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GENERAL & APPLIED ECONOMICS | RESEARCH ARTICLE

Determinants of the downward sloping segment of the EKC in high-income countries: The role of income inequality and institutional arrangement

Hyangsuk Cho^{1*}

Abstract: Even among developed countries, each country has very different circumstances and political institutions regarding environmental issues. Moreover, the differences in individual attitudes about environmental issues within national borders and in the types of environmental behaviors affect the environmental policy of each country. Therefore, in contrast to the Environmental Kuznets curve (EKC) hypothesis, the effect of economic growth on environmental degradation differs between high-income countries. Evidences show that economic growth is not the only determinant of environmental change, particularly in high-income countries. In this respect, this paper examines the existence of the EKC as well as the effects of the level of political institution on the relationship between greenhouse gas (GHG) emission per capita and income inequality; it does this by using unbalanced data for 33 OECD countries from 1990 to 2014. The findings of this study show that the level of income inequality differentially affects the GHG emission depending on the level of institution. The EKC hypothesis holds only in countries with a high level of institution, and the threshold of the EKC is positioned at a lower income level in countries with stronger institutional arrangement, and such countries also show lower GHG emission per capita.

Subjects: Sustainable Development; Environment & the Developing World; Environmental Economics

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PUBLIC INTEREST STATEMENT

It has previously been widely believed that economic growth has a strong connection with environmental degradation. However, economic growth alone cannot explain all environmental issues, or why countries at the same developmental stage show different effects of economic growth on environmental degradation. Therefore, this paper provides new insights into environmental degradation as income increases by assessing how the relationship between environmental degradation and income inequality is affected by the levels of institutions. The finding of this paper demonstrates that relative income (income inequality) depends on individual preference for environmental protection, which is associated with institutional quality. In addition, the main result show that the turning point of EKC will appear at a lower level of average income when the level of institution is relatively stronger.

Keywords: Environmental degradation; income inequality; political institution; environmental Kuznets curve; greenhouse gas emission; environmental tax

1. Introduction

The relationship between environmental degradation and economic growth has long been debated and studied by many economists over the last few decades. In the early 1990s, some empirical findings indicated that air and water pollution increase and then decrease as income per capita rises (G.M. Grossman & Krueger, 1994; Panayotou, 1993; Selden & Song, 1994; Shafik, 1994). In 1995, with the introduction of the hypothesis of Environmental Kuznets curve (EKC), this argument has grown, and until recently, many studies attempting to clarify this effect have continued to be conducted (Friedl & Getzner, 2003; Heil & Selden, 2001; Holtz-Eakin & Selden, 1995; G. M. Grossman & Krueger, 1995). The EKC hypothesis refers to an initial increase in environmental degradation with increasing per capita income up to a certain level of income, after which it declines. In this view, economic growth constitutes an absolute constraint that results in environmental degradation or improvement.

However, it is important to note that as time changes, there is a limit to explaining environmental pollution and issues solely through economic growth. In fact, economic growth alone cannot solve all environmental problems (Singh & Shishodia, 2007), and further analysis is needed to determine what factors ensure that economic growth is compatible with an improving environment. While the EKC hypothesis has been widely tested to explain the relationship between environment and income, the results have not been the same for all countries, indicating that this relationship is influenced by various other factors (Dinda, 2004; Kijima et al., 2010; Lv, 2017; Zhang & Meng, 2019). Indeed, the appearance of the downward sloping segment of the EKC differs with the political framework and relative income, even among similarly high-income countries (Magnani, 2000). Early researchers presented conflicting views regarding the impact of income inequality on environmental quality. First, some researchers have insisted that greater income inequality leads to higher levels of environmental degradation (Bimonte, 2002; Borghesi, 2000; Boyce, 1994; Marsiliani & Renström, 2000; Magnani, 2000; Torras & Boyce, 1998). Specifically, they hypothesize that powerful winners receive disproportionate economic benefits from the environmental degradation that occurs as a result of increasing economic activity. Under this hypothesis, if the rich are more powerful than the poor, there is more environmental degradation. Second, other researchers have suggested that economic and political inequality lead to low environmental degradation (Coondoo & Dinda, 2008; Grunewald et al., 2017; Heerink et al., 2001; Ravallion et al., 2000; Scruggs, 1998; Vona & Patriarca, 2011). Scruggs (1998) criticized the Boyce (1994) hypothesis and argued that income inequality may or may not be a prerequisite for reducing environmental degradation. Therefore, they indicate that if relatively rich and powerful people prefer to protect the environment, the level of environmental protection will be higher under a more democratic society than under a society involving authoritarianism and a more unequal income distribution.

On the other side, some researchers have suggested that the existence of EKC depends on a more equal power distribution (e.g., greater political freedom and civil rights, strengthened democracy, and less corruption) and an equitable income distribution (Clement & Meunie, 2010; Eriksson & Persson, 2003; He et al., 2007; Kinda, 2011; Torras & Boyce, 1998). The findings of previous studies have shown an effect of income inequality on environmental degradation with the existence of EKC. However, there has been no sufficient evidence showing why the downward sloping segments in the EKC differ between countries with the degrees of income distribution and the levels of institutions. Specifically, while all the results follow the EKC hypothesis, the effects of economic growth on environmental degradation differ between high-income countries. This means that degrees of income distribution could produce a gap between the country's ability to pay expenditure for environmental protection (Bimonte, 2002; Magnani, 2000). Therefore, expecting different levels of institution could lead to this gap, this study investigated whether countries at

the same developmental stage might face different levels of environmental degradation caused by different levels of institution. This paper empirically examines the impact of income inequality on the relationship between economic growth and environmental degradation in a situation wherein the level of institutional quality differs between high-income countries. In particular, this paper examines:

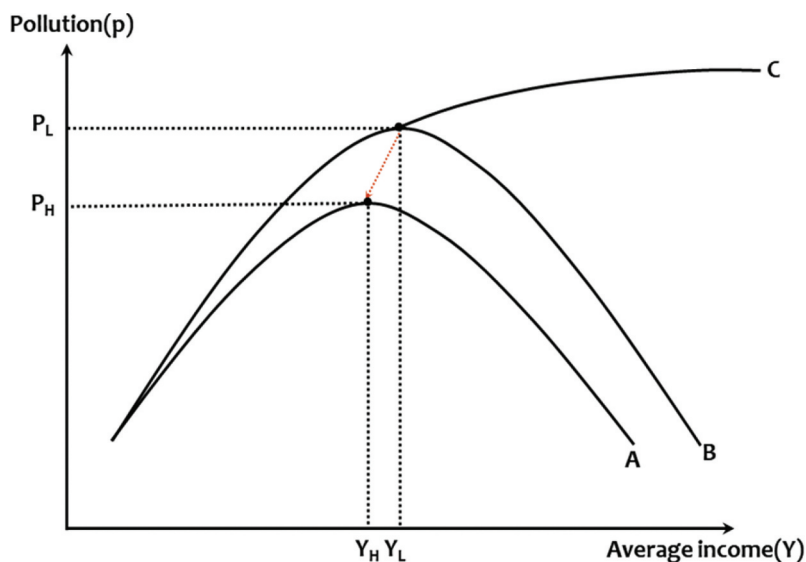
- how the curve between income inequality and greenhouse gas (GHG) emissions is affected by the institutional quality.
- the interaction effect of institutions on the relationship between income inequality and GHG emissions and the existence of EKC, and how it is affected by institutional quality.
- the effect of the level of institutional quality on the turning point of EKC in countries with high-level institutions.

2. Conceptual framework

Magnani (2000) suggested further developing this argument with EKC and discussed the impact of income inequality on pollution among high-income countries. He theoretically and empirically examined the impact of income inequality on public expenditure for environmental protection. The paper suggests that a theoretically positive effect of increased relative income (the ratio between personal income and average income) on environmental protection is the benefit of a reduction in pollution that occurs by shifting the environmental preferences of the median voter toward environmental protection. Bimonte (2002) also argued that more equal income distribution with, more income effects could lead to conservation of environmental quality. He found that while the income level influenced the relationship between environmental quality and income, social participation determined the level of environmental quality. Findings of these two studies greatly contributed to extending the EKC hypothesis to the perspective of income distribution. This paper is in line with the above discussion which shows that more equal income distribution can reduce pollution. However, it assumes that political institutions can influence the relationship between demand for environmental quality and income distribution. Thus, the level of political institution is the main driver that determines that relationship between individual income distribution and environmental degradation. In other words, this relationship may be explained by the level of countries' political institution which becomes prompt to implement environmental policies at the national level.

