The impact of economic growth and energy consumption on carbon emissions: evidence from panel quantile regression

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Abstract. This study investigates the impact of economic growth and energy consumption on carbon emissions in ten top selected countries contributing to the total carbon emissions in the world with an aim to test the validity of the Environmental Kuznets Curve (EKC) hypothesis, including five developing countries (China, India, Brazil, Mexico and South Africa) and four developed countries (European Union, the United States of America, Canada and Japan). This paper adopts a panel quantile regression model that takes unobserved individual heterogeneity and distributional heterogeneity into consideration. Moreover, to avoid an omitted variable bias, certain related control variables are included in our model. Our empirical results show that the effect of the independent variables on carbon emissions is heterogeneous across quantiles. Energy consumption increases the carbon dioxide emissions, with the strongest effects occurring at different quantiles for sample groups data. But the effects of energy consumption on carbon emissions for developed countries are greater than developing countries. In view of the economic development, developing countries and developed countries present the obvious stage characteristics. The empirical findings are in support of inverted U-shaped curve of the in the selected countries.

1. Introduction

In recent years, the issue of atmospheric pollution caused by the excessive carbon emissions has gradually received extensive attention of the international community. It is a global environmental pollution problem involved in social production, life, and many other dimensions. Therefore, not only will it affect development of the economy in the future, but also the choice of the current economic development path. In addition, it will affect distribution of patterns of economic interests and the policy choice of countries around the world. In the view of the world economic development, all countries present the obvious stage characteristics. Some main developed countries and region have finished the industrialization development of high energy consumption and high carbon dioxide emission. Such as the United States of America, Canada, Japan and European Union. In addition, industry structure of developed countries is mainly composed of the tertiary industry which has low energy consumption and low carbon dioxide emissions. However, developing countries are still standing at the process of industrialization. And their economic development pattern is given priority to the secondary industry which is high in energy consumption with high carbon dioxide emissions. Who should take the primary responsibilities for such carbon emissions, those products and services producing countries or those consuming countries?
The developing countries will naturally speed up environmental degradation due to their large amount of carbon dioxide emission. These issues have led to extensive and heated debates all over the world. Developed countries have reached the high level of economic development. However, carbon dioxide emissions need to spend 50 to 200 years to metabolize, so the developed countries are still responsible for their developmental bads leftovers.

With rapid growth of the economy, the industrial structure has changed. Continuous and rapid economic growth generates a series of benefits such as increased income, social stability and increased employment. Yet, emerged with rapid economic growth are woefully some negative phenomena, including excessive energy wastes and environmental degradation. When the agricultural sector switches from an extensive undertaking to an energy intensive farming, it makes use of many modern energy sources which can generate high-polluting carbon. Oil has accounted for a serious amount of the total energy consumption in agricultural sector for a long time in the recent history. Meanwhile, the developed countries have finished the industrialization period already and are coming into the times of knowledge economy. The carbon dioxide emissions show a downward trend, but they should not ignore the historical responsibility of the high carbon dioxide emissions during their industrialized period. Developed countries should work together with developing countries to control carbon dioxide emissions. Economic growth often shows the rapid increase of energy consumption and the large amount of carbon dioxide emissions. At present, the growth pattern with characteristically high energy consumption and carbon dioxide emissions still sustains the economic growth of developing countries as well as some developed countries. Therefore, the world as a whole is facing the great pressure to control the increase of carbon dioxide emissions. In macroeconomic view, the increase of energy consumption greatly impacts energy price and its fluctuations in the world market. It is quite imperative to solve the current issue of high energy consumption and carbon dioxide emissions to maintain the economic growth.

Energy is the prerequisite to guarantee the economic development. No matter what the stage of economic development and the level of society’s development are, energy consumption cannot be separated. The study of the relationship between energy and economic growth began in the early 1970s. Energy is the basis and the guarantor of economic growth, which provides impetus for the development of the national economy. The degree of industrial structure evolution determines the primary energy demand under economic growth. For developing countries, the rapid economic development requires a lot of energy resources because of the backward technology and being kept in the process of industrialization.

