Anthropogenic Carbon Dioxide Emission in Asia: Effect of Population, Affluence and Energy Efficiency[1]

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Abstract

This study was conducted to determine the effects of population, affluence and energy efficiency (the ratio of real GDP to commercial energy use) on the level of Anthropogenic Carbon Dioxide Emissions in Asia from 1980 to 2004. It also sought to provide empirical evidence for the Environmental Kuznets Curve (EKC) hypothesis in Asia.

Results of the study showed that the level of anthropogenic carbon dioxide emissions increased by 265.20 percent from 1980 to 2004. CO_2 emissions rose with increases in population and GDP per capita, and decreased with increasing energy efficiency. Results showed that 97 percent of the variation in the level of anthropogenic carbon dioxide emission could be explained by changes in population, GDP per capita and energy efficiency. Results also confirmed the existence of EKC in Asia, A monotonically upward trend in emissions with increasing income level was observed.

Keywords: anthropogenic carbon dioxide emissions, energy efficiency, environmental Kuznets curve.

Introduction

Concern about the buildup of carbon dioxide (CO_2) in the atmosphere and its effects to climate change has given rise to a considerable interest in the long-range projections of global CO_2 emissions (Mckitrick and Strazicich, 2005). Greenhouse gas emissions for the last 30 years had risen 70 percent, despite the 1997 Kyoto Protocol, and is expected to double or triple by the end of the century. Carbon dioxide levels, which had stood at the safe baseline of 275 parts per million for 10,000 years, were today approaching 400 parts per million, This has caused global temperatures to increase by 0.6°C in the last

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few years, sea levels to rise several centimeters, dry areas to become even drier and wet areas to get still wetter (United Nations sixty-second general assembly, 2007).

The level of CO_2 in the atmosphere will lead as to a "scale problem", a threat posed by economic activities to global life support system, where the Earth can no longer able to sustain human population growth, resource consumption and pollution. Human economic activities are now threatening the natural system at both the local and global levels. If this life support system is damaged beyond repair, then human civilization as we know will collapse. As population increases, linear increase in the level of consumption and production is expected. This increase in human activities would essentially increase emission of carbon dioxide in the atmosphere. Delays in the cutting of emissions would lead to higher stabilization level and increase the risk of more severe climate change impact, as more of the current high emission technologies would have deployed. (www.solarnavigator.net).

Worldwide, the United States generated over 21% of the world's carbon dioxide emissions, followed by China (17%), Russia (6%), Japan (5%) and India (4%). The per capita generation was nearly 22 tons per person; China, Russia, Japan and India was responsible for 3.5, 11, 11, and 1 ton, respectively (Stegman, 2005). Carbon dioxide emissions grew substantially in developing Asia between 1980 and 2001, rising 151%, 4.5% per year from 2,398 MMT (million metric tons) to 6,027 MMT. The bulk of the region's carbon dioxide emissions come from its two populous giants, India and China. This rapid growth reflected the region's industrialization and rural electrification efforts. In 2001, these two countries accounted for two thirds of all of Asia's carbon dioxide emissions. Throughout the 1980s and 1990s, Asia derived more than 90% of the energy it consumed from fossil fuels. This dependence remained roughly constant despite the region's dramatic increase in total energy consumption, from 30 quads in 1980 to 85 quads in 2001. Electricity consumption in developing Asia grew tremendously between 1980 and 2001. During the period, total regional demand for electricity increased an average of 7.7% per year, rising from 577 bkwh to 2,730 bkwh (eia.doe.gov).

Rationale of the Problem

Asia is the world's largest and most populous continent. It covers 8.6% of the earth's total surface area (or 29.4% of its land area). With almost 4 billion people, it accounts for more than 60% of the world's current human population. Asia has the third largest nominal GDP of all continents after North America and Europe, but the largest when measured in purchasing power parity (PPP). As of 2007, China, India and Japan are considered the largest national economy within Asia. Economic growth in Asia since World War II to the 1990s had been concentrated in quite a few countries of the Pacific

Rim, the Philippines, Thailand, Malaysia, Singapore, Hong Kong, Taiwan, Japan, and S. Korea (Wikepedia.org).