The framework in this study is constructed by including the institutional variables in Magnani's model. Environmental goods are normal goods, and when other conditions are constant, the median voter prefers a higher level of environmental quality as their income increases. If environmental goods are pure public goods, the same costs (in the form of a consistent tax rate) will be applied to all income classes, regardless of income level, to reduce environmental degradation. The level of demand for environmental quality is determined using this process. The important thing to note is that the curve representing the relationship between income and environmental demand may differ depending on the level of institution. In other words, when a country has institutions that encourage participation in environmental behavior as well as a well-developed regulatory system to implement environmental policy, then the higher a median voter's relative income, the more that voter is willing to pay for the consumption of environmental goods. Theoretically, the demand for environmental quality rises along with income. Indeed, economic growth is related to individual consumption and environmental degradation. A recent study by Cicatiello et al. (2020) has argued that regional economic activities in pollution can influence an individual's preference for pollution or environmental protection costs through the incidence of polluting activities. Since regional economics activities were considered as qualitative characteristics, in this respect, the hypothesis of this study (i.e., institutional quality affects environmental preference) is supported by their study. Vogel (2000) has stated that people may express their willingness to spend more money to achieve a higher environmental quality by supporting

Figure 1. Environmental Kuznets curve by level of institution. A and B are the strong and weak institutions within the high-level institution group; C is a low-level institution group.



environmental policies through voting. In other words, they might differentially express support for environmental policies based on the level of the country’s political institutions (Vogel, 2000). Thus, a higher relative income (i.e., a more equal income distribution) increases the demand for environmental quality in a country with a high level of institutions, whereas a higher relative income decreases the demand for environmental quality in a country with a low level of institutions.

This institutional effect is depicted by the curves in Figure 1. Economic growth will lead to a reduction of pollution if the environmental public expenditure increases as the relative income increases under a high-level institution. If this is extended to the Environmental Kuznets curve hypothesis, the form of the Environmental Kuznets curve will become different by institutional quality. In addition, it is worth noting that institutional quality may determine the turning point of EKC. In other words, Figure 1 shows that a country with a high level of institutions can attain greater progress in environmental policies than one with a weak level of institution, meaning that the threshold of EKC occurs at a lower level of income.

3. Data

To examine the impact of income inequality on greenhouse gas emissions, we use an unbalanced panel data set of 33 OECD countries spanning 1990–2014. The dependent variable is represented by total GHG emissions per capita excluding LULUCF (Land Use, Land-Use Change and Forestry), corresponding to the environmental quality. GHG emissions are the sum of emissions of seven gases (CO₂, CH₄, N₂O, CFCs, HFCs, PFCs, SF₆) related to the increase in direct emissions from human activities. Thus, a more useful measurement for capturing air pollution is GHG emissions per capita. These data were collected from the OECD database. They provide the GHG emission data from 1990 to 2018, but the observations for time series data are different in each country.

The data on income inequality are obtained from the Gini coefficient published by the UNU/WIDER Standardized World Income Inequality Database (SWIID). We used SWIID (version 6.2), which covers 192 countries from 1960 to the present, but each country has different observations. SWIID provides income inequality datasets by comparability for the largest sample, and using this source makes it possible to obtain greater coverage across countries and over time. This database provides cross-national comparative data on income inequality, which consists of inequality on disposable income, inequality in the market, absolute redistribution, or relative redistribution. The European Parliament (2016) stated that “Income” is typically defined as the disposable income of

an individual or household in a particular year; it covers any revenue stream coming from wages, interest on savings, and dividends, as well as public cash transfers like pensions that can actually be either consumed or saved after taxes and social security contributions have been deducted. Thus, we use disposable income as an indicator of inequality. The scale of the Gini index from SWIID is bounded between 0–100, and a higher Gini index indicates that a country has a more unequal income distribution.

The selected countries are divided into groups with high and low levels of institutions, based on the average institutional index ranking over the period from 1990–2014. The full lists of these countries are presented in Appendix [Table A1](#). The data on political institutional variables are collected from the International Country Risk Guide (ICRG); ICRG data provides country risk and rating information in financial, political, and economical terms for 146 countries for 1984–2016. In this study, we use institutional variables such as control of corruption, law and order, and democratic accountability from the ICRG 2017 version. The index ranges from 0 to 6, with higher scores denoting less corruption, stronger impartiality of the legal system, and higher levels of democratic accountability.

Another institutional variable affecting the economy is environmental tax revenue, which estimates the stringency of environmental protection policy. The data used in this study are obtained from taxes related to the energy sector aiming for carbon emissions reductions. Castiglione et al. (2014) found that enforcing the rule of law shifts the turning point of the Environmental taxation Kuznets curve (ETKC) to a lower income. We used energy tax revenues to estimate the role played by the enforcement of the environmental tax and its consequences in improving the quality of the environment. The 33 OECD countries analyzed in this study enforce their environmental regulations through their energy tax or carbon tax system.

Data on the economic variables affecting the environmental quality are presented as per capita GDP, which is mainly used to estimate the threshold of the EKC. Trade, industry value added, fossil fuel energy consumption, and renewable energy consumption are mainly used to control variables related to the analysis of CO₂ emissions. These data were obtained from the World Development Indicators (WDI) database. Trade denotes the sum of exports and imports of goods and services measured as a share of gross domestic product (GDP). Industry value added is also measured as a share of GDP. Fossil fuel energy consumption is measured as the share of coal, oil, petroleum, and natural gas products in total energy consumption. Finally, renewable energy consumption is measured as the share of renewable energy of all final energy consumption. [Table 1](#) and [Table 2](#) display the descriptions and descriptive statistics of all the variables used in the regression analysis, respectively.

4. Empirical strategy

This study investigates the relationship between income inequality and GHG emissions in terms of the national institutional level. To estimate the impact of the level of institution, countries are divided into two groups with high and low levels of institutions, and institutions in the high-level group are further divided into strong and weak institutional qualities. The high- and low-level groups consist of 19 and 14 countries, respectively; in the high-level group, the strong and weak groups consist of 9 and 10 countries, respectively.

4.1. Panel unit root test

Before estimating the fixed effect model, we need to check the time series properties in the panel datasets using two panel unit root tests: the IPS test and a Fisher-type test (Im et al., 2003; Maddala & Wu, 1999). In the case of non-stationary data (which possess a unit root), the analysis considering a fixed effect among countries provides spurious regression results (Dickey et al., 1986; Newbold & Granger, 1974).

The unit-root test of panel data for N countries and T periods can be represented as follows:

Table 1. Data description

Variables	Explanation	Sources
Dependent variable		
<i>Pghg</i>	Total greenhouse gas emissions per capita (kg per capita, thousand)	OECD
Independent variables		
<i>Gini</i>	Index of income inequality (Range from 0 to 100)	SWIID
<i>Pgdp</i>	Gross domestic product per capita (Unit: 2010 constant US\$)	WDI
<i>Inst</i>	Environmentally related tax revenue per capita (Unit: 2010 USP PPP)	OECD
	Corruption (Range from 0 to 6)	ICRG
	Law and order (Range from 0 to 6)	
	Democratic accountability (Range from 0 to 6)	
Control variables		
<i>Trade</i>	Sum of exports and imports of goods and services (% of GDP)	WDI
<i>Ind</i>	Industry value added (% of GDP)	
<i>Ffc</i>	Fossil fuel energy consumption (% of Total)	
<i>Renew</i>	Renewable energy consumption (% of Total final energy consumption)	
<i>Pop</i>	Total population (Unit: Million)	OECD