This study investigates the impact of economic growth (GDP), energy consumption, financial development, trade openness, and the lag variable of carbon emissions in developed countries (European Union, the United States, Canada, and Japan) and developing countries (China, India, Brazil, Mexico and South Africa). It is to find out the evidence to support an inverted U-shaped curve for the developing countries and developed countries. Finally, the researcher compares the data with the different economic growth level, the different carbon emissions of developing and developed countries. This paper makes three contributions: Firstly, this study provided more detailed description on the relationship of economic growth, energy consumption, other control variable and carbon emissions. We employ panel quantile regression to research the determinants of carbon dioxide emissions in the developing countries and developed countries. Especially we can observe that how the factors impact carbon dioxide emissions by panel data model. Secondly, the analytical approach of this study allows us to ascertain the validity of the EKC hypothesis Because of this method we find the relationship of income and carbon dioxide emissions to provide useful information to policymakers. Finally, our study included related variable as control variable to resolve omitted variable bias problems.

2. Literature review

There are two main research groups studying the environment–energy–growth nexus in the environmental economics literature. Firstly, according to the meaning work of Grossman and Krueger
(1995) [1]. Scholars focus on examining the relationship between economic growth and environmental pollution under the validity of the Environmental Kuznets Curve (EKC) hypothesis (Nasir M and Rehman, 2017 [2] and Gawande (2000) [3]). Although the Environmental Kuznets Curve (EKC) hypothesis illustrates an inverted U–shaped relationship between economic growth and CO₂ emissions, there is some evidence that the EKC hypothesis is a linear relationship (Khalid and Muhammad, 2013) [4]. Another evidence of EKC hypothesis on N–shaped relationship was shown by He and Richard (2010) [5]. However, some evidences suggest different configurations. Such as Zhu et al. (2012) [6] found little evidence in support of an inverted U– shaped curve in 5–ASEAN countries and Honma S 2014 [7]. In addition, recent studies appear to present mixed empirical results on the validity of the EKC. For example, Acaravci and Ozturk’s (2010) [8], on the causal relationship between carbon dioxide emissions, energy consumption, and economic growth by using autoregressive distributed lag (ARDL) bounds testing approach of cointegration for nineteen European countries, found a positive long–run elasticity estimate of emissions with respect to energy consumption at 1% significant level in Denmark, Germany, Greece, Italy, and Portugal. Positive long–run elasticity estimates of carbon emissions with respect to real GDP and the negative long–run elasticity estimates of carbon emissions with respect to the square of per capita real GDP at 1% significance level in Denmark and 5% significant level in Italy were also found. These results supported the validity of environmental Kuznets curve (EKC) hypothesis in Denmark and Italy. This study also explored causal relationship between the variables by using error–correction based Granger causality models.

Secondly, studies focus on energy consumption–carbon emissions nexus. Ang (2007) [9, 10] examined the dynamic causal relationships between pollutant emissions, energy consumption, and output for France using cointegration and vector error–correction modelling techniques. He argued that these variables were strongly inter–related and therefore their relationship must be examined using an integrated framework. The results provided the evidence for the existence of a fairly robust long–run relationship between these variables for the period 1960–2000. The causality results supported the argument that economic growth exerted a causal influence on growth of energy use and growth of pollution in the long run. The results also pointed to a unidirectional causality running from growth of energy use to output growth in the short run. Alam et al. (2016) [11] showed that CO₂ emissions have increased statistically significantly with increases in income and energy consumption in all four countries (Brazil, China, India and Indonesia). Methodology and data, Nasreen and Anwar (2000) [12] observed the impact of economic growth and trade openness for 15 Asian countries over the period 1980 and 2011 on energy consumption that was found to be positive. The panel Granger causality analysis revealed the bidirectional causality between economic growth and energy consumption, trade openness and energy consumption. Others including Antonakakis et.al, 2017) [13] and Joo et.al (2016) [14]

3. Methodology and Data

3.1. Methodology

The EKC hypothesis is basically used to examine the relationships between economic growth and environmental pollution. Following Saboori et al. (2013) [15], the general form of the EKC hypothesis can be formulated as:

$$ E = f(Y, Y^2, Z) $$

where E is a level of pollution measured as per capita carbon emission, Y is the income measured as real GDP per capita constant USD, and Z are other variables which affect the emissions. The quadratic form of income ($Y^2$) will allow the model to capture the inverted U–shape relationship between emissions and income.

In this paper, we will use a fixed effect panel quantile regression model to investigate the impact of economic growth, trade openness, and energy consumption on carbon emissions. By using a panel quantile regression methodology, we can examine the determinants of carbon emissions throughout the conditional distribution, especially in the countries with the most and least emissions. However,
traditional regression techniques focus on the mean effects, which may lead to under– or over–
estimating the relevant coefficient or even failing to detect important relationships.