During the past two decades, greenhouse gas emissions from Asian countries, have been increasing rapidly particularly due to CO_2, due mainly to industrialization and population growth. Four of the ten countries in the world with the highest CO_2 emissions from fossil-fuel use are located in Asia. China ranks second (2008), but may overtake the United States as the largest emitter by next year. India (fourth), Japan (fifth), and South Korea (seventh) also rank among the top eight emitters (eastwestcenter.org, 2008). The high concentration of greenhouse gases particularly carbon dioxide in the atmosphere is the main reason why the climate is changing too much too soon. Individual's daily activities such as heavy use of energy emit carbon dioxide leading to the rapid warming of the world. Climate change has manifested its impacts in the increasing global temperature, the rise of the sea level, the erratic weather patterns causing flooding, El Niño, La Niña and the vector-bourn diseases such as dengue and malaria, among others. A rise in sea level would result not only in the gradual submergence of the small island states such as the Maldives, but also create major problems for many of Asia's largest coastal cities, such as Jakarta, Bangkok, Manila and Shanghai. Ten of millions of people in Asia may have to be resettled, and massive expenditures incurred to protect the coastal cities from sea level rise, which under various scenarios developed for the Intergovernmental Panel on Climate Change, may range from about 20 centimeters to about 70 centimeters (about 8 inches to 2 feet) by the end of this century (eastwestcenter.org, 2008). The intergovernmental panel on climate change reported that the world has until about 2020 to reverse the trend of rising greenhouse gas emissions to avoid the worst effect of climate change.

Objectives of the Study

The general objective of the study is to present an over-all picture of anthropogenic carbon dioxide (CO_2) emissions of 43 Asian Countries and the effect of human activity to the level of carbon dioxide.

Specifically the study aimed:

1. To present the level of anthropogenic carbon dioxide emission in Asia;
2. To measure the effect of population, GDP per capita and energy efficiency to the level of anthropogenic CO_2 emissions of Asia; and
3. To verify the existence of Environmental Kuznets Curve (EKC) in Asia.

Scope and Limitations of the study

The study focused on the Anthropogenic Carbon Dioxide emission of the 43 Asian countries from 1980- 2004 specifically from solid fuel, liquid fuels, gas fuel, cement

manufacturing and gas flaring, other sources of carbon dioxide are not included in the study.

Data and Data Collection

All data used in the study were secondary time series data from 1980-2004. Total fossil fuels CO_2 emissions from five sources: solid (mainly coal) fuel consumption, liquid (mainly petroleum) fuel consumption, gas oil consumption, cement manufacturing and gas flaring were considered in this study. Data were taken from national data on fossil fuel CO_2 emissions from Marland et al (2004) CDIAC, Oak Ridge National Laboratory. The data relates to carbon dioxide emissions from the consumption of fossil fuels but is generally referred to as emissions throughout the paper[3]. Yearly population figures of 43 countries were based on the HNPStats – the World Bank's comprehensive database of Health, Nutrition and Population statistics. Classification of Asian countries by income level was based on the World Bank classification (Table 1). Affluence was captured by real GDP per capita in constant price (U.S Dollar) taken from the Economic Statistics branch of the United Nations Statistics Division (UNSD) national accounts main aggregates database. Energy efficiency (T) of economic activities was captured by the ratio of real GDP in US dollar to commercial energy use also obtained from UNSD.

Table 1. Classification of countries included in the study.