Table 2. Summary statistics

	Obs.		Mean		Std. Dev		Min		Max	
	High	Low	High	Low	High	Low	High	Low	High	Low
<i>Pghg</i>	437	322	16.2	9.8	9.2	4.0	5.8	3.9	64.0	35.6
<i>Pgdp</i>	475	350	38,014	13,386	18,849	8,928	7,910	1,738	118,824	40,180
<i>Gini</i>	425	325	28.9	33.8	4.1	7.4	21.0	20.6	38.0	48.6
<i>Petax</i>	398	293	844	404	772	333	-1,875	0	3,280	1,172
<i>Cor</i>	474	326	4.9	3.3	0.8	1.0	2.0	1.9	6.0	5.0
<i>Law</i>	474	326	5.7	4.4	0.4	0.9	4.5	1.0	6.0	6.0
<i>Dem</i>	474	326	5.8	5.2	0.3	0.9	4.0	2.0	6.0	6.0
<i>Trade</i>	475	334	84.5	79.6	57.2	38.0	16.0	27.8	382.3	183.4
<i>Ind</i>	426	307	24.9	28.5	4.8	5.3	10.7	13.7	40.3	41.1
<i>Ffc</i>	475	350	74.2	80.0	16.9	16.8	29.8	14.5	98.5	98.1
<i>Renew</i>	475	350	16.5	11.2	15.3	8.0	0.6	0.4	61.4	38.6
<i>Pop</i>	475	350	39.6	29.8	66.9	29.8	0.4	1.3	318.6	124.2

$$\Delta y_{it} = \alpha_i + (\rho_i - 1)y_{it-1} + \varepsilon_{it}, \quad i = 1, 2, \dots, N, t = 1, 2, \dots, T \quad (1)$$

If the null hypothesis $H_0 : (\rho_i - 1) = \gamma_i = 0$, for all i , then the null hypothesis is rejected, and the data are considered stationary.

Table 3 lists the result of the panel unit root test for each variable. The test statistics indicate that the null hypothesis can be rejected at the 1% level of significance in at least one unit root test. Therefore, all the series are stationary in panel, and the fixed effect model can be used for estimation.

4.2. Fixed effect model

The panel regression includes per capita GDP ($Pgdp$) and squared terms of per capita GDP ($Pgdp^2$) to support the existence of the EKC hypothesis. As estimations of the effect of income inequality on per capita GHG emissions ($Pghg$) depend on the level of income inequality, the model can contain a Gini coefficient ($Gini$) and a multiplicative term with per capita GDP. The equation for the fixed effect model then becomes:

$$\ln Pghg_{it} = \beta_0 + \beta_1 \ln Pgdp_{it} + \beta_2 \ln Pgdp_{it}^2 + \beta_3 Gini_{it} + \beta_4 Int1_{it} + \beta_4 C_{it} + u_{it} \quad (2)$$

for $t = 1, \dots, T$; $i = 1, \dots, N$, where T refers to the number of observations over time and N refers to the number of individual countries; C_{it} is the control variables and the error term $u_{it} = \mu_i + \varepsilon_{it}$ is a composite error term which is assumed to be uncorrelated with the independent variables; the unobserved effect μ_i represents a country effect and the observed effect ε_{it} differs for each country i at each point in year t . If the unobserved fixed effect is fixed over time, μ_i should be excluded from the fixed effect model. Notice that $Int1_{it}$ is an interaction term, $(\ln Pgdp_{it} \times Gini_{it})$. This model uses log transformations of GHG emission and GDP data to make them conform to normality.

To satisfy the EKC hypothesis, we should expect a negative value for β_2 but a positive value for β_1 , which would indicate that the EKC strongly holds (inverted U-shaped curve) in equation (2). If the variable $Int1_{it}$ has a positive value, then income inequality will strengthen the positive relationship between per capita GDP and per capita GHG emissions.

When the institutional variables ($Inst$) are included in the model, we can estimate the augmented EKC model based on income inequality and institutional quality:

$$\ln Pghg_{it} = \beta_0 + \beta_1 \ln Pgdp_{it} + \beta_2 \ln Pgdp_{it}^2 + \beta_3 Gini_{it} + \beta_4 Int2_{it} + \beta_4 C_{it} + u_{it} \quad (3)$$

The variable $Int2_{it}$ is an interaction term, $(Gini_{it} \times Inst_{it})$. If a high level of institution will mitigate the positive relationship between income inequality and per capita GHG emission, then the variable $Int2_{it}$ will have a negative value.

4.3. Fixed effect panel threshold model

This study applies the fixed effect panel threshold model proposed by Hansen (1999), which has the ability to estimate the threshold of the EKC. In this model, the period of data is 1994–2014, since this model is only valid when it is balanced data. Consider the following threshold model:

$$Pghg_{it} = \mu_i + \delta_1 I(Pgdp_{it} \leq \gamma) + \beta_1 Pgdp_{it} I(Pgdp_{it} \leq \gamma) + \beta_2 Pgdp_{it} I(Pgdp_{it} > \gamma) + \beta_3 Gini_{it} + \beta_4 Int3_{it} + \beta_4 C_{it} + u_{it} \quad (4)$$

where $I(\cdot)$ is the indicator function defined by the threshold variable $Pgdp_{it}$ and γ is the threshold level that divides the equation into two regimes with coefficients β_1 and β_2 . The coefficients β_1 and β_2 denote the marginal effects of per capita GDP on GHG emissions in the low- and high-income

Table 3. Panel unit root test

	lnpghg	lnpgdp	Gini	Petax	Cor	Law	Dem
IPS	-0.86	-4.87***	-1.29*	-6.52***	-4.63***	-8.21***	-6.95***
Fisher-ADF	136.68***	177.74***	223.86***	160.31***	188.25***	401.62***	254.77***
Fisher-PP	42.24	98.34***	142.27***	118.09***	137.21***	268.84***	109.94***

The values in square brackets denote t-statistics. *** and * represent the significance at 1% and 10%, respectively. The ADF and PP tests check whether the panel data contains a unit-root on each panel data separately, then combine the p-values to obtain an overall value. The difference between these unit root tests is that the ADF test uses a parametric autoregressive while the PP test uses non-parametric corrections based on the long-run variance of Δy_{it} estimation. The IPS allows for a common autoregressive parameter to be used for all panels and assumes that the time periods are fixed.

regimes, respectively. If below the threshold β_1 is positive while the threshold β_2 is negative, then the EKC hypothesis strongly holds. We also stated that the EKC hypothesis weakly holds when below the threshold β_1 is positive but insignificant. μ_i is the country-specific fixed effect and the residual term u_{it} is assumed to be $u_{it} \sim (0, \sigma^2)$. The variable $Int3_{it}$ is an interaction term, $(Gini_{it} \times Inst_{it})$. When the equation includes a multiplicative term so as to capture interaction effects between income inequality and institutional quality, the augmented EKC can be moved up and down the slope depending on the level of institutions.

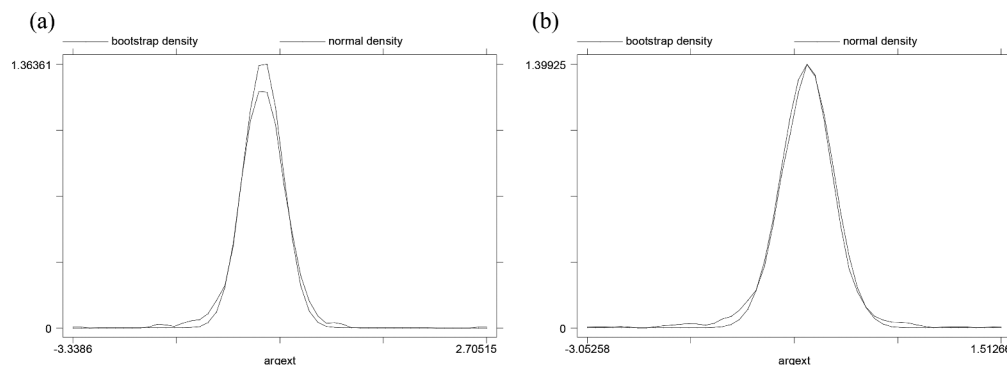
5. Results

5.1. Fixed effect model

The panel regression is estimated with fixed effect (FE) and random effect (RE) using unbalanced panel data. The model includes year dummies to control the year-specific effect in each country (Wooldridge, 1999; 2002). The results also show that a Hausman test should be conducted to choose between a fixed effect model or a random effect model. Table 4 lists the results regarding the impact of income inequality on GHG emissions with EKC in the high-level group. The results of the Hausman test reject the null hypothesis; thus, a fixed effect model is suitable for this analysis.

