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Impacts of Income Inequality on CO_2 Emission under Different Climate Change Mitigation Policies

Jeong Hwan Bae*

This study empirically examines whether income inequality affects CO_2 emission under various climate change mitigation policies. The climate change mitigation policies include carbon tax, emission trading, renewable portfolio standard, feed-in tariff, and renewable fuel standard. The total marginal effect of inequality on CO_2 emission is divided into direct, indirect, and interaction effects. Results show that high-income inequality directly raises CO_2 emission while indirectly reducing it through its impact on economic growth. Inequality weakens the effectiveness of certain climate change mitigation policies through an interaction effect between inequality and climate change mitigation policies. Whether inequality increases CO_2 emission or vice versa cannot be confirmed from the empirical outcomes of total marginal effects of inequality on CO_2 emission under different climate change mitigation policies. However, the effectiveness of climate change mitigation policies may be diminished when high inequality exists in a country.

JEL Classification: Q42, Q53, Q58
Keywords: Income Inequality, CO_2 emission, Economic Growth, Climate Change Mitigation Policies

I. Introduction

Fairness of income distribution, economic growth, and environmental conservation form the three pillars of sustainable development (Pearce and Atkinson, 1998). According to Kuznets (1955), income inequality can be exacerbated at the initial stage of economic development, but inequity decreases as economic growth exceeds an income tipping point. Grossman and Kruger (1995) and other scholars (Holtz-Eakin and Selden, 1992; Selden and Song, 1994) claimed

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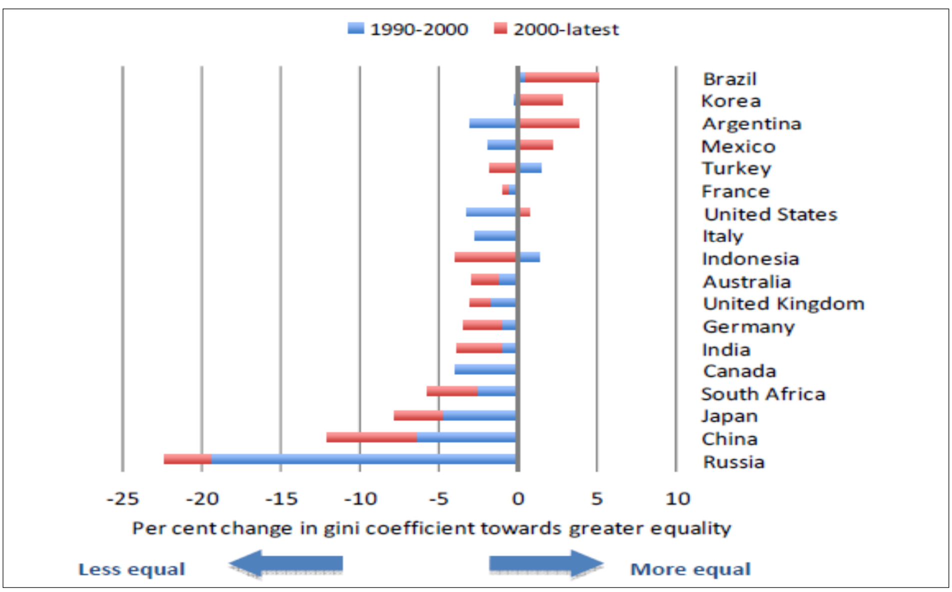
* Department of Economics, Chonnam National University, South Korea. Address: Yangsantaekjiro 20, Hyunjin Evervil 109-301, Buk-gu, Gwangju, South Korea, Tel. +82-62-530-1542, Fax: +82-62-530-1559, Email: jhbae@jnu.ac.kr

an inverted U-shaped curve relationship between environmental pollution and income, which is now called the "environmental Kuznets curve (EKC) hypothesis." The EKC hypothesis states that environmental devastation increases with economic growth, but environmental pollution is mitigated beyond an income turning point. When the EKC hypothesis is combined with Kuznets' argument on the relationship between inequity and growth, economic growth beyond a threshold income level can resolve the problems of inequity as well as environmental pollution. Economic growth can be a panacea for not only environmental pollution but also the problem of income inequality in society.

However, many industrialized countries have experienced aggravation of income inequality during the last two decades. As shown in Figure 1, income inequality has been growing in most G20[1] countries. Over half of the poorest people worldwide live in G20 countries. Moreover, G20 countries utilize most of the global natural resources, causing CO_2 emission and environmental devastation. On these grounds, the pursuit of economic growth alone cannot get rid of income inequality and environmental degradation.

[Figure 1] Comparison of relative changes in GINI coefficients to GDP for G20 countries between 1990 and 2010



Source: Oxfam, 2012, "Left behind by the G20? How inequality and environmental degradation threaten to exclude poor people from the benefits of economic growth," 157 Oxfam Briefing Paper.

[1] The G20 is an international forum for the governments and central bank governors from 20 major economies.

This study explores the nexus between income inequality and CO_2 emission while considering various climate change mitigation policies. Two existing hypotheses require testing. First, income distribution affects CO_2 emission, not only directly but also indirectly, through economic growth. Whether income inequality directly or indirectly affects environmental degradation is not generally known. Only a handful of studies have been conducted since the hypothetical study on the relationship between inequality and environmental degradation by James Boyce (1994). He claimed that large inequality of power and wealth causes environmental degradation for three reasons: asymmetry in power-weighted social decision principle, influence on the valuation of benefit and cost of environmentally harmful activities, and impact on time preference regarding the environment (Boyce, 1994).

Since Boyce's study, Scruggs (1998), Marsiliani and Renstrom (2000), Ravallion et al. (2000), and Borghesi (1999) joined in the debate on relationships among inequality, environment, and growth. Scruggs (1998) argued that democratic decision making may worsen environmental pollution as high-income groups are more concerned about a clean environment, whereas the low- and middle-income groups are more interested in economic growth than environmental conservation. Marsiliani and Renstrom (2000) supported Scruggs' argument by claiming that poor individuals are less concerned about protecting the environment due to the low marginal rate of substitution between the environment and private consumption. They prefer income redistribution to environmental conservation under unequal income distribution. Ravallion et al. (2000) argued that the influence of income distribution on the environment differs depending on the marginal propensity of low-income groups to emit pollution. By contrast, Borghesi (1999) claimed that cooperative strategy should be considered one of the most important factors in resolving environmental pollution and that cooperative strategy will not be rendered functional in an unequal society.

To examine the first hypothesis on the direct and indirect effects of inequality on CO_2 emission, a two-stage least squares estimation (2SLS) is applied. This approach can capture the indirect effects of income inequality on CO_2 emission through its impact on economic growth and the direct effect of inequality on CO_2 emission (Cole, 2007; Leitão, 2010). At the first stage, income inequality is assumed to affect gross domestic product (GDP) per capita in addition to the general driving forces of economic growth. The predicted value of GDP per capita from the first-stage estimation is used as one of the explanatory variables for estimating CO_2 emission at the second stage. The 2SLS method enables us to derive indirect effects of inequality on CO_2 emission through their influences on economic growth.

