO	(7) PW	(8) CO
Freedom	0.203**	0.155***			−0.641	−0.860*		
House index	(0.046)	(0.046)			(0.475)	(0.501)		
Polity index			0.004	−0.106			−0.410	−0.937*
			(0.524)	(0.062)			(0.511)	(0.565)
MVA	−0.005***	0.003*	0.005**	0.001	−0.002	0.028	−0.010	0.020
	(0.002)	(0.002)	(0.002)	(0.002)	(0.014)	(0.019)	(0.015)	(0.016)
ln(capita)	0.006	0.003	−0.046**	−0.029*	1.043***	1.173***	0.921***	1.060***
	(0.019)	(0.018)	(0.021)	(0.016)	(0.172)	(0.208)	(0.147)	(0.178)
Price level	−0.053**	−0.045*	0.012	−0.013				
	(0.024)	(0.023)	(0.030)	(0.021)				
ln(labor force)					0.708***	0.493***	0.765***	0.519***
					(0.081)	(0.147)	(0.082)	(0.133)
Year dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Constant	−2.001	−0.713	−1.478	−0.169	−9.502***	−7.594***	−9.304***	−6.728***
	(0.813)	(0.957)	(1.136)	(0.966)	(1.106)	(1.430)	(1.134)	(1.453)
N	24	23	24	23	24	23	24	23
ρ	0.464	0.168	0.501	0.257	0.975	0.857	0.976	0.824
Durbin–Watson statistic	1.820	1.820	0.949	0.949	0.685	0.685	0.688	0.688
R square	0.959	0.873	0.988	0.832	0.996	0.905	0.996	0.909

Note: Standard errors in parentheses, *$p < 0.1$, **$p < 0.05$, ***$p < 0.01$.

Table 8. Robust analysis, fixed effect.

	Energy efficiency				ln(CO_2)			
Dependent Variable	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Freedom house	0.027***	0.029***			−0.132*	0.126		
Index	(0.009)	(0.009)			(0.076)	(0.079)		
Polity index			0.023**	0.022**			−0.297***	−0.295***
			(0.010)	(0.010)			(0.079)	(0.081)
MVA	−0.001**	−0.0003	−0.001***	−0.001	−0.004	−0.003	−0.0003	−0.0001
	(0.0003)	(0.0004)	(0.0003)	(0.0004)	(0.003)	(0.003)	(0.003)	(0.003)
ln(capita)	−0.022***	−0.027***	−0.022***	−0.026***	0.206***	0.205***	0.229***	0.245***
	(0.003)	(0.004)	(0.003)	(0.004)	(0.027)	(0.029)	(0.028)	(0.030)
Price level	0.020*	0.015	0.018*	0.014				
	(0.010)	(0.011)	(0.010)	(0.012)				
ln(labor force)					0.760***	0.636***	0.852***	0.812***
					(0.056)	(0.080)	(0.063)	(0.087)
Year dummies	No	Yes	No	Yes	No	Yes	No	Yes
Country dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Constant	1.391***	1.533***	1.413***	1.520***	−6.384***	−4.534***	−8.613***	−8.362***
	(0.067)	(0.092)	(0.067)	(0.094)	(0.671)	(1.123)	(0.734)	(1.210)
N	422	422	407	407	479	479	407	407
R square	0.152	0.205	0.161	0.203	0.687	0.692	0.761	0.763

Note: Standard errors in parentheses, *$p < 0.1$, **$p < 0.05$, ***$p < 0.01$.

efficiency or CO_2 emissions is still significant and consistent with the above empirical outcomes.

Next we applied the fixed effect to test whether the time trend or the regime's character affects the main outcomes in the before estimation. 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. Acemoglu et al.[7,9] used about 150 countries' democratized index in the Polity IV, Freedom House, and OLS estimates and found that democratic indicators and economic growth are significantly associated with each other under OLS estimation. However, there is no significant relationship between democracy and economic growth in the fixed effect. According to Acemoglu et al.[4,7,9] and Rodrik,[3] 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 are curious that whether the influence of democratization on national energy efficiency will be weakened when we consider the fixed effect.

The results in Table 8 are consistent if we consider the fixed effect, the estimation of the coefficient on democracy are positive on energy efficiency and negative on CO_2 emission, indicating 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.

Conclusions

This study explores whether the development of democracy can significantly affect CO_2 emissions and energy efficiency of the countries. Database reference from Freedom House, Polity IV project and World Development Indicator (WDI) is applied to analyze the relationship between the democracy development, CO_2 emissions and energy efficiency of 26 countries in America from year 1990 to 2013. Empirical result shows that the deepening of democracy and the reduction of national CO_2 emissions have an obvious positive connection and the deepening of democracy brings a positive influence on energy efficiency. Further application of quantile regression also indicates that the positive impact democratization has on energy efficiency is greater when energy efficiency evolves from a low level to a higher level. We hold the opinion that democratization deepens the institutionalization of legal system and promotes energy efficiency. In addition, economic development raises the living standard of people while enhancing their awareness of environmental protection, thereby promoting the energy efficiency.

Though our study shows that democratization influences national CO_2 emissions and energy efficiency significantly, there are still some deficiencies. For example, we have not figured out the reason why the legal and social or political mechanisms derived from democratization could affect energy use and environmental quality of a country, which remains to be further discussed. What's more, we are not sure whether the empirical results of our study could be applied to specific regions such as Africa, Middle East or other regions, which also needs to be further analyzed; therefore, we would keep focusing on the relevant issues in our future research.

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Supplemental material

The whole database provided in this study is available online at: http://databank.worldbank.org/data/home.aspx (WDI); https://freedomhouse.org/ (Freedom House); http://www.systemicpeace.org/polity/polity4.htm (Polity IV project).

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