The results show that income inequality is positively related to per capita GHG emissions. The log of per capita GDP and the quadratic log of per capita GDP are significantly positive and negative, respectively, thus supporting the EKC hypothesis. The control variables *Trade* and *Ind* are not significant, but *Ffc* and *Renew* are significantly positive and negative, respectively. In general, in

Figure 2. The critical income levels. Graphs (a) and (b) plot the estimates of the critical income levels reported in Table 4. “argext” indicates the turning point of a positive value between income inequality and emissions. To obtain the turning point, we carried out a command “wherext” using STATA version 14.1.



terms of the energy component, the high consumption of fossil fuel energy leads to stringent air

Table 4. The fixed and random effect model results in the high-level group

	(1) RE	(2) FE	(3) RE	(4) FE
<i>lnPgdp</i>	0.168*** (0.069)	0.163*** (0.069)	0.109** (0.058)	0.102*** (0.058)
<i>lnpgdp²</i>	-0.101*** (0.026)	-0.100*** (0.026)	-0.087*** (0.025)	-0.085*** (0.025)
<i>Gini</i>	0.032*** (0.006)	0.037*** (0.007)	0.030*** (0.007)	0.034*** (0.007)
<i>Gini x lnPgdp</i>			0.036* (0.020)	0.034* (0.020)
<i>Trade</i>	0.001 (0.000)	0.001 (0.000)	0.001 (0.000)	0.001 (0.000)
<i>Ind</i>	0.003 (0.005)	0.002 (0.003)	0.002 (0.003)	0.001 (0.003)
<i>Ffc</i>	0.008*** (0.001)	0.007** (0.003)	0.008*** (0.003)	0.007** (0.003)
<i>Renew</i>	-0.016*** (0.003)	-0.019*** (0.003)	-0.015*** (0.003)	-0.018*** (0.003)
<i>Constant</i>	1.273*** (0.311)	1.276*** (0.296)	1.381*** (0.306)	1.382*** (0.271)
Marginal effect of <i>Gini</i>			0.034*** (0.007)	0.037*** (0.007)
Critical income levels			0.217 (US\$ 12,418)	0.178 (US\$ 11,936)
Year dummies	Yes	Yes	Yes	Yes
Hausman test	-	12.671	-	16.560
(P-value)	-	(0.081)	-	(0.020)
R-squared	0.407	0.408	0.369	0.370
Observation	346	346	346	346

The values in parentheses are the standard errors. ***, **, and * represent the significance at 1%, 5%, and 10%, respectively.

pollution, whereas, in the renewable energy sector, efforts to reduce the emission of greenhouse gas emissions and energy intensity are ongoing (OECD/IEA, 2014; Van Vuuren et al., 2017).

Next, the results from (3) and (4) are used to explain the results for the model including the interaction term with income inequality and the log of per capita GDP. The interaction term has a positive value and is statistically significant at the 1% level, indicating that higher income inequality strengthens the positive relationship between per capita GHG emissions and the log of per capita GDP. In other words, a more equal income distribution helps reduce emissions as income grows at the high-income level. Figure 2 shows the critical income at which the income inequality and emission relationship become positive for the high-level group. The graphs depict an estimated kernel density of the distribution of per capita income (*argext*), overlaid with the normal distribution. The level of critical income at which the income inequality and emission relationship becomes positive is calculated by $Pgdp = \exp[-\beta_3/\beta_4]$. Calculating the estimated coefficient using this formula, the critical income per capita is found to be US\$ 12,418 and US\$ 11,936 from the random and fixed effect models, respectively. According to these results, in countries with per

Table 5. The fixed and random effect model results of the low-level group

	(1) RE	(2) FE	(3) RE	(4) FE
<i>lnPgdp</i>	0.063*	0.074*	0.022	0.030
	(0.037)	(0.040)	(0.127)	(0.063)
<i>lnPgdp</i> ²	0.058***	0.062***	0.077***	0.068***
	(0.018)	(0.019)	(0.020)	(0.020)
<i>Gini</i>	-0.011**	-0.010*	-0.009*	-0.010*
	(0.005)	(0.006)	(0.005)	(0.006)
<i>Gini x lnPgdp</i>			0.004***	0.026**
			(0.001)	(0.013)
<i>Trade</i>	0.001**	0.002**	0.002***	0.002***
	(0.001)	(0.001)	(0.001)	(0.001)
<i>Ind</i>	-0.001	-0.001	-0.002	-0.008**
	(0.003)	(0.003)	(0.003)	(0.003)
<i>Ffc</i>	0.006*	0.004	0.008***	0.004
	(0.004)	(0.004)	(0.005)	(0.005)
<i>Renew</i>	-0.027***	-0.026***	-0.026***	-0.025***
	(0.008)	(0.004)	(0.009)	(0.009)
<i>Constant</i>	3.169***	2.922***	3.222***	2.887***
	(0.391)	(0.476)	(0.311)	(0.476)
Marginal effect of <i>Gini</i>			0.005	0.010*
			(0.005)	(0.006)
Critical income levels			0.261	0.388
			(US\$ 12,976)	(US\$ 11,978)
Year dummies	Yes	Yes	Yes	Yes
Hausman test	-	12.671	-	16.560
(P-value)	-	(0.081)	-	(0.020)
R-squared	0.407	0.408	0.369	0.370
Observation	346	346	346	346

The values in parentheses are the standard errors. ***, **, and * represent the significance at 1%, 5%, and 10% respectively.

capita GDP exceeding these critical values, a reduction in equal income distribution leads to a rise in per capita GHG emissions. Thus, after the critical income level, income equity seems to have intensified efforts to cut emissions. In addition, the marginal effect of income inequality is significantly positive, and the values (0.034 and 0.037) show increases in emissions caused by changes in the Gini coefficient while assuming the other variables are held constant from each model. The upward slope of the curve illustrates that the per capita emissions increase as income inequality is worsened.

Table 5 presents the results regarding the impact of income inequality on GHG emissions with EKC in the low-level group. Comparing Table 4 and Table 5 disproves the proposed relationship that environmental degradation depends on the level of income distribution under different levels of institutions; we also obtain an interesting empirical finding. First, income inequality increases per capita GHG emission as income rises in countries with high levels of institutions, whereas income equity increases emissions as income rises for countries with low levels of institutions. Specifically, the level of critical income at which the income inequality and emission relationship becomes

Table 6. The results based on institutional quality in the high-level group

	(1)	(2)	(3)	(4)
<i>lnPgdp</i>	0.122*** (0.037)	0.274*** (0.051)	0.224*** (0.039)	0.242*** (0.052)
<i>lnPgdp</i> ²	-0.074*** (0.014)	-0.048*** (0.014)	-0.047*** (0.012)	-0.037*** (0.015)
<i>Gini</i>	0.025*** (0.004)	0.038*** (0.007)	0.029*** (0.004)	0.039*** (0.006)
<i>Gini x Petax</i>	-0.046** (0.019)			
<i>Gini x Cor</i>		-0.001* (0.000)		
<i>Gini x Law</i>			-0.001*** (0.000)	
<i>Gini x Dem</i>				-0.0001** (0.000)
<i>Trade</i>	0.0001 (0.000)	0.0002*** (0.000)	0.001*** (0.000)	0.001*** (0.000)
<i>Ind</i>	0.009*** (0.002)	0.003*** (0.001)	0.005*** (0.001)	0.002*** (0.001)
<i>Ffc</i>	0.005*** (0.001)	0.005*** (0.001)	0.004*** (0.001)	0.005** (0.001)
<i>Renew</i>	-0.019*** (0.002)	-0.013*** (0.002)	-0.012*** (0.001)	-0.013*** (0.002)
<i>Constant</i>	1.548*** (0.173)	1.376*** (0.182)	1.575*** (0.131)	1.365*** (0.181)
Observation	352	395	395	395
R-squared	0.816	0.893	0.865	0.894
Number of Countries	19	19	19	19

The values in parentheses are the standard errors. ***, **, and * represent the significance at 1%, 5%, and 10%, respectively.

positive was already beyond that for the high-level group, but the value for the low-level group was not reached. The results explain that a more equal income distribution instead leads to a rise in emissions as income increases in countries with a low-level of institutions at the current income level. Second, the EKC hypothesis strongly holds for the high-level group but not for the low-level group. In fact, developed countries with high-level institutions and relatively high income are on the low-carbon pathway. However, the emissions continuously increase even beyond the income threshold in the low-level group.