Apart from the first hypothesis, the effectiveness of climate change mitigation policies is hypothesized to interact with the degree of distributional fairness, following a study conducted by Harring (2013). He argued that people living in a society with high-income inequality tend to hold weak trust in the effectiveness of incentive-based environmental policies. Following Harring's argument, we assume that incentive-based climate change mitigation policies in countries with high-income inequality will have poor effectiveness because citizens distrust public policies. The empirical test will be implemented if interaction terms between income inequality and the incentive-based climate change mitigation policies positively affect CO_2 emission.

Next, the total effects of income inequality on CO_2 emission across various climate change mitigation policies will be derived by combining direct, indirect, and interaction effects of inequality. The analysis will also determine whether the effectiveness of climate change mitigation policies can be influenced by the interaction effect between inequality and implementation of climate change mitigation policies. Finally, the sample countries are divided into Organization for Economic Cooperation and Development (OECD) and non-OECD countries to examine whether developed and developing countries differ in terms of effectiveness of climate change mitigation policies on CO_2 emission as well as relationship between economic growth and inequality.

The next section reviews the literature on the relationships among income equality, economic growth, and environmental pollution. A conceptual framework is derived from the literature review. Section 3 describes the model specifications and data. Section 4 explains the estimation results and interpretation. The last section includes a conclusion with policy implications explored through analysis.

II. Literature Review and Conceptual Framework

With regard to the relationship between economic growth and income inequality, that is, the first hypothesis in the present study, Alesina and Rodrik (1994) and Benabou (2000) suggested that income inequality may be a major obstacle to economic growth. However, other researchers (Benhabib and Spiegel, 1998; Forbes, 2000; Li and Zou, 1998) argued that income inequality trigger economic growth through competition in the short run, and income redistribution policies can bring harm to economic growth. Therefore, from the literature review, whether inequity positively or negatively affects economic growth is indeterminate. The first stage estimation in this research will empirically determine the nexus between economic growth and distributional fairness.

From a different perspective, in a pioneer study on the relationship between inequity and environmental pollution, Boyce (1994) argued that environmental degradation can be exacerbated as income inequality worsens in two ways. First, the balance of power between winners and losers from environmental degradation determines the degree of environmental degradation. Considering that the power of winners is larger than that of losers, the environment deteriorates further. Second, the aggravation of income inequality increases the rate of time preference for both the rich and the poor, which results in more weight on the present exploitation of environmental resources. He underlined the importance of democracy and equity in terms of environmental protection. Concerning the arguments of Boyce, Scruggs (1998) claimed that democratic decision making is not a necessary condition for environmental improvement and that high-income groups may have more interest in environmental conservation. He further argued that environmental pollution may increase with improved income inequality. Given these conflicting arguments, the direct effect of inequality on CO_2 emission cannot be predetermined.

As for the literature associated with the second hypothesis of this study, Marsiliani and Renstrom (2000) and Harring (2013) focused on the effect of distributional equity on environmental policy. Marsiliani and Renstrom (2000) theoretically examined if distributional fairness affects political decision making and is associated with environmental protection, demonstrating that high-income inequality can lead to low environmental taxes through democratic decision making. Harring (2013) claimed that people in corrupt and unequal countries are inclined to perceive economic incentive policies for environmental conservation as less effective. We will investigate how income inequality affects CO_2 emission through its interaction with the climate change mitigation policies.

[Figure 2] Nexus between inequality, growth, CO_2 emission, and climate change mitigation policy

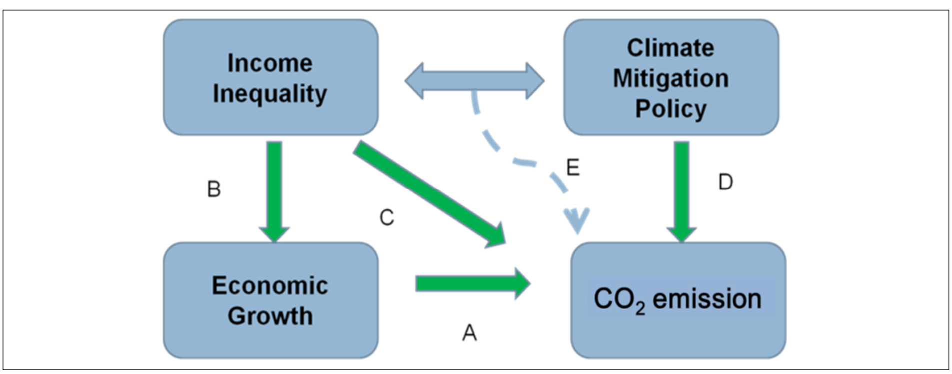


Figure 2 shows a conceptual framework for this study. Direction A indicates that income inequality directly affects CO_2 emission, and combining directions B and C explains how fairness of income can influence CO_2 emission through its impact on economic growth. Direction D demonstrates a direct effect of climate change mitigation policies on CO_2 emission. Direction E implies an interaction effect between income inequity and climate change mitigation policies on CO_2 emission. Incorporating all of the effects described in Figure 2 captures the direct, interaction, and indirect effects of inequality on CO_2 emission, given various climate change mitigation policies.

III. Model Specification and Data

3.1. Model Specification

A joint estimation method is employed to test the first hypothesis that income inequality (measured as Gini coefficient) directly or indirectly affects CO_2 emission. To estimate the indirect effect of income inequality on CO_2 emission, income inequality is assumed to influence economic growth (measured as per capita GDP) at the first stage, and income inequality and economic growth are accounted as determinants of CO_2 emission levels at the second stage. However, the CO_2 emission equation may suffer from an endogeneity problem as GDP and CO_2 emission equations are estimated jointly.[2] Thus, 2SLS method is applied to remove the endogeneity issue (Greene, 2008). Before we estimate the CO_2 emission equation, GDP is estimated using instrumental variables at the first stage. The estimated value of GDP from the first equation is then utilized as an explanatory variable in the CO_2 emission equation instead of the GDP variable at the second stage.

Specifically, per capita GDP is a dependent variable at the first stage, whereas the Gini coefficient (GINI), the Corruption Perceptions Index as an indicator of institutional quality (CPI), population growth rate (POPG), capital per worker (KPW), inflation rate (INF), ratio of industry production relative to GDP (IND_GDP), and ratio of foreign direct investment (FDI) to GDP are accounted as instrumental (explanatory) variables in Equation (1).

$$GDP_{it} = \alpha_0 + \alpha_1 GINI_{it} + \alpha_2 GINI_{it}^2 + \alpha_3 CPI_{it} + \alpha_4 POPG_{it} + \alpha_5 KPW_{it} + \alpha_6 INF_{it} + \alpha_7 IND\_GDP_{it} + \alpha_8 FDI_{it} + u_{it} . \quad (1)$$

The typical independent variables, including POPG, KPW, INF, IND_GDP, and FDI have been frequently used in the literature as major determinants of economic growth (Cole, 2007; Leitao, 2010; Levine and Zervos, 1993; Mankiw et al.,

[2] Endogeneity is defined as corr (X, U) $\neq$ 0, where X is a vector of explanatory variables, and U is a vector of error terms in simultaneous equations. Dynamic models, simultaneous equations (demand and supply), or measurement error can cause endogeneity (Greene, 2008). This study uses "joint estimation" rather than simultaneous equations, so the likelihood of suffering from endogeneity is low. However, GDP can be endogenously associated with environmental pollution (Barassi and Spagnolo, 2012; Coondoo and Dinda, 2002; Dinda and Coondoo, 2006).