High income country (13)
Bahrain, Brunei, Cyprus, Israel, Kuwait, Macao, United Arab Emirates, South Korea, Japan, Singapore, Hong Kong, Qatar, Saudi Arabia,
Upper middle income country (4)
Malaysia, Oman, Lebanon, Turkey
Low middle income country (13)
Albania, Armenia, Bhutan, China, Egypt, Indonesia, Iran, Jordan, Maldives, Philippines, Syria, Sri Lanka, Thailand
Low income country (13)
Afghanistan, Bangladesh, Cambodia, India, North Korea, Laos, Mongolia, Myanmar, Nepal, Pakistan, Yemen, Sri Lanka, Vietnam

Source: World Bank. (2007). Data & Statistics: Country Groups.

[3] Carbon dioxide is considered the most important human influenced greenhouse gas for climate analysis and policy targeting because it accounts for around two-thirds of greenhouse gas radiative forcing (the enhancement of the greenhouse effect) and because it is relatively easy to monitor. Fossil fuel accounts for around three quarters of Anthropogenic CO_2 emissions (IPCC, 2001).

Statistical Analysis

To estimate the role of the regressor' on carbon dioxide emissions, the study followed the Dietz and Rosa's stochastic model (1997), which takes the form:

$$\ln I_{it} = \beta_o + \beta_1(\ln P_{it}) + \beta_2(\ln A_{it}) + \beta_3(\ln T_{it}) + e_{it} \qquad (1)$$

where, P stands for population size, and A for affluence, and T for technology, or specifically, the energy efficiency of economic activities. The subscript i denotes to country and t denotes to the year, and e is the error term. The dependent variable (I) is carbon dioxide emissions.

The above model imposes a linear relationship between affluence and emissions. Other studies however found an inverted U-shaped relationship between affluence and emissions, where emissions initially worsen but ultimately improve with income. To check for the existence of the "Environmental Kuznets Curve", the study used another specification with a polynomial term of affluence in the model:

$$\ln I_{it} = \beta_o + \beta_1(\ln P_{it}) + \beta_2(\ln A_{it}) + \beta_3(\ln A_{it})^2 + \beta_4(\ln T_{it}) + e_{it} \qquad (2)$$

With time series data, serial correlation is expected. To correct for autocorrelation, adjustment was made for autocorrelation using Maximum Likelihood Estimation (Greene 1993).

Estimation Methods

To estimate the coefficients for equations 1 and 2, Shazam version 9.0 was used. Descriptive results were presented through graphical presentation using Microsoft Excel.

RESULTS AND DISCUSSION

Anthropogenic CO_2 emissions in Asia

Carbon dioxide emissions in Asia as shown in Figure 1, showed increasing trend during the period 1980 to 2004 with slight dip in 1980's and 1998 due to economic recession (Engleman 1994). The emissions came from solid fuels, liquid fuels, gas fuels, cement manufacturing and gas flaring. CO_2 grew by 265.20% from 1980 to 2004. By income group, middle income (MI) countries accounted for more than half (59%) of the total anthropogenic carbon dioxide emissions in Asia. High income (HI) countries emitted about 26% of the total emissions and Low income countries (LI) accounted for nearly 15%. This pattern is consistent with the argument described by Kuznets that High income and

low income countries have clean environments and are less polluted while middle-income countries are the most polluted.