The quantile regression technique was introduced in the seminal paper by Koenker and Bassett (1978) [16]. This method is a generalization of median regression analysis to other quantiles. The conditional quantile of $y_i$ given $x_i$ is as follows

$$Q_{y_i} = (\tau| \chi_i) = \chi_i^T \beta$$  \hspace{1cm} (2)

We study the effect of economic growth, trade openness, energy consumption, industrial structure, and financial development on carbon emissions by modifying the specifications of previous studies. But the variable of industrial structure, financial development and trade openness is control variable. We specify the conditional quantiles function for quantile $\tau$ as follows

$$Q_{y_i}(\tau| \alpha_i, \xi_t, \chi_i) = \alpha_i + \xi_t + \beta_1 \text{ENC}_{it} + \beta_2 \text{GDP}_{it} + \beta_3 \text{TO}_{it} + \beta_4 \text{GDP}_{it}^2 + \beta_5 \text{CO}_{2t-1} + \beta_6 \text{FIN}_{it}$$ \hspace{1cm} (3)

where the countries are indexed by $i$ and time by $t$. $y_{it}$ is the emissions indicator.

3.2. Data

The purpose of this paper is to investigate the impact of energy consumption, economic growth, financial development and trade openness on carbon emissions by using data from developing countries (China, India, Brazil, Mexico and South Africa) and developed countries (European Union, the United States of America, Canada, and Japan).

The dependent variable is carbon dioxide emissions in terms of metric tons per capita. As previously indicated, carbon emission is regarded as initial greenhouse gas responsible for global warming. The main independent variables are economic growth and energy consumption. Economic growth is expressed by real GDP per capita in constant USD at 2010 prices. Energy consumption is expressed in terms of kg of oil equivalents per capita. Because the economic growth and energy consumption relation with carbon emissions can be affected by other factors, it is appropriate to adopt a multivariate approach to avoid omitted–variable bias. According to precious literature, we choose trade openness and financial development as control variable. Trade openness is measured by the share of trade openness in GDP. Financial development is the total value of domestic credit to the private sector (% of GDP). The data covers the period of 1981 – 2013 which are the World Development Indicators from World Bank. All variables are transformed into natural logarithms prior to estimation to help eliminate heteroscedasticity. Details about the data are provided in table 1.

| Variable | Definition | Source                        |
|----------|------------|-------------------------------|
| CO₂      | Carbon dioxide emissions (metric tons per capita) | World Development Indicators |
| EC       | Energy consumption (kg of oil equivalents per capita) | World Development Indicators |
| GDP      | Economic growth (real GDP per capita constant USD at 2005 prices) | World Development Indicators |
| TO       | Trade openness (% of GDP) | World Development Indicators |
| FIN      | Financial development, domestic credit to the private sector (% of GDP) | World Development Indicators |

4. Empirical findings

4.1. Panel root test results

Our results indicate that the null hypothesis of the existence of a unit root could be rejected for one of the variables at the selected level. However, the unit root null hypothesis for one of the variables at the first difference could almost be completely rejected at 1% level. Therefore, an empirical analysis that uses the first difference sequence is necessary.
4.2. Panel co-integration results
As the results of the panel unit root tests indicate that the variables contain a panel unit root at their first difference, we can proceed to examine whether there is a long–run relationship among these variables using the Johansen Fisher panel cointegration test proposed by Maddala and Wu (1999). In the Johansen–type panel cointegration test, results are known to depend heavily on the VAR system lag order. Our results from the use of one lag indicate that four cointegrating vectors exist.

4.3. Quantile regression
From the results, firstly, table 2 reports the impact of economic growth for the developing countries on carbon emissions is positive. There are some significant different percentiles in the conditional distribution of ΔCO₂. Initially, the coefficient of ΔGDP slightly decreases then turns to slightly increase, approaching the peak along the increasing path of carbon emissions from the 5th quantile to the 30th quantile. But the increasing level of carbon emission fluctuates the coefficient of ΔGDP from the 30th quantile to 95th quantile, and as GDP per capita increases 1% the level of carbon emissions increases by 0.266%–0.332%. Regarding ΔGDP², the coefficient of ΔGDP² is negative and we can observe that ΔGDP² is clearly heterogeneous. There are highly significant differences across different percentiles in the conditional distribution of ΔCO₂. Overall, GDP per capita reflects the level of income and social development. The group of developing countries exhibits an inverted U-shaped curve, meaning that the economic growth level initially increases and then decreases along with the increase of carbon emissions.