1992). Increases in population will provide abundant labor to industries with low wages, thereby prompting them to become competitive. A high capital per worker will increase labor productivity, which results in high economic growth. An economy that conditionally suffers from a high inflation rate will then increase the overall consumption, which will lead to low production. An increase in the share of industry output in a country's GDP will facilitate technological innovation. Consequently, the economy will be dominated by productive and profitable firms. Studies pointed out that technological innovation mainly occurs in the manufacturing sector (Kaldor, 1970; Cornwall, 1977; Syrquin, 1986). Thus, this sector is a major driving force of economic growth.[3]

Although the proposition on whether corruption positively or negatively affects economic growth remains debatable, extant studies have predominantly found that corruption is an obstacle to economic growth. The "sand the wheels" hypothesis[4] (Mauro, 1995) states that corruption increases economic inefficiency by allocating resources to unproductive activities, thereby deterring economic growth. Thus, the coefficient of CPI is assumed to have a positive sign as a high CPI value implies transparency (less corruption).[5]

A square and linear term of the Gini coefficient was included in the econometric model to test if an inverted U-shaped relationship exists between GDP and GINI. Banerjee and Duflo (2003) found an inverted U-shaped relationship between net changes in income inequality and economic growth rate by applying a non-parametric approach. Their results supported the result of Barro (2000), in that a negative relationship exists between inequity and growth of the developing countries, but the relationship is positive for industrialized countries.

The predicted value of the GDP from Equation (1), (EGDP), is used as a determinant of CO_2 emission in the second stage estimation as presented in Equation (2). The square term of the EGDP ($EGDP^2$) was included to test the evidence of the EKC hypothesis. In addition, the following factors were accounted for as affecting CO_2 emission as described in Equation (2): IND_GDP; openness of an economy (OPEN); population density (POPD); energy intensity (EI); ratio of

[3] Kniivilä (2007) discusses the role of industrial development in the economic development of Asian countries, such as China, South Korea, Taiwan, and Indonesia.

[4] Contrary to the "sand the wheels" hypothesis, the "grease the wheels" hypothesis argues that corruption may enhance allocative efficiency when bribery speeds up bureaucratic procedures (Shleifer and Vishny, 1994). However, the argument of efficient corruption has been criticized to have a number of problematic assumptions and is also supported by little empirical evidence (Aidt, 2003).

[5] A few scholars assumed that the corruption variable suffers from the endogeneity problem when considered as a determinant of economic growth (Cole, 2007; Leitão, 2010). They used an instrumental variable approach to determine the endogeneity issue. This study employed the same instrumental variable approach but found that the estimates did not provide better outcomes relative to the panel fixed effect models. The result obtained with the instrumental variable approach is available upon request.

fossil fuels in electricity generation (FFEC); dummies on climate change mitigation policies ($\mathrm{CMP}_{k,it}$); where $\mathrm{CMP}_k = 1$ for country *i* that adopted climate policy *k* in given year *t*; otherwise, $\mathrm{CMP}_k = 0$; and the interaction term between climate change mitigation policies and GINI (CMP*GINI).

$$CO_{2,it} = \beta_0 + \beta_1 EGDP_{it} + \beta_2 EGDP_{it}^2 + \beta_3 IND\_GDP_{it} + \beta_4 OPEN_{it} + \beta_5 EI_{it} + \beta_6 FFEC_{it} + \beta_7 CMP_{k,it} + \beta_8 CMP_{k,it} * GINI_{it} + \beta_9 GINI_{it} + \varepsilon_{it}. \quad (2)$$

The climate change mitigation policies are divided into explicit and implicit policies. The former includes emission trading system (ETS) and carbon tax (CTAX), and the latter includes renewable portfolio standard (RPS), renewable fuel standard (RFS), and feed-in tariff (FIT). The implicit policies have mainly been implemented to diffuse renewable energy technology, such as solar, wind, bio, hydro, geothermal, ocean, and waste energy. Renewable energy is known as a clean and low carbon energy production technology, which is used in place of fossil energy, so the RPS, RFS, and FIT can be considered as indirect CO_2 mitigation policies. As for the basic mechanism of the climate change mitigation policies, the ETS, RPS, and RFS policies are based on quantity control, whereas the CTAX and FIT policies are dependent on price control. The ETS and RPS policies are similar in that a regulator sets a quantity cap and penalty levels, but the market determines the equilibrium quantity and price for CO_2 emission permits in the ETS. The equilibrium quantity and price for renewable certificates are derived from the renewable certificate market in the RPS.

In most countries, the RFS is under the full control of a regulator; thus, a government determines the total amount of renewable fuels for transport that should be provided annually, the quality of the fuels, credits applied to different renewable fuel sources, and the amount of penalty for a violation. However, certain countries have a combined subsidy policy on renewable fuel production with the RFS. Finally, a CTAX is imposed on the emission of CO_2, whereas an FIT policy subsidizes gaps in electricity production costs of renewable and fossil fuels. Consequently, the implicit as well as explicit climate change mitigation policies share the feature of resorting to economic incentives to mitigate CO_2 emission.

In empirical tests of the EKC hypothesis, the following factors are commonly used as explanatory variables: GDP, IND_GDP, OPEN, EI, POPD, FFEC, and CMP (Heerink et al., 2001). The GDP and squared GDP are included as explanatory variables to test the EKC hypothesis on CO_2 emission. The industry share of GDP captures the "composition effect," which was proposed by Grossman and Kruger (1995). The shared sum of export and import in GDP was included to examine whether an openness of an economy or dependency on trade affects CO_2 emission. If a country trades with nations with more (less) stringent environmental regulations, then a high share of trade relative to domestic production will lead to low (high) environmental pollution or CO_2 emission. The population density was used as a determinant of environmental pollution in a few studies, but mixed results were reported (Grossman and Krueger, 1995; Panayotou, 1997). According to some studies (e.g., Selden and Song, 1994; Patel et al., 1995), a high concentration of population mitigated environmental pollution. They argued that high population density may enhance awareness of environmental degradation, thereby advocating stringent environmental policies and clean technologies. However, environmental pollution may worsen with increases in population density if the concentration of population leads to more heightened demands for transport, resources, goods, and services than the dispersed population. Moreover, a high population density may derive demands for energy-intensive services that will not be required in areas with a low population density (Holdren, 1991).