5.2. Fixed effect model with institutional variables

Table 6 presents the results for panel regression with institutional variables in the high-level group. The results include the institutional variable related to political or economic institutions that influence environmental policy, as well as household preference for environmental quality.

The estimation results strongly support the EKC hypothesis, since the log of per capita GDP is positively significant and the quadratic log of per capita GDP is negatively significant. Income inequality is also positive and statistically significant. Result (1) includes the interaction term used to multiply income inequality and per capita tax revenue related energy. The coefficient of the

Table 7. The results based on institutional quality in the low-level group

	(1)	(2)	(3)	(4)
<i>lnPgdp</i>	0.087*	0.133***	0.140***	0.139***
	(0.044)	(0.033)	(0.033)	(0.033)
<i>lnPgdp</i> ²	0.022	0.046***	0.049***	0.047***
	(0.025)	(0.015)	(0.015)	(0.015)
<i>Gini</i>	-0.014	-0.001	-0.006	-0.0004
	(0.009)	(0.005)	(0.006)	(0.005)
<i>Gini x Petax</i>	0.002			
	(0.000)			
<i>Gini x Cor</i>		0.001***		
		(0.000)		
<i>Gini x Law</i>			0.001***	
			(0.000)	
<i>Gini x Dem</i>				0.0001
				(0.000)
<i>Trade</i>	0.0002	0.001*	0.001	0.001
	(0.001)	(0.001)	(0.001)	(0.001)
<i>Ind</i>	0.011*	0.004	0.006**	0.004
	(0.005)	(0.003)	(0.003)	(0.003)
<i>Ffc</i>	-0.001	-0.002	-0.001	-0.003
	(0.007)	(0.003)	(0.003)	(0.003)
<i>Renew</i>	-0.022***	-0.026***	-0.025***	-0.026***
	(0.006)	(0.003)	(0.003)	(0.003)
<i>Constant</i>	2.561***	2.232***	2.289***	2.162***
	(0.837)	(0.357)	(0.361)	(0.363)
Observation	265	278	278	278
R-squared	0.685	0.669	0.667	0.657
Number of Countries	14	14	14	14

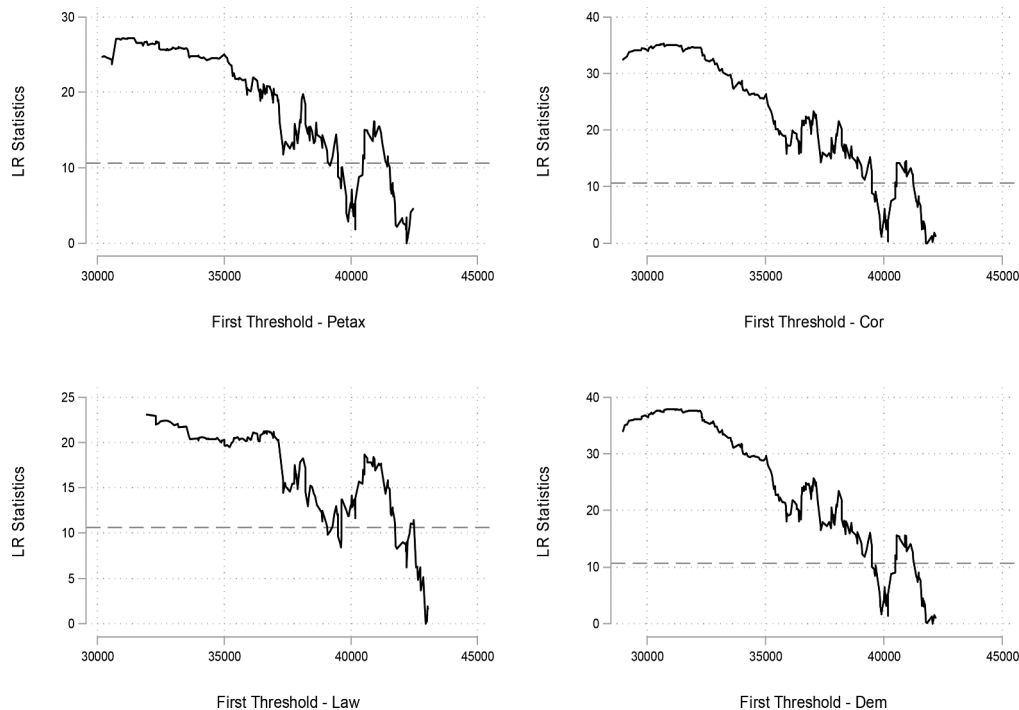
The values in parentheses are the standard errors. ***, **, and * represent the significance at 1%, 5%, and 10%, respectively.

interaction term (*Gini x Petax*) is significantly negative. This means the tax has a mitigation impact on the positive relationship between income inequality and per capita GHG emission as per capita GDP increases. For the high-level group, such a tax is a useful instrument for reducing emissions.

The stronger the political institutions in an area, the more efficiently an individual or firm can participate in environmental protection and the implementation of governmental environmental policy (Dasgupta et al., 2016; Kinda, 2011). The results including the political institution variable have a negative and significant value. Therefore, a low level of corruption, a stronger law and order, and increased democratic accountability can reduce emissions caused by higher income inequality as income rises in the high-level group. The success of an environmental policy depends on the political process around it, which is related to the institutions, cultural discourse, and the distribution of power and resources involved (Hughes & Lipsy, 2013; Jacobsson & Lauber, 2006; Lockwood, 2013).

Table 7 lists the results from the low-level group. The EKC hypothesis does not hold from all models because the log of per capita GDP and its quadratic term are positively linked with per

Figure 3. The threshold value of per capita GDP for the high-level group.



capita GHG emissions. While income inequality has a positive value, it is not significant. The interaction effect of energy tax is positive but insignificant. The low-level group includes many countries with less pronounced green movements (Sterner and Köhlin, 2017).

The interaction effect of *Cor* and *Law* has a positive significant value, whereas *Dem* does not have a significant effect on GHG emission. The previous literature attempting to estimate the relationship between corruption and pollution suggest two partial effects: first, corruption will reduce the stringency of environmental regulation, thus leading to higher pollution. Second, corruption could lead to reduced pollution at some income levels and increased pollution at other levels (Cole, 2007; Goel et al., 2013; Sekrafi & Sghaier, 2018; Welsch, 2004). Given this background, we again deploy the estimated result related to corruption. Controlling corruption contributes to economic growth, but as economic growth increases GHG emissions, low corruption indirectly leads to higher emissions in the low-level institutions group. In other words, the growth in emissions caused by equal income distribution will be strong even with higher controls of corruption as income increases.

5.3. Fixed effect panel threshold model

5.3.1. High- and low-level groups

The main purpose of this study is to calculate the income threshold value of the EKC while considering the impact of institutional level on the relationship between income inequality and GHG emissions. To this end, we first performed a threshold effect test to select the threshold regimes based on a bootstrap method (Hansen, 1999) by institutional group. Table 8 presents the threshold effect test using a single and double threshold model. The high-level group fits a single threshold model based on the fact that the single threshold test rejects the null hypothesis. On the other hand, we set the linear model for the countries with low levels of institutions because the test does not reject the single and double threshold tests.

Table 8. Threshold effect test (bootstrap = 300)

	RSS	MSE	F-statistics	P-value	Crit10	Crit5	Crit1
High-level							
Single	375.65	1.09	52.75	0.06	47.50	53.11	60.66
Double	358.26	1.04	16.75	0.57	41.74	45.63	53.63
Low-level							
Single	1138.79	2.85	34.56	0.21	46.29	54.75	95.87
Double	1127.93	2.82	3.85	1.00	35.80	40.05	46.15

RSS and MSE are the residual squared error and the mean square error, respectively. Crit10, Crit5, and Crit1 are the critical values at the 10%, 5%, and 1% significance levels, respectively.