Table 2. Panel regression results for developing countries (1983–2013).

| VARIABLE | 0.1  | 0.2  | 0.3  | 0.4  | 0.5  | 0.6  | 0.7  | 0.8  | 0.9  |
|----------|------|------|------|------|------|------|------|------|------|
| ΔENC     | 0.903| 0.906| 0.848| 0.930| 0.876| 0.894| 0.875| 0.906| 0.873|
|          | ***  | ***  | ***  | ***  | ***  | ***  | ***  | ***  | ***  |
|          | (58.551)| (30.633)| (28.915)| (31.929)| (36.030)| (19.333)| (19.162)| (94.315)| (26.827)|
| AFIN     | -0.007| -0.006| -0.005| -0.009| 0.010| -0.005| -0.008| -0.012| -0.008|
|          | ***  | ***  | ***  | ***  | ***  | ***  | ***  | ***  | ***  |
|          | (-4.118)| (-1.915)| (-2.010)| (-3.916)| (-4.242)| (-1.604)| (-3.191)| (-19.86)| (-3.291)|
| ΔGDP     | 0.250| 0.270| 0.393| 0.266| 0.312***| 0.332| 0.317| 0.298| 0.313|
|          | ***  | ***  | ***  | ***  | ***  | ***  | ***  | ***  | ***  |
|          | (6.097)| (4.195)| (10.752)| (7.735)| (6.574)| (6.140)| (4.654)| (30.037)| (21.901)|
| ΔGDP²    | -1.232| -1.481| -2.334| -1.605| -1.735| -1.971| -1.847| -1.787| -1.584|
|          | ***  | ***  | ***  | ***  | ***  | ***  | ***  | ***  | ***  |
|          | (-3.156)| (-3.108)| (-7.529)| (-9.133)| (-4.342)| (-5.518)| (-4.095)| (-9.636)| (17.471)|
| ΔTO      | 0.023| 0.020| 0.019| 0.015| 0.025***| 0.016| 0.026| 0.018| 0.022|
|          | ***  | *    | ***  | ***  | ***  | ***  | ***  | ***  | ***  |
|          | (4.143)| (1.865)| (3.584)| (2.452)| (2.946)| (3.563)| (3.835)| (12.136)| (5.066)|
| ΔCO₂₉₋₁  | 0.075| 0.066| 0.076| 0.071| 0.072| 0.051| 0.069| 0.069| 0.080|
|          | ***  | ***  | ***  | ***  | ***  | ***  | ***  | ***  | ***  |
|          | (4.425)| (4.604)| (5.864)| (6.869)| (6.210)| (4.015)| (4.097)| (17.331)| (10.223)|

Note: 1) This table shows the results of the panel quantile regression model with different carbon emissions as dependent variables and economic growth, energy consumption and control variables as independent variables. 2) Figures in parentheses are t-values
*** Statistical significance at the 1% level. ** Statistical significance at the 5% level. * Statistical significance at the 10% level.
Table 3. Panel Regression Results for Developed Countries (1983–2013).