Two kinds of energy variables, namely, energy intensity (EI_{it}) and share of fossil fuels in electricity production ($FFEC_{it}$), are included as determinants of CO_2 emission. Energy intensity is the share of energy use (kg of oil equivalent) per \$1,000 of GDP, which measures energy efficiency. Since Grossman and Kruger (1995), the energy efficiency measure has been used to capture the "technological effect" in the study of the EKC hypothesis. Fossil fuels used in electricity production include coal, petroleum, and natural gas. High-energy intensity (low-energy efficiency) is assumed to increase CO_2 emission, whereas a low share of fossil fuels used in electricity production will reduce CO_2 emission. Finally, various kinds of climate change mitigation policies are introduced to identify which policies are effective in abating CO_2 emission.

Based on Equations (1) and (2), the total marginal effect of inequality on CO_2 emission can be derived from the sum of the direct effect (second term on the right hand side [R.H.S]), interaction effect (first term on the R.H.S), and indirect effect (last term on the R.H.S) of inequality (Equation 3).

$$\frac{dCO_{2,it}}{dGINI_{it}} = \frac{\partial CO_{2,it}}{\partial GINI_{it}} + \frac{\partial CO_{2,it}}{\partial EGDP_{it}} \frac{\partial EGDP_{it}}{\partial GINI_{it}}$$
$$= \hat{\beta}_8 \overline{CMP} + \hat{\beta}_9 + (\hat{\beta}_1 + 2\hat{\beta}_2 \overline{EGDP})(\hat{\alpha}_1 + 2\hat{\alpha}_2 \overline{GINI}), \quad (3)$$

where $\overline{CMP}$, $\overline{EGDP}$, and $\overline{GINI}$ are mean values of CMP_{it} , $EGDP_{it}$, and $GINI_{it}$.

The sign of the direct effect is ambiguous because Boyce (1994) claimed that income inequality will increase environmental degradation, whereas Scruggs (1998) argued that greater equality may aggravate environmental degradation as discussed in the literature review. With regard to the interaction effect between climate policies and inequality, greater inequality can negatively affect people's confidence on the effectiveness of climate change mitigation policies, which can increase CO_2 emission. Harring (2013) proposed that aggravation of inequality (GINI) can negatively influence people's perception of the effectiveness of incentive-based environmental policies, such as a low-income group will be relatively affected by the environmental taxes on petroleum. Furthermore, the environmental policies can cause unfair distributional consequences, which lead to free-riding problems.

The indirect effect of inequality is complicated because the Gini coefficient non-linearly affects per capita GDP, which, in turn, has an inverted U-shaped relationship with CO_2 emission. Considering the ambiguity of the directions of the interaction as well as indirect effects, the direction of the total effect of inequality on CO_2 emission cannot be predetermined.

Finally, the total marginal effect of climate change mitigation policies (CMP) on CO_2 emission is the sum of the direct effect (first term of R.H.S) of the CMP and the interaction effect (second term of R.H.S) between CMP and GINI (Equation 4).

$$\frac{dCO_{2,it}}{dCMP_{it}} = \frac{\partial CO_{2,it}}{\partial CMP_{it}} + \frac{\partial CO_{2,it}}{\partial CMP_{it}} * \overline{GINI}_{it} = \hat{\beta}_7 + \hat{\beta}_8 \overline{GINI} \,. \tag{4}$$

Countries, which have implemented climate change mitigation policies, are expected to have low carbon emission. Accordingly, the first term on the R.H.S of Equation (4) should have a negative sign. However, when countries suffering from severe inequality implement climate change mitigation policies, the coefficient of the interaction term between GINI and CMP (the second term of the R.H.S. of Equation [4]) may have a positive sign, which implies that a lax climate change mitigation policy leads to increases in CO_2 emission. As the dummy variable on climate policies only delivers information regarding whether a country has implemented any climate change mitigation policy in a given year, it cannot provide information on the degree of effectiveness of the policies. However, the interaction term between the CMP and GINI coefficients may provide additional information on the effectiveness of the climate change mitigation policies.

3.2. Data

The data for this study cover CO_2 emission of 110 countries with GINI, CPI, per capita GDP, and other control variables from 2000 to 2010. Three-year average values for all of the variables are used to avoid business cycle effects inherent in time series data (Saha and Gounder, 2013).[6] At the time of data collection (June 2013–

[6] Three-year average conversion yields four time periods (2000–2002, 2003–2005, 2006–2008, and

Aug. 2014) for this research, data on per capita CO_2 emission were available until 2010. Transparency International (TI) began announcing CPI for 40 countries from 1995 and increased the number of countries in 2000.

A small number of industrialized countries had implemented climate change mitigation policies until the 1990s. The climate change mitigation policies have been adopted in a few developing countries as well as the developed world since 2000. Hence, the time period of this study is restricted from 2000 to 2010. Most data, except CPI and CMP, were collected from the World Development Indicators (WDI). Information on whether or not a country implemented one of the climate change mitigation policies in a specific year was collected from various sources, such as the Renewable Energy Policy Network for the 21st Century (REN21), Environmental Protection Agency (US EPA), European Commission (EU), the Carbon Share page of the Commons Share website, Regional Green House Gas Initiatives (RGGI), and individual country reports.[7]

As a measure of per capita income of a country, we used real GDP per capita in constant, 2005 U.S. dollars. The CPI reflects a degree of corruption ranging between 0 and 10 (0: very high corrupt status, 10: very low corrupt status). The GINI coefficient ranges from 0 to 100, implying that zero is a perfectly fair distribution, and a high value is an unequal distribution of income. A per capita CO_2 emission level for each country is used to represent the degree of CO_2 emission. POPD is measured as a number of persons per km^2. The following items are denoted as a percentage (%): the share of export plus import in GDP (OPEN), IND_GDP, POPG, INF, and the share of fossil fuels in electricity generation (FFEC). The ETS, CTAX, RPS, RFS, and FIT represent dummy variables for climate change mitigation policies. Thus, "1" implies that a country implements a specific climate change mitigation policy in a given year; "0" implies otherwise. Among the 110 countries, between 2000 and 2010, the FIT is the most widespread policy, with a ratio of approximately 20%, whereas the RFS is the least popular one (nearly 7%).

IV. Results

4.1. Marginal Effects of Inequality on Economic Growth

To test Equation (1), the Hausman test confirms that the fixed effect models are preferred to the random effect models (Table 1) for all model specifications. This

2009–2010). Although the maximum number of the original observations was 700, three-year averaged data comprise 440 observations.

[7] Additional details on the data sources are summarized in the Appendix.

means that the fixed effect model should be adopted in the presence of unobservable country-specific effects. The Model GDP1 considers POPG, KPW, and FDI as explanatory variables of GDP. CPI, GINI, and square term of GINI are added incrementally to models GDP2, 3, and GDP4.