Table 9. Fixed effect panel threshold results for the high-level group

	(1)	(2)	(3)	(4)
<i>Impact of Pgdp</i>				
β_1	0.091** (0.050)	0.067 (0.045)	0.078 (0.055)	0.092** (0.044)
β_2	-0.018*** (0.006)	-0.015*** (0.005)	-0.021*** (0.006)	-0.017*** (0.005)
<i>Gini</i>	0.135** (0.065)	0.154*** (0.058)	0.385** (0.158)	0.212*** (0.067)
<i>Gini x Petax</i>	-0.0001* (0.0003)			
<i>Gini x Cor</i>		-0.006* (0.003)		
<i>Gini x Law</i>			-0.003** (0.001)	
<i>Gini x Dem</i>				-0.016** (0.006)
<i>Pop</i>	-0.079*** (0.014)	-0.060*** (0.012)	-0.102*** (0.018)	-0.057*** (0.012)
<i>Constant</i>	13.681 (1.968)	13.827*** (1.745)	15.657*** (2.519)	12.105*** (1.710)
Threshold (US\$)	42,185.80	41,821.12	42,957.52	42,058.75
Lower	41,910.82	41,615.82	42,668.53	41,778.46
Upper	42,246.95	42,022.51	42,996.36	42,137.01
Observation	399	475	475	475
Number of Countries	19	19	19	19

The values in parentheses are the standard errors. ***, **, and * represent the significance at 1%, 5%, and 10%, respectively.

Table 9 presents the results regarding the relationship between GHG emission per capita and income inequality including institutional variables using a fixed effect panel threshold model for the high-level group. The results related to income inequality show that the variable of *Gini* led to an increase in GHG emissions.

β_1 and β_2 denotes the marginal effect of per capita GDP on GHG emissions in the low and high regime; that is, when income is below and above the threshold value, respectively. In accordance with the results for the high-level group, we found that above the threshold is negative and significant, while below the threshold is positive and significant according to results (1) and (4). This shows that the EKC hypothesis strongly holds when the model includes the variable *Petax* and *Dem*. Examining the threshold value yields that the turning point is US\$ 42,185 from (1), but when we estimate the model that includes other institutional variables, we find different turning points. Figure 3 shows a graphical illustration of the threshold value of PGDP following the estimated model including each variable, such as *Petax*, *Cor*, *Law*, and *Dem*, respectively.

Castiglione et al. (2014) supports that result (1) is valid. They explain, “The level of environmental taxation increases since greater attention is given to environmental issued as income increases, up to a turning point. After this point, high income and enforcement of the rule of law lead to

a decrease in pollution levels and, consequently, to a decrease in taxation.” In consideration of their finding, we evaluate the direct effect of environmental tax on GHG emissions in the model. Even if the environmental tax increases, while the reduction in emissions does not appear at first, the emissions will gradually decrease as environmental tax policy is implemented. The interaction term ($Gini \times Petax$) has a negative effect since the value is negative and statistically significant. This indicates that environmental taxes help reduce the increase in GHG emissions due to income inequality. Therefore, the GHG emissions decrease at low levels of income inequality when the environmental tax effect becomes stronger than the income effect for the high-level group (Dissou & Siddiqui, 2014).

Since the interaction effect of the level of political institutions has a significantly negative value, a higher quality of institutions mitigates the positive relationship between income inequality and emissions for the high-level group. That is, citizens who reject ineffective policy and instead aim for better policy shed their apathy toward environmental issues as income equality grows.

The results for the low-level group are presented in Table 10. The EKC hypothesis does not hold because above and below the thresholds both have significantly positive values. This reveals that emissions are continuously increasing during the analysis period. This finding also indicates that economic development is still the main driving factor increasing GHG emissions for the low-level group.

Interestingly, income inequality shows different patterns between the high- and low-level groups. The variable of $Gini$ has a positive value in the high-level group, whereas it has a negative value in the low-level group. The results are the same whether using the fixed or random effect model, as described in section 5.2.

The policy regarding the energy tax and the raw and order have no significant effect on the reduction of GHG emissions, but the interaction term of Cor and Dem has a significantly negative effect. This result indicates that the negative relationship between income inequality and GHG emissions is mitigated under lower levels of corruption and higher democratic accountability.

5.3.2. Strong and weak groups in the high-level group

Table 11 and Table 12 list the results for the strong and weak groups, respectively. In the high-level group, countries in the first to ninth ranking are called “strong institutional arrangement” countries, while those ranked tenth to nineteenth are called “weak institutional arrangement”. The results show that GHG emissions increase as the income distribution becomes more unequal.

The interaction effect of environmental tax has a significantly negative value for GHG emissions, which may in turn influence the reduction of the positive impact of income inequality on emissions in the strong-level group. In fact, with increasing enforcement of the energy tax, emissions gradually increase at first, but after reaching a certain point at which the environmental tax revenue can be used for environmental preservation, emissions begin decreasing (Burtraw et al., 2012). Due to the regressive nature of such an environmental tax, the effects of the tax may also increase income inequality, which could in turn lead to rising pollution. However, our results do not show any evidence of a regressive impact of such an environmental tax, and it contributed to the reduction of GHG emissions in the strong group. The environmental tax is one of the most commonly used environmental policies in European countries. Countries in the strong institution group have implemented energy taxes or carbon taxes, particularly in Europe, where the first country introduced a carbon tax regime in 1990; further details are presented in Appendix Table A2. On the other hand, there is no evidence indicating that the environmental tax affects the relationship between emissions and income inequality through the indirect channel in the weak group.

Table 10. Fixed effect panel threshold results for the low-level group

	(1)	(2)	(3)	(4)
<i>Impact of Pgdg</i>				
β_1	0.052*	0.056**	0.058**	0.094***
	(0.00002)	(0.00002)	(0.00002)	(0.00002)
β_2	0.128***	0.127***	0.136***	0.166***
	(0.00002)	(0.00002)	(0.00002)	(0.00002)
<i>Gini</i>	-0.236***	-0.218***	-0.235***	-0.138**
	(0.066)	(0.066)	(0.065)	(0.069)
<i>Gini x Petax</i>	-0.00002			
	(0.00002)			
<i>Gini x Cor</i>		-0.005**		
		(0.003)		
<i>Gini x Law</i>			-0.0001	
			(0.0001)	
<i>Gini x Dem</i>				-0.011***
				(0.006)
<i>Pop</i>	-0.052*	-0.062**	-0.047	-0.030
	(0.029)	(0.029)	(0.030)	(0.029)
<i>Constant</i>	16.725***	17.056***	16.471***	13.658***
	(2.525)	(2.468)	(2.512)	(2.545)
Observation	294	350	350	350
Number of Countries	14	14	14	14

The values in parentheses are the standard errors. ***, **, and * represent the significance at 1%, 5%, and 10%, respectively.

Figure 4. The threshold value of per capita GDP for the strong group.