| VARIABLE | 0.1 | 0.2  | 0.3 | 0.4  | 0.5 | 0.6  | 0.7 | 0.8  | 0.9 |
|----------|-----|------|-----|------|-----|------|-----|------|-----|
| ΔENC     | 1.068* | 1.054* | 1.072  | 1.037  | 0.980  | 1.091  | 1.028  | 1.100  | 1.082  |
|          | *** | *** | ** | ** | ** | ** | ** | ** | ** |
|          | (20.835) | (53.471)  | (21.598)  | (31.820)  | (23.159)  | (39.917)  | (67.913)  | (24.186)  | (20.497)  |
| ΔFIN     | 0.009  | 0.0038 | 0.017  | 0.020  | 0.007  | 0.013  | 0.016  | 0.010  | 0.021  |
|          | *** | *** | ** | ** | ** | ** | ** | ** | ** |
|          | (10.192) | (14.158)  | (21.721)  | (18.019)  | (7.583)  | (32.690)  | (53.72)  | (132.356)  | (260.801)  |
| ΔGDP     | 0.276  | 0.171  | 0.227  | 0.249  | 0.344  | 0.201  | 0.367  | 0.276  | 0.277  |
|          | *** | *** | ** | ** | ** | ** | ** | ** | ** |
|          | (1.615) | (3.124)  | (21.288)  | (10.752)  | (43.541)  | (47.420)  | (117.867)  | (254.701)  | (615.083)  |
| ΔGDP²    | –0.594 | 0.797  | – | – | – | – | – | – | –1.248*** |
|          | 0.383* | 1.285** | 0.352* | 0.235** | 0.974*** | 0.987*** | – | – | – |
|          | (–0.280) | (0.735)  | (–1.806)  | (–2.736)  | (–2.756)  | (–2.091)  | (–10.671)  | (–56.498)  | (–111.459)  |
| ΔTO      | 0.276  | 0.171** | 0.227** | 0.249** | 0.344** | 0.201** | 0.367** | 0.276** | 0.277*** |
|          | * | * | * | * | * | * | * | * | * |
|          | (1.031) | (4.347)  | (7.989)  | (12.181)  | (–2.517)  | (17.241)  | (72.374)  | (199.945)  | (204.998)  |
| ΔCO₂t-1  | 0.020  | 0.018  | 0.021  | 0.019  | –0.005  | 0.016  | 0.023  | 0.017  | 0.013  |
|          | *** | *** | ** | ** | ** | ** | ** | ** | ** |
|          | (–1.656) | (–3.766)  | (–8.585)  | (10.435)  | (19.071)  | (–9.623)  | (–58.131)  | (160.412)  | (–342.501)  |

Note: 1) This table shows the results of the panel quantile regression model with different carbon emissions as dependent variables and economic growth, energy consumption and control variables as independent variables. 2) Figures in parentheses are t-values
*** Statistical significance at the 1% level. ** Statistical significance at the 5% level. * Statistical significance at the 10% level.

Table 4. Panel regression results for all countries (1983–2013).

| VARIABLE | 0.1  | 0.2 | 0.3  | 0.4 | 0.5  | 0.6 | 0.7 | 0.8 | 0.9  |
|----------|------|-----|------|-----|------|-----|-----|-----|------|
| ΔENC     | 0.906*** | 0.917** | 1.043** | 0.960** | 0.994*** | 1.026** | 1.026** | 1.005** | 1.090** |
|          | * | * | * | * | * | * | * | * | * |
|          | (13.341) | (17.307) | (42.388) | (45.024) | (40.177) | (37.279) | (55.091) | (79.780) | (82.667) |
| ΔFIN     | –0.0042* | –0.002 | –0.001 | –0.005 | 0.002* | 0.002 | –0.002* | – | 0.002 |
|          | * | * | * | * | * | * | * | * | * |
|          | (–1.920) | (–0.627) | (–1.407) | (–1.339) | (1.896) | (1.351) | (–1.77) | (–2.015) | (7.553) |
| ΔGDP     | 0.156*** | 0.298** | 0.100** | 0.210** | 0.066 | 0.065** | –0.012 | 0.059** | 0.104** |
|          | * | * | * | * | * | * | * | * | * |
|          | (2.829) | (4.185) | (2.745) | (3.456) | (1.494) | (2.064) | (–0.265) | (2.539) | (6.002) |
| ΔGDP²    | 3.196*** | 2.603** | 2.296** | 3.013** | 2.221*** | 2.717** | 2.970** | 3.324** | 2.487** |
|          | * | * | * | * | * | * | * | * | * |
|          | (–8.549) | (–6.793) | (–5.989) | (–5.553) | (–2.615) | (–5.854) | (–6.974) | (–14.131) | (22.225) |
| ΔTO      | 0.003 | 0.008 | –0.004 | 0.003 | –0.002 | –0.003 | 0.002 | –0.006 | 0.039 |
|          | * | * | * | * | * | * | * | * | * |
|          | (0.768) | (1.662) | (–0.904) | (1.453) | (–0.445) | (–1.15) | (0.396) | (–1.690) | (17.941) |
| ΔCO₂t-1  | 0.043*** | 0.0143 | –0.001 | 0.094** | 0.092*** | 0.087** | 0.045 | 0.088 | 0.095** |
|          | * | * | * | * | * | * | * | * | * |
|          | (2.486) | (0.585) | (–0.051) | (18.89) | (13.626) | (9.732) | (1.620) | (10.690) | (29.157) |