[Table 1] Descriptive statistics

Variable	Mean	Std. Dev.	Min	Max
GINI	39.2198	9.5335	17.2267	67.4000
CPI	4.4082	2.2444	0.8000	9.8667
GDP	12187	16596	139	85607
CO_2	5.7382	6.2915	0.0411	44.0265
IND_GDP	31.7088	10.8559	7.5246	77.7115
POPG	1.3897	1.7378	-1.8662	16.7957
KPW	0.0155	0.0244	0.0003	0.2764
OPEN	0.4461	0.3215	0.068	2.2082
POPD	116.0789	148.0897	1.5578	1154.755
FFEC	71.4474	25.6704	0	100.9032
FDI	0.0386	0.1075	-0.7601	1.9637
ETS	0.1874	0.3905	0	1
CTAX	0.1089	0.3116	0	1
RPS	0.1122	0.3158	0	1
RFS	0.0696	0.2546	0	1
FIT	0.1964	0.3975	0	1

For all model estimations, POPG, KPW, and FDI positively affect the GDP with statistical significance. Positive signs for constant terms over all models imply that technological progress contributes to economic development. The coefficient of the CPI is significant and positive, which means that a transparent government increases economic growth. When both linear and square terms of the GINI were included, an inverted U-shaped relationship between inequality and income was identified as in the GDP4 model. On the contrary, the GDP3 model, including only the linear term of the GINI, demonstrates that the estimates of the GINI were insignificant. The estimation of the GDP4 model states that degeneration of inequality positively affects the GDP per capita at the initial stage of economic growth; however, the GDP per capita declines as inequality aggravates further. The GDP4 model provides the highest R^2 as well as correct signs and statistical significances for all parameter estimates. Thus, the predicted value of per capita GDP is used as an explanatory variable in the estimation of Equation (2) based on the GDP4 model.

[Table 2] Estimation results for economic growth models

Dependent variable: lnGDP	GDP1	GDP2	GDP3	GDP4
POPG	0.184***	0.249***	0.397***	0.384***
	(0.041)	(0.045)	(0.052)	(0.047)
KPW	0.783***	0.727***	0.996***	0.864***
	(0.049)	(0.054)	(0.073)	(0.067)
FDI	0.214	0.173	2.831***	2.970***
	(0.132)	(0.139)	(0.606)	(0.546)
LnCPI		0.007*	0.008*	0.010**
		(0.004)	(0.004)	(0.004)
LnGINI			-0.048	26.676***
			(0.252)	(2.957)
$LnGINI^2$				-3.978***
				(0.439)
Constant	28.584***	27.948***	29.209***	-15.870***
	(0.234)	(0.359)	(1.049)	(5.063)
Within R^2	0.3228	0.3291	0.5094	0.6029
Hausman test	6.95*	21.96***	23.36***	32.17***
N of obs.	700	587	416	416

Notes: All values are converted to three-year average. Ln stands for natural logarithmic form. Parentheses are standard errors. * means significant within 10%, ** means significant within 5%, and *** means significant within 1%.

4.2. Marginal Effects of Inequality on CO_2 Emission

Each model in Table 3 differs, depending on the type of climate change mitigation policy. All parameter estimates in the second column represent estimates using an ETS as a climate change mitigation policy. All models are estimated based on the panel fixed effect method, as the Hausman test rejects the null hypothesis that allows for no correlations between explanatory variables and residuals. The predicted value of per capita GDP from model GDP4 (EGDP) in Section 4.1 is utilized as the explanatory variable of the CO_2 emission models. For all models, the estimation results support the EKC hypothesis between income and CO_2 emission as both EGDP and $EGDP^2$ are significant; $EGDP^2$ is negative, whereas the EGDP is positive.

A high share of industry in GDP increases CO_2 emission. A country that relies on trade and energy-intensive industries generates high CO_2 emission levels. A high share of fossil fuels used for electricity production increases CO_2 emission, and a high population density reduces CO_2 emission. The parameter estimates for the population density are statistically significant for most climate change mitigation policies, except RFS. All parameter estimates of the constant terms are significant and negative, which imply that technological progress considerably reduces CO_2 emission.

[Table 3] Estimation results for CO_2 emission models with various climate change mitigation policies

Climate Policy	ETS	CTAX	RPS	RFS	FIT
EGDP††	0.714***	0.832***	0.892***	0.902***	0.793***
	(0.205)	(0.195)	(0.190)	(0.192)	(0.197)
$EGDP^2$	-0.013***	-0.015***	-0.016***	-0.017***	-0.014***
	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)
IND/GDP	0.011***	0.012***	0.010***	0.011***	0.010***
	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)
OPEN	0.102***	0.093***	0.101***	0.095***	0.095***
	(0.017)	(0.015)	(0.015)	(0.015)	(0.015)
EI	0.283***	0.287***	0.280***	0.276***	0.280***
	(0.033)	(0.033)	(0.033)	(0.034)	(0.033)
POPD	-0.194**	-0.185**	-0.196**	-0.093	-0.173**
	(0.087)	(0.087)	(0.085)	(0.093)	(0.087)
FFEC	0.879***	0.893***	0.892***	0.866***	0.880***
	(0.071)	(0.071)	(0.069)	(0.073)	(0.071)
CMP_K†	-0.244*	-0.273	-0.497***	-0.204	-0.203
	(0.139)	(0.314)	(0.146)	(0.164)	(0.138)
CMP_K†_ LnGINI	0.065*	0.088	0.126***	0.045	0.050
	(0.039)	(0.082)	(0.040)	(0.044)	(0.039)
LnGINI	0.130***	0.122***	0.114**	0.121***	0.125***
	(0.047)	(0.047)	(0.046)	(0.047)	(0.047)
Constant	-13.364***	-14.891***	-15.517***	-15.916***	-14.455***
	(2.701)	(2.560)	(2.497)	(2.524)	(2.596)
Within R^2	0.7314	0.7306	0.7415	0.7295	0.7327
Hausman test†††	75.06***	71.77***	82.49***	73.98***	72.33***

Notes: Number of observation is 341 for all models. All values are converted to three-year average. Ln stands for natural logarithmic form. † suggests that K includes climate mitigation policies, such as emission trading system (ETS), carbon tax (CTAX), renewable portfolio standard (RPS), renewable fuel standard (RFS), and feed-in tariff (FIT). Parentheses are standard errors. †† means that EGDP is the predicted value of per capita GDP estimated from the model GDP4. ††† means that χ^2 statistics is used for Hausman test. * means significant within 10%. ** means significant within 5%. ***means significant within 1%.

Among the climate change mitigation policies, the ETS and RPS policies were found to contribute to deterring CO_2 emission within 10% and 1% statistical significance, individually. The RPS was estimated as the most effective policy in mitigating CO_2 emission, followed by the CTAX, ETS, RFS, and FIT policies. However, once the interaction effect of the climate change mitigation policies and inequality was accounted for in the estimation, the effects of climate change mitigation policies diminish considerably. In particular, the interaction between GINI and the ETS or RPS policies are statistically significant, with positive impacts on CO_2 emission. Therefore, our analysis indirectly supports the study of Harring

(2013), that is, people's trust on the effectiveness of incentive-based environmental policies can be affected by the degree of income inequality.

The outcome can also be explained by the argument of Magnani (2001) that the preference of median voters in the OECD countries determines the stringency of environmental policies, and high-income inequality diminishes the relative income of the median voters; thus, they prefer private consumption to environmental quality. Therefore, the interaction term between GINI and CMP_k reflects social perception on the climate change mitigation policies as well as the stringency of climate change mitigation policies.