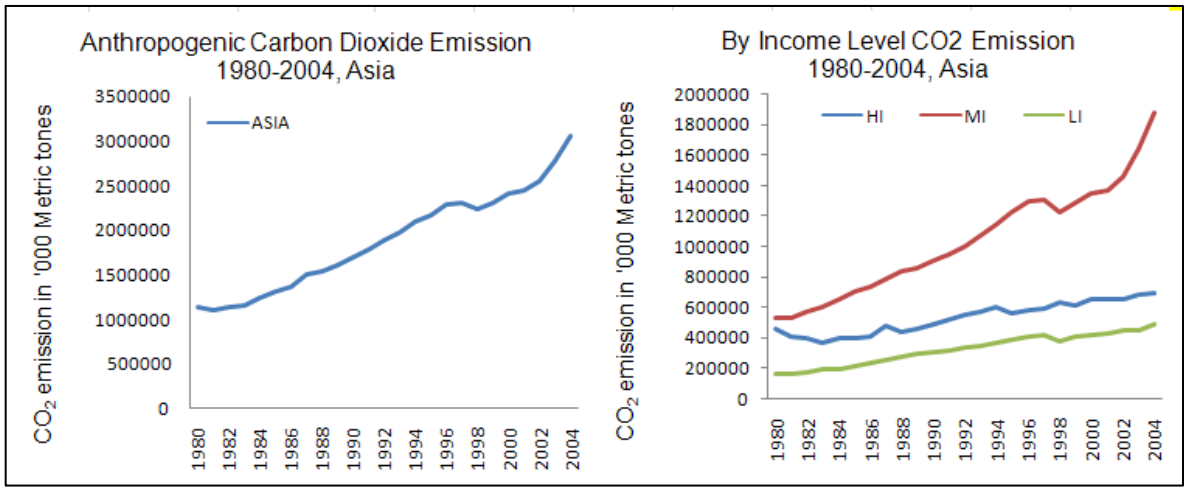

Figure 1. Anthropogenic Carbon Dioxide emission in Asia, 1980-2004.

Population Trend

Asia is the most populous continent in the world accounting for 62% of the total population. In 2004, Asia has recorded 3,969,662,321 people increasing by 31% from 1980 (Figure 2). By income groups, middle income (MI) countries accounted for 53.7 % of the total population in Asia and increasing by 1.4% annualy. Low income (LI) countries accounted for 38.1%, and 8% for high income (HI) countries.

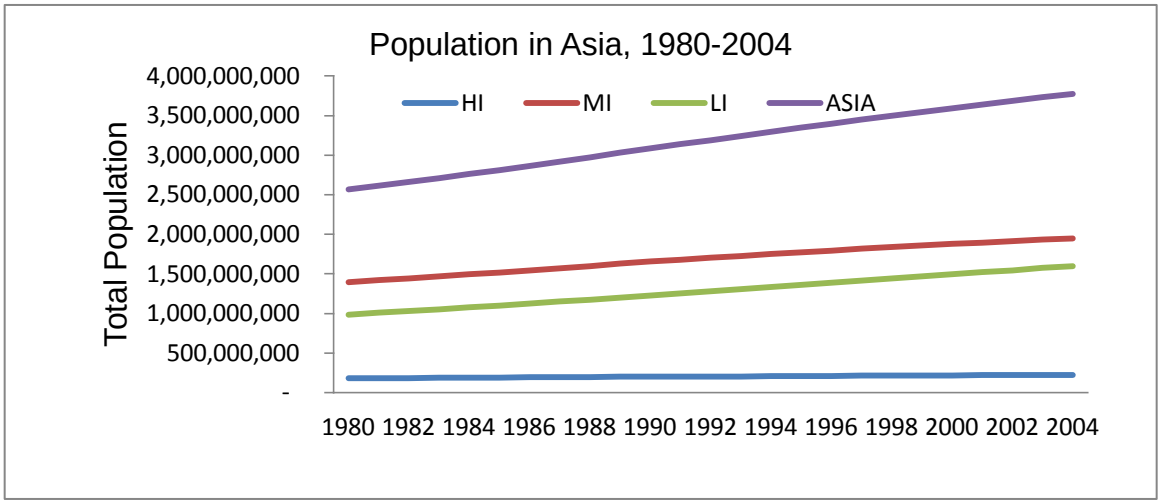

Figure 2. Total population in Asia, by income group, 1980-2004.

GDP per capita (Affluence)

The level of Gross domestic product per capita in 2004 shows that HI countries accounted for almost ¾ of the total income in Asia (Figure 3). It is followed by UMI with 22.67% and LI countries with 2.4%.