Note: 1) This table shows the results of the panel quantile regression model with different carbon emissions as dependent variables and economic growth, energy consumption and control variables as independent variables. 2) Figures in parentheses are t-values
*** Statistical significance at the 1% level. ** Statistical significance at the 5% level. * Statistical significance at the 10% level.
Overall, compared with previous researches, these results provide not only evidence that tests the validity of EKC hypothesis but also a more complete picture of economic growth and pollution emissions nexus. However, in terms of developed countries, table 3 illustrates panel quantile regression estimation for developed countries from 1983 to 2013. Regarding economic growth, there are all strongly significant across different percentiles in the conditional distribution of ΔCO₂. The coefficient of ΔGDP fluctuates from the 20th quantile to 90th quantile. As real GDP per capita increases by 1%, the level of carbon emissions increases by 0.171%–0.367%. At the 60th quantile, the coefficient of ΔGDP is the highest among all quantiles and the coefficient of ΔGDP fluctuates from 20th quantile to 90th quantile. This indicates that under the higher level of economic development can mitigate the increase of carbon emission for higher income countries. In terms of ΔGDP², the impact of ΔGDP² on carbon emissions is clearly heterogeneous. It is significant and negative from 30th to 90th quantiles. Therefore, the results support EKC hypothesis that the environmental degeneration rises at the first stage with increasing economic growth and then turns to decrease at the final stage after reaching a threshold level given the level of income. In addition, the developed countries have the coefficient values of ΔGDP greater than developing countries. One possible explanation of this phenomenon is that developing countries may not have achieved desired level of income at the development stage. Table 4 presents the coefficient of ΔGDP² is negative and significant at all quantile regression, implying that GDP per capita cannot support EKC hypothesis at different quantiles. Thus confirming the inverted U shape of EKC and implying that the high emissions countries may have achieved a desired level of income at the development stage in the third group. In a nutshell, EKC hypothesis contends that the level of environmental pollution first increases with income and then stabilizes and declines. Overall, our all results provide not only evidence that tests the validity of EKC hypothesis but also a more complete picture of economic growth and pollution emissions nexus.

The results illustrate the effects of energy consumption on carbon emissions to be greater in developed countries than in developing countries under the different quantiles. The results indicate that although the developed countries finish the industrialization period and come into the times of knowledge economy, their historical carbon emissions need to spend 50 to 200 years to metabolize. So the developed countries still have to be responsible together with developing countries.

5. Conclusions
The main purpose of this study is to explore the impact of economic growth and energy consumption on carbon emissions by using panel quantile regression to achieve the objectives. And the empirical observations are in support of the Environmental Kuznets Curve (EKC) theory in the selected three groups which included developed countries, developing countries and all countries.

Carbon dioxide emissions are mainly attributable to energy consumption, while economic growth is determined by the industrial structure. The level of carbon emissions of a country directly reflects its social and economic development and the development of low–carbon economy. The major developed countries have gone through the industrialization period, and now they are in the last industrialization period dominated by the third industry. The carbon emissions of the Tertiary Industries are low, and some industries even produce zero CO₂ emissions. It determines that CO₂ emissions in developed countries have passed through the peak period, and some developed countries such as EU, USA, and Canada have shown a downward trend in carbon emissions per capita. However, the developing countries are still in the process of industrialization. The mode of economic development in the Second Industries is a high CO₂ emission and a high energy consumption industry model. This mode determines the development of developing countries cannot reduce the high carbon emissions in the short term. Developing countries needs more carbon space to meet the development needs.

While energy consumption was promoting economic growth and leading to the carbon emission increase, energy already achieved its own upgrading and development. Economic growth requires large–scale energy exploitation and utilization, and the limited fossil energy is not enough to satisfy the needs of economic growth. Hence, in order to improve energy efficiency, promoting the development of new energy consumption structure is the focus of economic development in the future.
Economic growth is the development and application of new energy fund. Only renewable energy can be used instead of fossil energy for growth of economy of each country. Carbon dioxide emissions can be significantly reduced when the environmental pressure is really reduced, so each country can have the sustainable development of economy.

From the results of the study, the following policy implications must be pursued in order to improve environmental quality in the world. In views of energy consumption, energy development program needs to shift from fossil fuels, such as oil, to clean and renewable energy. Government should invest more on technology for promoting development of new energy resources and renewable energy sources. The findings suggest that countries with high CO\(_2\) emissions could benefit the most from the economic growth. Therefore, carbon emissions control measures should be tailored differently across the nations with both low and high CO\(_2\) emissions.

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