Moreover, the estimated coefficients of GINI are positive on CO_2 emission for all climate change mitigation policies within a 1% significance level, which implies that a direct effect of income inequality on CO_2 emission was identified. This result lends further support to Boyce's hypothesis that unfairness of income distribution and environmental degradation are positively correlated.

4.3. Total Marginal Effects of Income Inequality on CO_2 Emission

Table 4 illustrates the total marginal effects of GINI on CO_2 emission for different climate change mitigation policies and as derived from the outcomes of Table 3. The total marginal effects are divided into direct, indirect, and interaction effects. The direct effect is a marginal change in CO_2 emission resulting from a one unit increase in the GINI. The indirect effect is the product of 1) the impact of inequality on GDP and 2) the impact of GDP on CO_2 emission. The interaction effect captures how income inequality affects CO_2 emission by interacting with the implementation of a climate policy. The marginal effects presented in the first row of Table 4 are the impact of the GINI on GDP, and those in the second row are the impact of GDP on CO_2 emission. The third row represents the indirect effects of the GINI on CO_2 emission, derived as a product of the first and second rows. The fourth row is the interaction effect between the GINI and climate change mitigation policies, and the fifth row is the direct effect of GINI on CO_2 emission. Insignificant interaction effects between GINI and CTAX, RFS, or FIT are accounted as zero. The last row represents total marginal effects, which are the sum of the direct, indirect, and interaction effects.

For all climate change mitigation policies, the impacts of the GINI on GDP were negative. This finding means that high inequality will reduce per capita GDP. Next, the impacts of per capita GDP on CO_2 emission were positive for all climate policies. Therefore, high-income inequality reduced CO_2 emission indirectly. Furthermore, the interaction effect between the GINI and the ETS or RPS policies was estimated as positive; thus, high-income inequality increases CO_2 emission when it interacts with the ETS or RPS.

Consequently, the total marginal effects of the GINI on CO_2 emission for all climate change mitigation policies were calculated as having negative signs, suggesting that high-income inequality reduces CO_2 emission.

[Table 4] Marginal effects of GINI on CO_2 emission

Marginal effect	ETS	CTAX	RPS	RFS	FIT
Impact of GINI on GDP	-2.2905	-2.2905	-2.2905	-2.2905	-2.2905
Impact of GDP on CO_2 emission	1.3708	1.5899	1.7004	1.7609	1.5004
Indirect Effect of GINI on CO_2 emission	-3.1398	-3.6416	-3.8947	-4.0333	-3.4365
Interaction effect of GINI and policy	0.0122	-	0.0141	-	-
Direct effect of GINI on CO_2 emission	0.1300	0.1220	0.1140	0.1210	0.1250
Total Effect of GINI on CO_2 emission	-2.9976	-3.5196	-3.7666	-3.9123	-3.3115

Note: Insignificant interaction effects are accounted as zero for CTAX, RFS, and FIT models.

4.4. Total Marginal Effects of Climate Change Mitigation Policies on CO_2 Emission

The total marginal effect of climate change mitigation policies on CO_2 emission can be divided into direct and interaction effects between the climate change mitigation policy and GINI as represented in Equation (4). Although the direct effects of climate change mitigation policies reduce CO_2 emission, the total marginal effects of climate change mitigation policies diminish remarkably, depending on the type of climate change mitigation policy, as presented in Table 5. In particular, the total marginal effects of CTAX on CO_2 emission are found to be positive. Therefore, when the significant interaction effect between climate policy and inequality is accounted, the effectiveness of climate change mitigation policies, such as ETS and RPS, was found to decline remarkably.

[Table 5] Marginal effects of climate policy on CO_2 emission

Marginal effect	ETS	CTAX	RPS	RFS	FIT
Impact of policy on CO_2	-0.2440	-0.2730	-0.4970	-0.2040	-0.2030
Interaction effect of policy and GINI	0.2367	-	0.4587	-	-
Total effect	-0.0073	-0.2730	-0.0383	-0.2040	-0.2030

Note: Insignificant interaction effects are accounted as zero for CTAX, RFS, and FIT models.

4.5. Comparison of OECD vs. Non-OECD Countries

The effectiveness of climate change mitigation policies on CO_2 emission as well as relationship between economic growth and inequality can probably differ between developed and developing countries. Thus, we split the entire sample into OECD and non-OECD countries.

Analysis of the effect of inequality on economic growth follows the same approach as Section 4.1. Panel random effect model was applied to estimate the parameters of economic growth model for OECD countries, and panel fixed effect model was employed to estimate the economic growth model for non-OECD countries based on the Hausman test. The estimation results of the economic growth model for OECD countries demonstrate no significant impact of inequality (natural log of GINI) on economic growth (natural log of per capita GDP). However, other explanatory variables, such as population growth, capital per worker, FDI, and corruption variables are significant in explaining economic growth (Table 6). By contrast, the estimation result for non-OECD countries demonstrates an existing inverted U-shaped relationship between inequality and economic growth. All other independent variables are statistically significant (Table 6).

[Table 6] Estimation results for economic growth models (OECD vs. Non-OECD countries)

Type of country	OECD	Non-OECD
Model type	Random Effect	Fixed Effect
POPG	0.160***	0.457***
	(0.051)	(0.075)
KPW	1.043***	0.799***
	(0.056)	(0.117)
FDI	0.731**	6.432***
	(0.299)	(1.336)
CPI†	0.096**	0.011*
	(0.041)	(0.006)
LnGINI	0.640	29.541***
	(0.394)	(3.455)
$LnGINI^2$		-4.391***
		(0.511)
Constant	27.552***	-21.347***
	(1.467)	(6.010)
Within R^2	0.7249	0.6206
Hausman test††	3.62	35.5***

Notes: All values are converted to three-year average. Ln stands for natural logarithmic form. Parentheses are standard errors. Number of observation is 198 for OECD and 229 for non-OECD countries. † CPI was utilized to estimate GDP model for non-OECD countries. †† X^2 statistics is employed for Hausman test. * means significant within 10%. ** means significant within 5%. *** means significant within 1%.

Next, using the same approach as Section 4.2, CO_2 emission models are estimated for both OECD and non-OECD countries as presented in Tables 7 and 8. Economic growth increases CO_2 emission for both OECD and non-OECD countries. Thus, the EKC relationship does not exist for both groups. The estimation results of the CO_2 emission model for OECD countries demonstrate that industry share (IND_GDP), population density (POPD), fossil fuel consumption share of electricity production (FFEC), and inequality index (GINI) are significant determinants of CO_2 emission. Openness to trade (OPEN), energy intensity (EI), and fossil fuel consumption share of electricity production (FFEC) are significant as explanatory variables for non-OECD countries. Population density is not significant for certain CO_2 models, where the CTAX and FIT policies are used as climate change mitigation policies for non-OECD countries.