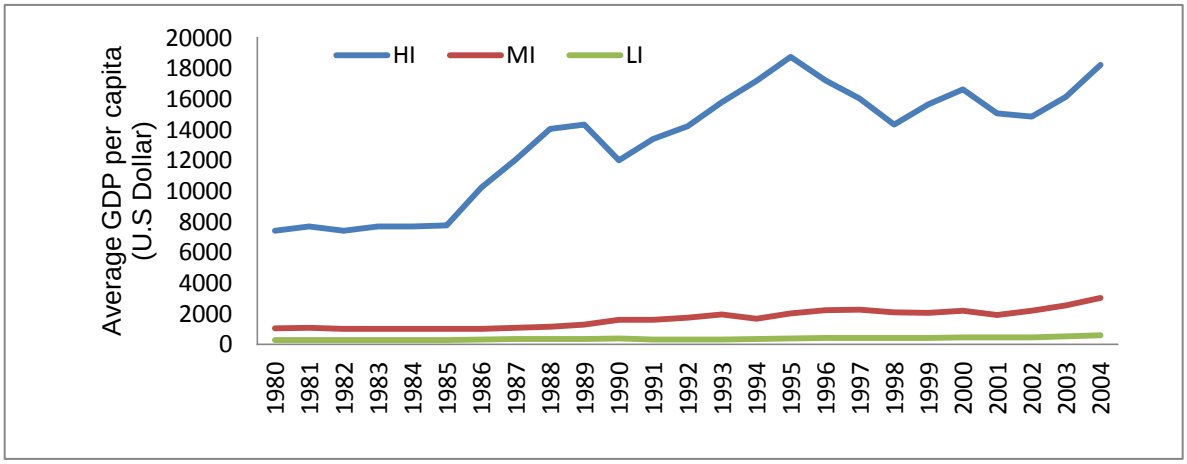

Figure 3. Average GDP per capita in Asia, by income level, 1980-2004

Energy Efficiency

Figure 4 shows the average energy efficiency in Asia and by income level. It showed that MI countries are higher efficient in commercial production compared to other income groups.

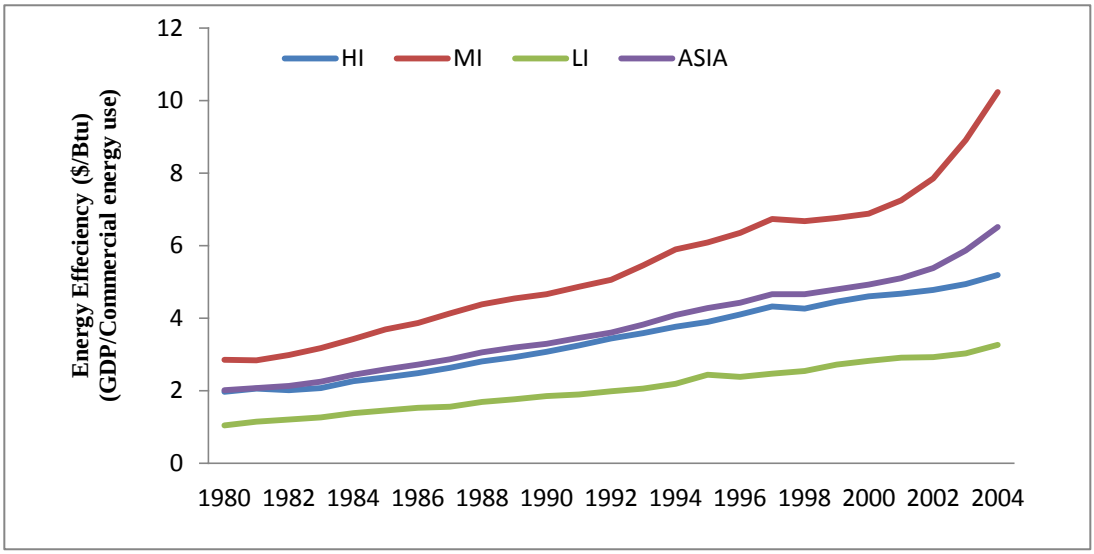

Figure 4. Average energy efficiency in Asia and by income level.