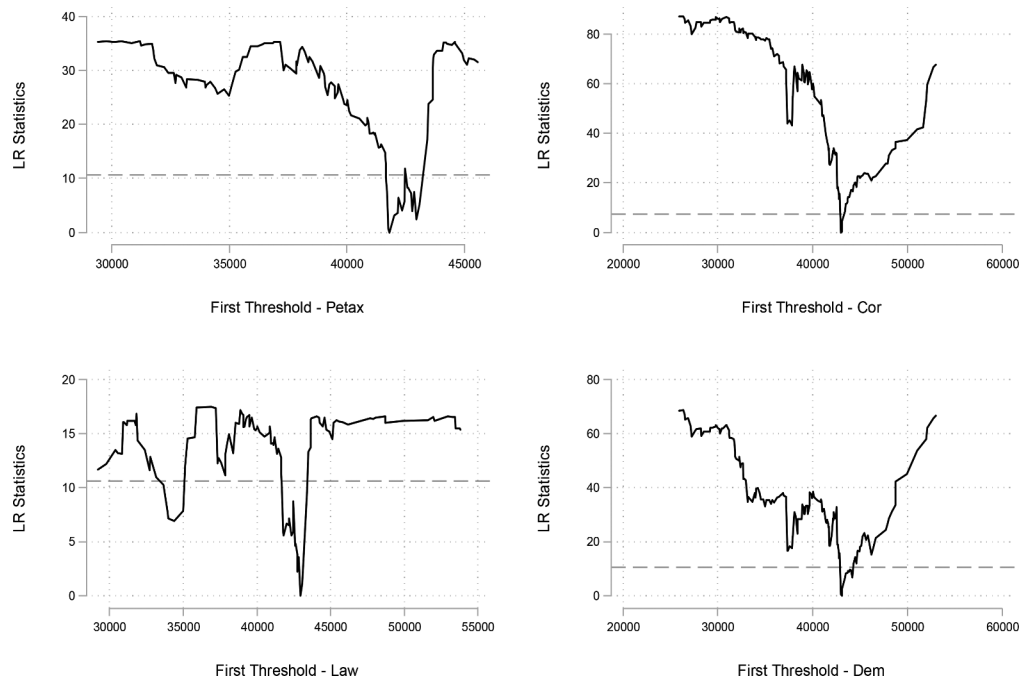


Table 11. Fixed effect panel threshold results for the strong group

	(1)	(2)	(3)	(4)
<i>Impact of Pgdp</i>				
β_1	0.268*** (0.085)	0.230*** (0.047)	0.181** (0.086)	0.345*** (0.086)
β_2	-0.005*** (0.002)	-0.005*** (0.003)	-0.006*** (0.002)	-0.010*** (0.005)
<i>Gini</i>	0.182** (0.085)	0.240*** (0.086)	0.463* (0.267)	0.767 (0.128)
<i>Gini x Petax</i>	-0.0001*** (0.00003)			
<i>Gini x Cor</i>		-0.010 (0.007)		
<i>Gini x Law</i>			-0.005** (0.002)	
<i>Gini x Dem</i>				0.011 (0.019)
<i>Pop</i>	-0.622*** (0.105)	-0.391*** (0.098)	-0.721*** (0.141)	-0.356*** (0.099)
<i>Constant</i>	17.085*** (2.041)	9.974*** (1.942)	21.651*** (2.980)	8.228*** (2.232)
Threshold (US\$)	41,821.12	42,957.52	42,957.52	43,074.64
Lower	41,735.54	42,865.58	42,668.53	42,907.01
Upper	42,022.52	43,074.64	43,088.06	43,088.06
Per capita GHG emission	13.4835	13.5055	13.3048	13.5055
Observation	189	225	225	225
Number of Countries	9	9	9	9

The values in parentheses are the standard errors. ***, **, and * represent the significance at 1%, 5%, and 10%, respectively.

In both groups, the strong enforcement of relevant laws provides benefits in terms of reduced GHG emissions. Countries with high levels of institutions implement the EU Emissions Trading System (EU-ETS) for the abatement of carbon dioxide emissions, and several countries with weak group, such as Germany, Ireland, Switzerland, and the United Kingdom, have successfully implemented emissions trading systems involving a carbon tax to reduce emissions. It is expected that a strong law and order facilitates the establishment of anti-pollution laws by the government. Further, the introduction of the emissions trading system has made it possible to achieve more equal distribution by securing additional tax revenues. This eventually mitigates the increase in emissions caused by income inequality. The interaction effect of corruption and democratic accountability plays a substantial role which mitigates the positive relationship between income inequality and GHG emissions only in the weak-level group. Though deterioration in income distribution could result in increased GHG emissions, the emission level decreases with lower levels of corruption, which improves the quality of environmental regulation (He et al., 2007). With respect to pollution, since higher democratic participation also leads to a higher environmental standard (Fredriksson et al., 2005) by increasing citizen preferences for environmental protection, achieving this goal will help limit the growth of emissions.

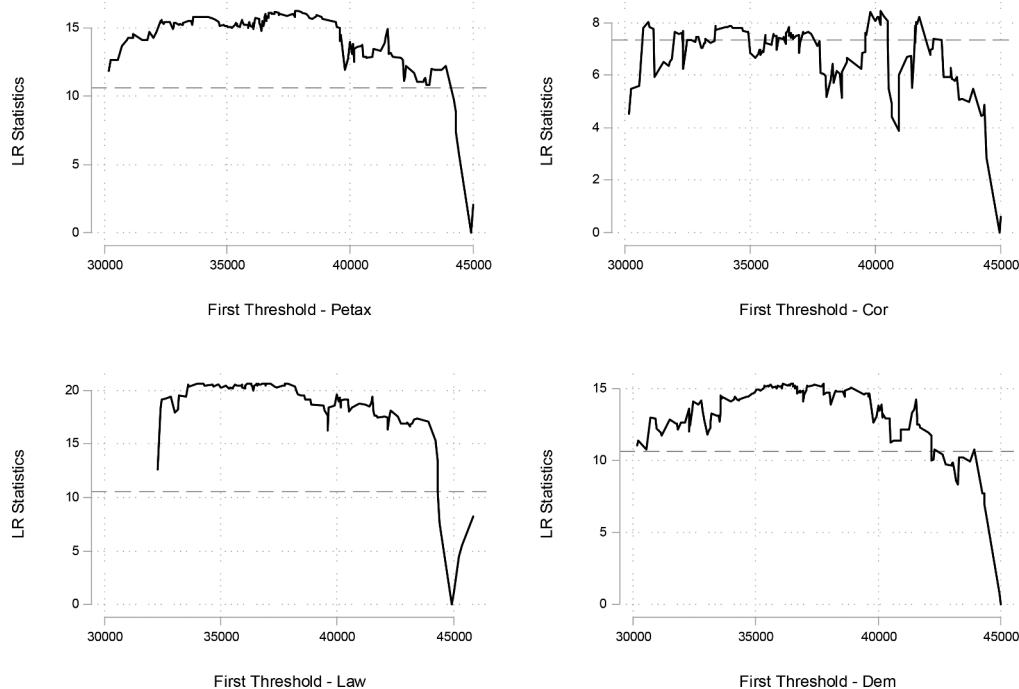
Table 12. Fixed effect panel threshold result for the weak group

	(1)	(2)	(3)	(4)
<i>Impact of Pgdp</i>				
β_1	0.356*** (0.106)	0.322*** (0.087)	0.202* (0.106)	0.328*** (0.100)
β_2	-0.012*** (0.002)	-0.015*** (0.002)	-0.019*** (0.003)	-0.011*** (0.002)
<i>Gini</i>	0.227** (0.107)	0.267** (0.107)	0.746*** (0.220)	0.475*** (0.118)
<i>Gini x Petax</i>	-0.00003 (0.00005)			
<i>Gini x Cor</i>		-0.012*** (0.004)		
<i>Gini x Law</i>			-0.004* (0.002)	
<i>Gini x Dem</i>				-0.032*** (0.007)
<i>Pop</i>	-0.109*** (0.017)	-0.097*** (0.018)	-0.139*** (0.109)	-0.107*** (0.016)
<i>Constant</i>	18.039*** (2.944)	17.522*** (2.802)	17.677*** (3.717)	15.262*** (2.830)
Threshold (US\$)	44,928.19	44,928.19	44,928.19	45,007.05
Lower	44,372.23	43,529.68	44,425.54	44,622.10
Upper	45,007.05	45,007.05	45,018.23	45,018.23
Per capita GHG emission	14.5556	14.5556	14.3146	14.5556
Observation	210	250	250	250
Number of Countries	10	10	10	10

The values in parentheses are the standard errors. ***, **, and * represent the significance at 1%, 5%, and 10%, respectively.