[Table 7] Estimation results for CO_2 emission models with various climate change mitigation policies (OECD countries)

	ETS	CTAX	RPS	RFS	FIT
EGDP[††]	0.084***	0.072***	0.077***	0.081***	0.090***
	(0.021)	(0.021)	(0.021)	(0.019)	(0.020)
IND_GDP	0.017***	0.016***	0.016***	0.017***	0.017***
	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)
OPEN	-0.015	0.002	0.011	-0.008	-0.011
	(0.023)	(0.022)	(0.022)	(0.021)	(0.021)
EI	0.038	0.040	0.041	0.008	0.035
	(0.047)	(0.045)	(0.045)	(0.046)	(0.046)
POPD	-0.363***	-0.399***	-0.384***	-0.292***	-0.370***
	(0.076)	(0.075)	(0.074)	(0.077)	(0.076)
FFEC	2.165***	2.189***	2.057***	2.077***	2.171***
	(0.123)	(0.111)	(0.113)	(0.111)	(0.119)
CMP_K	-0.010	-0.969**	-0.115	0.544	0.243
	(0.164)	(0.488)	(0.161)	(0.388)	(0.199)
CMP_K[†]_ LnGINI	0.005	0.293**	0.025	-0.169	-0.071
	(0.048)	(0.140)	(0.046)	(0.113)	(0.058)
LnGINI	0.300***	0.162	0.239***	0.323***	0.309***
	(0.078)	(0.102)	(0.075)	(0.072)	(0.074)
Constant	-9.664***	-8.780***	-8.645***	-9.396***	-9.801***
	(1.066)	(1.018)	(1.055)	(0.928)	(0.981)
Within R^2	0.8304	0.8370	0.8405	0.8430	0.8310
Hausman test	75.92***	72.36***	65.71***	70.99***	75.65***

Notes: Number of observation is 189. All values are converted to three-year average. Ln stands for natural logarithmic form. [†] suggests that K includes climate mitigation policies, such as emission trading system (ETS), carbon tax (CTAX), renewable portfolio standard (RPS), renewable fuel standard (RFS), and feed-in tariff (FIT). Parentheses are standard errors. [††] means that EGDP is the predicted value of per capita GDP estimated from the GDP model for OECD countries in Table 6. [†††] means that X^2 statistics are used for Hausman test. * means significant within 10%. ** means significant within 5%. *** means significant within 1%.

[Table 8] Estimation results for CO_2 emission models with various climate change mitigation policies (Non-OECD countries)

	ETS	CTAX	RPS	RFS	FIT
EGDP††	0.100***	0.095***	0.099***	0.096***	0.101***
	(0.023)	(0.023)	(0.023)	(0.024)	(0.023)
IND_GDP	-0.000	0.000	-0.001	0.000	-0.000
	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)
OPEN	0.161***	0.160***	0.164***	0.153***	0.156***
	(0.023)	(0.022)	(0.023)	(0.022)	(0.022)
EI	0.414***	0.410***	0.416***	0.388***	0.405***
	(0.048)	(0.047)	(0.048)	(0.050)	(0.048)
POPD	0.231*	0.188	0.218*	0.315**	0.179
	(0.127)	(0.123)	(0.128)	(0.136)	(0.125)
FFEC	0.619***	0.637***	0.620***	0.601***	0.650***
	(0.084)	(0.080)	(0.086)	(0.086)	(0.081)
CMP_K	-2.519	0.117**	-1.873	-0.407	-0.730**
	(5.819)	(0.049)	(1.266)	(0.329)	(0.316)
CMP_K†_ LnGINI	0.623	(dropped)	0.463	0.094	0.186**
	(1.460)		(0.309)	(0.084)	(0.081)
LnGINI	0.382***	0.384***	0.391***	0.363***	0.385***
	(0.072)	(0.071)	(0.072)	(0.072)	(0.072)
Constant	-8.406***	-8.210***	-8.365***	-8.418***	-8.348***
	(1.045)	(1.031)	(1.041)	(1.049)	(1.031)
Within R^2	0.8018	0.8072	0.8036	0.8072	0.807
Hausman test	28.93***	27.54***	34.02***	36.13***	27.79***

Notes: Number of observation is 163. All values are converted to three-year average. Ln stands for natural logarithmic form. † suggests that K includes climate mitigation policies, such as emission trading system (ETS), carbon tax (CTAX), renewable portfolio standard (RPS), renewable fuel standard (RFS), and feed-in tariff (FIT). Parentheses are standard errors. †† means that EGDP is the predicted value of per capita GDP estimated from the GDP model for Non-OECD countries in Table 6. ††† means that X^2 statistics are used for Hausman test. * means significant within 10%. ** means significant within 5%. *** means significant within 1%.

With regard to the effectiveness of climate change mitigation policies, only CTAX is a significant policy in reducing CO_2 emission for OECD countries, whereas FIT is a unique policy that can significantly mitigate CO_2 emission for non-OECD countries. In the developed world, most countries have adopted the ETS policy compared with CTAX (37 vs. 16). However, whether the ETS policy has been effective in reducing CO_2 emission is doubtful because the cap of emission permits has been criticized as favorable to domestic industry in most countries that have implemented the ETS policy. By contrast, imposition of CTAX on CO_2 emission is directly associated with mitigation of CO_2 emission, even if the CTAX policy is not as popular as the ETS policy.

Developing countries prefer FIT to other policies in raising renewable energy share of energy production, which is supposed to reduce CO_2 emission in the developing countries (see further details in the Appendix Table A1). The other climate change mitigation policies, such as ETS, CTAX, RPS, and RFS are not dominant in the developing world.

Finally, total marginal effects of inequality on CO_2 emission are derived for OECD and non-OECD countries, following the same process presented in Table 4 (see Table 9). As indirect and direct marginal effects of GINI on CO_2 emission were insignificant for OECD countries, only interaction between GINI and CTAX policy was accounted in deriving total marginal effect. Direct, indirect, and interaction effects of GINI with FIT policy were significant for non-OECD countries. All of the marginal effects were considered in calculating total marginal effect. For both OECD and non-OECD countries, high (low) inequality causes high (low) emission. However, the relative impact of inequality on emission is considerably larger for the developing world than for the developed world. Notably, we achieve outcomes opposite to that of the whole sample; indirect effects were significant for the whole sample but insignificant when the sample was segregated.

Table 10 presents the total marginal effects of climate change mitigation policies on CO_2 emission for OECD and non-OECD countries. The interaction effect between climate change mitigation policies and GINI was significant for CTAX in OECD countries, and for FIT in non-OECD countries, similar to Table 9.

[Table 9] Marginal effects of income inequality on CO_2 emission

Marginal effects of GINI	CTAX for OECD	FIT for non-OECD
Impact of GINI on GDP	-	20.7590
Impact of GDP on CO_2 emission	-	0.1010
Indirect effect of GINI on CO_2 emission	-	2.0967
Interaction of GINI and policies	0.0708	0.0242
Direct effect of GINI on CO_2 emission	-	0.3850
Total marginal effect of GINI on CO_2 emission	0.0708	2.5058

Note: Insignificant marginal effects are not accounted for deriving marginal effects. The other climate mitigation policies, such as ETS, RPS, and RFS are excluded in calculating the marginal effects as indirect and interaction effects were insignificant.

[Table 10] Marginal effects of climate change mitigation policies on CO_2 emission

Marginal effects	CTAX for OECD	FIT for non-OECD
Direct effect of policy on CO_2	-0.9690	-0.7300
Interaction of GINI and policy	1.0258	0.6899
Total marginal effect	0.0568	-0.0401

Note: Insignificant marginal effects are not accounted for deriving marginal effects. The other climate mitigation policies, such as ETS, RPS, and RFS are excluded in calculating the marginal effects as indirect and interaction effects were insignificant.

Although CTAX for OECD and FIT for non-OECD countries are effective in mitigating the emission, total marginal effect of the policy on the emission was largely reduced due to the interaction effect between the climate change mitigation policies with GINI.

V. Conclusion

This study empirically examines the various pathways in which income inequality can affect CO_2 emission. We divided the total marginal effect of income inequality on CO_2 emission into direct, indirect, and interaction effects. Boyce (1994) and Scruggs (1998) gave conflicting arguments regarding the direct effect. Thus, the direction of the direct effect cannot be predetermined. The indirect effect of inequality through its impact on economic growth on CO_2 emission is also indeterminate because it depends on the relationship between economic growth and CO_2 emission. The 2SLS approach was implemented to measure the indirect effect of inequality on CO_2 emission. The interaction effect of income inequality with climate change mitigation policies was based on Harring's argument (2013) that people's perception of the effectiveness of incentive-based environmental policies may be affected by the fairness of income distribution and the proposal of Marsiliani and Renstrom (2002) that high-income inequality lead to low environmental taxes. Total marginal effects of income inequality on CO_2 emission for different climate change mitigation policies were derived for the whole sample and for OECD and non-OECD countries as well. Similarly, total marginal effects of various climate change mitigation policies on CO_2 emission were derived for the whole sample and for OECD and non-OECD countries.

This study contributes to the literature in terms of integrating the multiple relationships among income inequality, economic development, and CO_2 emission over various climate change mitigation policies. The panel fixed effect method employed for over 110 countries in the period between 2000 and 2010 demonstrated the following results. First, we found an inverted U-shaped relationship between inequity and economic growth, meaning that income inequality positively affects economic growth at the initial stage but negatively after an income turning point. Second, inequality directly increases CO_2 emission, whereas the indirect effect of inequality on CO_2 emission, through its impact on per capita GDP, is negative. Third, we found significant, positive interaction effects between income inequality and certain climate change mitigation policies, such as ETS and RPS. Thus, the positive interaction effects of these climate change mitigation policies overwhelm negative direct effects of GINI on CO_2 emission. The interaction effects were also positive but statistically insignificant for the other climate change mitigation policies, such as CTAX, RFS, and FIT. Consequently, the total marginal effects aggregating the direct, indirect, and interaction effects of inequality on CO_2 emission were found to have negative directions for the whole sample. However, the total effects for OECD or non-OECD countries were estimated as negative, which means that high inequality increases CO_2 emission for both OECD and non-OECD countries. Thus, we cannot derive a consistent outcome on the relationship between inequality and CO_2 emission.

By contrast, when the interaction effects were accounted for when estimating the impacts of the climate policies on CO_2 emission, we found that climate policies did not substantially mitigate CO_2 emission on the whole. In particular, the CTAX policy was positively related to CO_2 emission when the policy interacts with income inequality for OECD countries, whereas the FIT policy reduced CO_2 emission even if the interaction effect with inequality was considered for non-OECD countries.

The outcomes of this study shed light on the income redistribution policies of a country, indicating that further allocation of public funds to income redistribution programs directly mitigate CO_2 emission but indirectly increase CO_2 emission through its impact on economic growth. Thus, the bureaucrat responsible for income redistribution policies should cooperate with those engaged in climate change mitigation programs to minimize unexpected side effects arising from the interaction of inequality and CO_2 emission. Moreover, countries with severe inequality are recommended to control CO_2 emission by using command and control policies rather than economic incentive programs because citizens who have experienced severe income inequality are inclined to suspect the effectiveness of economic incentive-based environmental policies. Therefore, improving unequal income distribution is important when economic incentive policies are implemented for the mitigation of CO_2 emission.

Although this study attempted to use the most reliable data, we admit that data on climate change mitigation policies used in this study cannot reflect the effectiveness of those policies. More fundamentally, performance information should have been used in evaluating the effectiveness of climate change mitigation policies. Even if certain climate change mitigation policies are introduced in a country, they may not be implemented for reasons, such as economic recession or political instability.

[Table A1] List of countries that implemented climate change mitigation policies from 2000 to 2010

ETS[1)]	Austria, Belgium, Brazil, Canada, Croatia, Cyprus, Czech Republic, Denmark, Ecuador, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Japan, Latvia, Lithuania, Luxembourg, Madagascar, Malta, Netherlands, New Zealand, Norway, Poland, Portugal, Romania, Slovak Republic, Slovenia, Spain, Sweden, United Kingdom, United States
Carbon Tax[2)]	Australia, Costa Rica, Denmark, Finland, France, Germany, India, Ireland, Japan, Netherlands, New Zealand, Norway, South Africa, Sweden, Switzerland, United Kingdom
RPS/RO[3)]	Belgium, Brazil, Chile, China, Greece, Hungary, India, Israel, Italy, Japan, Republic of Korea, Madagascar, Netherlands, Norway, Poland, Portugal, Slovak Republic, South Africa, Sweden, Turkey, United Kingdom, Romania, Russia, Slovak Republic, South Africa, Sweden, Turkey, United Kingdom
RFS[4)]	Argentina, Australia, Austria, Brazil, Canada, Columbia, Costa Rica, France, Germany, Hungary, India, Netherlands, Norway, Paraguay, Peru, Philippines, Romania, Spain, Thailand, United Kingdom, United States
FIT[5)]	Algeria, Argentina, Australia, Belarus, Belgium, Bosnia and Herzegovina, Bulgaria, Canada, China, Chinese Taipei, Columbia, Columbia, Croatia, Cyprus, Czech Republic, Denmark, Ecuador, Estonia, Finland, France, Germany, Greece, Hungary, India, Indonesia, Iran, Ireland, Israel, Italy, Japan, Jordan, Kenya, Republic of Korea, Latvia, Lithuania, Luxembourg, Malaysia, Maldives, Malta, Mauritius, Mongolia, Montenegro, Netherlands, Peru, Philippines, Portugal, Russia, Serbia, Slovak Republic, Slovenia, South Africa, Spain, Switzerland, Thailand, Tunisia, Turkey, Ukraine, United Kingdom, United Republic of Tanzania, Uruguay

Sources: 1) European Commission. “Emissions Trading System (EU-ETS)” from (http://ec.europa.eu/clima/policies/ets/).

2) Carbon Share Homepage http://www.carbonshare.org/californiaAB32.html.

3) REN21. 2012. “RENEWABLES 2012 GLOBAL STATUS REPORT’;”

4) EPA. 2013. “EPA Issues Final Rule for Additional Qualifying Renewable Fuel Pathways under the RFS Program;” and 5) Transatlantic Climate Policy Group. 2009. “Feed-in Tariffs in America: Driving the Economy with Renewable Energy Policy that Works.”

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