We now turn to testing the EKC hypothesis. The basic idea is that a “strong” institutional quality in developed countries implies that the government will engage in a greater reduction of pollution and that the public will participate in environmental protection as well. Therefore, the strong institutional quality will shift the turning point of EKC to lower levels of income and emissions. The results listed in [Table 11](#) and [Table 12](#) indicate that there is evidence supporting the EKC hypothesis in both groups, and the threshold values from significant result (3) are US\$ 42,957 and US\$ 44,928 for the strong and weak groups, respectively. These results meet the requirement that the threshold of the EKC be positioned at a relatively lower level of PGDP in countries with stronger levels of institutions. Surprisingly, lower GHG emissions are also found in the strong-level institution group, as the emissions per capita were reported to be about 13.5 thousand kg for the strong group and about 14.5 thousand kg for the weak group when the per capita GDP peaked each turning point. This is confirmed in [Figure 1](#), which graphically illustrates the significant effect of the threshold by the institution group. More specifically, environmental tax shifts the slope of EKC by income equality, so its effect contributes to lower GDP per capita and lower GHG emissions per capita in countries with strong levels of institutions (compare [Figure 4](#) and [Figure 5](#)). A higher quality of political institutions plays the same role as an environmental tax in countries with weak institutional arrangement.

Figure 5. The threshold value of per capita GDP for the weak group.



6. Conclusions

It has previously been widely believed that economic growth has a strong connection with environmental degradation. However, economic growth alone cannot explain all environmental issues, or why different countries at the same developmental stage show different effects of economic growth on environmental degradation. The previous literature has shown a relationship between the level of income distribution and environmental quality. Previous studies have also shown that social policies can influence the level of environmental degradation. However, they did not provide any crucial results about the factor determining the relationship between income inequality and environmental degradation. Therefore, this paper provides new insights into environmental degradation as income increases by assessing how the relationship between environmental degradation and income inequality is affected by levels of institutions. In this paper, this concept is constructed by including the institutional variable in Magnani's (2000) model. The model of this paper demonstrates that relative income (income inequality) depends on individual preference for environmental protection, which is associated with institutional quality. In addition, the main hypothesis is that the turning point of EKC will appear at a lower level of average income when the level of institution is relatively stronger.

The first empirical findings indicate that the level of income inequality affects GHG emissions differently depending on the institutional quality. The income inequality increases per capita GHG emission as income rises in countries with high levels of institutions, whereas income equality increases per capita GHG emissions as income increases in countries with low levels of institutions. In addition, the EKC hypothesis holds only for countries with high levels of institutions. For countries with weak institutions, emissions continuously increase even after the turning point of per capita GDP. In sum, these results explain that the median voter prefers to spend money toward environmental protection under a high institutional level; thus, when there is more equal income distribution, emissions decrease. However, the median voter is not interested in environmental protection under a low institutional quality, so when relative income increases, emissions increase as income rises. These results ultimately show that levels of institutions can affect individual behaviors towards environmental protection.

The impact of institutions shows that higher environmental tax revenue, control of corruption, law and order, and democracy accountability all play significant roles in the relationship between income inequality and GHG emission. This shows that better institutional quality can help reduce emissions as income equality increases. Environmental policies in OECD countries follow the institutional arrangement. Results of this study show that environmental tax is an efficient instrument for countries with strong institutions, whereas, the level of political institutions has a meaningful effect for countries with weak institutions. More specially, Pascal Saint-Amans, Director of the OECD's Centre for Tax Policy and Administration said, "Higher energy taxes are a good tool to avert catastrophic climate risks and curb air pollution. Good policy design and the wise use of the additional revenues raised can help improve energy affordability for vulnerable households." In addition, a report on "The impact of energy taxed on the affordability of domestic energy" using household-level data covering 20 OECD countries show that higher energy prices can help achieve social policy objectives by reducing harmful carbon emissions and air pollution (OECD, 2017). Whereas, the level of political institutions has a meaningful effect for countries with weak institutions.

The empirical analysis also investigated the threshold value of EKC between countries with strong and weak institutions. The main implication of this paper is that the threshold of EKC is positioned at a lower income level in countries with stronger institutional arrangement, along with lower GHG emissions. Therefore, the effective implementation of environmental protection policies contributes to improving environmental quality through institutional enforcement.

This paper has some limitations regarding data availability. The fixed effect panel threshold model needs to transform the data to balanced data. In other words, it has potential sample selection bias, and a subjective choice had to be made between a longer period and fewer individual or a shorter period and more individuals.

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Appendix

Table A1. The list of countries by institutional arrangement

Groups		Countries
High	Strong	Canada, Denmark, Finland, Iceland, Netherlands, New Zealand, Norway, Sweden, Switzerland
	Weak	Australia, Austria, Belgium, France, Germany, Ireland, Japan, Portugal, United Kingdom, United States
Low		Chile, Czech Republic, Estonia, Greece, Hungary, Israel, Italy, Korea, Mexico, Poland, Slovak Republic, Slovenia, Spain, Turkey

The standard values of the level of institution are adapted from ICRG Methodology. The points at 80% or more of the total are very low risk; 70 ~ 80% range, low risk; 60 ~ 70% range, moderate risk; 50 ~ 60% range, high risk; and less than 50%, very high risk. Since the maximum value of each variable is 6, the sum total of the institutional variable is 18. Therefore, an average of 14.4 points, which is 80% of the total, is defined as the high-level group, and below that is defined as the low-level group. Meanwhile, the dividing point separating the strong and weak groups is 16.2, which is 90% of the total.

Table A2. The contents of energy and carbon taxes in OECD 7 countries

Countries	Tax category	Started	Contents
Denmark	Energy	1995	- “Energy Package” was implemented in 1995.
	Carbon	1992	- 1st stage: Introduction of carbon tax in household sector in May 1992. - 2nd stage: Introduction of carbon tax in industry sector in January 1993.
Finland	Energy	1980s	- Introduction of environmental tax for energy resources in late 1980s.
	Carbon	1990	- Introduction of the world’s first carbon tax for CO ₂ emissions reduction and government financial reform.
Germany	Energy	1999	- Existing “Mineral oil tax” + Introduction of “Eco-tax” and electricity tax in 1999.
Netherland	Energy	1988	- “General Environmental Provision Act” + new clause of “General Fuel Charge” in 1988.
	Carbon	1990	- Energy tax + Introduction of “General Fuel Tax”.
Norway	Carbon	1991	- Introduction of energy tax on oil in 1970s - Introduction of carbon tax in 1991, followed by abolition of energy tax in 1993.
Sweden	Energy	1980s	- Transformation of tax system from income tax to energy tax.
	Carbon	1991	- Carbon tax rate in 1991: 0.25SEK/Kg per CO ₂ .
UK	Energy	1990	- Introduction of “Fossil Fuel Levy”.
	Carbon	2001	- Introduction of “Climate Change Levy”: tax levy on natural gas, electricity, and coal consumption

Finland was the first country to introduce a carbon tax in 1990, and according to the Prime Minister’s Office, Finland (Prime Minister’s Office, 2000), emissions were 7% lower in 1998 than they would have been without the carbon tax. Sweden and Norway introduced a carbon tax in 1991; as of 2009, Sweden had decreased its GHG emissions by 9% from cars (UNFCCC, 2014 2014), while as of 2003, Norway had reduced GHG emissions per unit of production by 22%, compared to that in 1992 (UNFCCC, 2006). In Denmark, which has had a carbon tax since 1992, per capita emissions were reduced by 15% from 1990–2005 (NREL (the National Renewable Energy Laboratory), 2009). The EU ETS is a policy followed by the EU to combat climate change, and it was first introduced in 2005 as the largest greenhouse gas emission trading scheme in the world. It helps industries cut their CO₂ emissions in a cost-effective way, and it requires a cap on emissions for all large CO₂ emission sector. The member states are 28 EU states and three EEA-EFTA (European Economic Area-European Free Trade Association): Iceland, Liechtenstein, and Norway. In 2006, four-member states (France, Greece, Switzerland, and the United Kingdom) had already reached a level below their Kyoto target. Eight additional member states (Austria, Belgium, Finland, Germany, Ireland, Luxembourg, the Netherlands, and Portugal) are expected to achieve their targets. Through the ETS, EU-15 members cut their base-year emissions by 3.4%, and they are expected to meet the target of cutting GHG emissions by 8% for Phase 2 of the period from 2008–2012 (European environment agency, 2008). In recent years (Phase 3), ETS usage has been accelerating in the power and heat sector, but industry emissions have remained stable (European environment agency, 2017).



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