Energy efficiency score per country is presented in Table 2. Highest score means a higher energy efficiency in output processing. It showed that China is the leader for efficient production of goods with less energy intensity and consumption. India from low income classification with 31.044, followed by Japan, South Korea and Saudi Arabia.
In contrast, Cambodia has the lowest energy efficiency score 0.015, followed by Maldives, Seychelles, Afghanistan and Bhutan. This countries needs technological assistance in terms of decreasing commercial energy consumption and increasing their output.

Table 2. List of 10 Asian coutries with the highest and lowest energy efficiency score in 2004.

Country		High score*	Country		Low score*
1. China	-	119.837	1. Cambodia	-	0.015
2. India	-	31.044	2. Maldives	-	0.020
3. Japan	-	22.721	3. Seychelles	-	0.024
4. South Korea	-	17.958	4. Afghanistan	-	0.034
5. Saudi Arabia	-	12.415	5. Bhutan	-	0.041
6. Indonesia	-	10.243	6. Laos	-	0.053
7. Thailand	-	6.912	7. Macao	-	0.064
8. Iran	-	6.3936	8. Nepal	-	0.102
9. Malaysia	-	5.318	9. Albania	-	0.116
10. Egypt	-	5.173	10. Cyprus	-	0.117

* Scores were computed from total GDP and total commercial energy use.

Regression Results

Table 3 presents the estimates of the double log Model (see equation on page 7) as well as countries classification. It is a baseline model with total emission as the dependent variable. The independent variables are total population, GDP per capita and energy efficiency. Table 3 shows the result of the OLS estimation, corrected for autocorrelation. The result shows that population, affluence (GDP per capita), and energy efficiency significant on influenced to CO_2 emissions and consistent with existing theories. Population and affluence exhibited positive relationship with CO_2 emission. A % increase in population increases the level of anthropogenic carbon dioxide emission by 1.3%, while a % increase in affluence increases $C0_2$ emission by 0.68%. On the other hand, CO_2 emission decreases by 0.79% for a % increase in energy efficiency. Over 97% of the variability of carbon dioxide emissions can be explained by changes in total population, GDP per capita and energy efficiency.

Table 3. Effect of population, affluence, and energy efficiency in logarithms by income group, Asia, 1980-2004.

Variables	Asia Estimated Coefficients[b]	Country Classification: Low Income (LI)[b]	Middle Income (MI)	High Income (HI)
Intercept	-28.435*	-26.463*	-23.719*	-22.750*
	(1.583)	(0.666)	(0.460)	(0.700)
Population	1.324*	1.098*	1.108*	0.977*
	(0.037)	(0.023)	(0.010)	(0.014)
GDP per capita	0.685*	0.991*	1.140*	0.115*
	(0.070)	(0.049)	(0.028)	(0.047)
Energy efficiency	-0.795*	-0.947*	-0.581*	-0.747*
	(0.034)	(0.037)	(0.035)	(0.031)
$\overline{R}^2$	0.970	0.990	0.973	0.940
Number of countries	43	13	16	14

* significance at $p<0.05$ [ns] not significant at $p<0.05$

[b] Adjusted for autocorrelation using Maximum Likelihood Estimation

The same pattern was observed when countries were disaggregated by income level. The effect of population was slightly lower when compared with the aggregate. The effect of GDP per capita on CO_2 emissions, however, was slightly higher when compared to all countries. The effect of energy efficiency was mixed, it was lowwith low incomw countries and higher with MI and HI countries.

Result for the existence of the Environmental Kuznets Curve (EKC), corrected for autocorrelation is shown in Table 4. Results showed that GDP per capita has positive coefficient which suggests that CO_2emissions rise with GDP per capita by 3.7% for 1% change in per capita GDP and it eventually falls after a certain period of time. This confirmed the presence of the EKC as the quadratic term has negative coefficient. A monotonically upward trend in emissions with increasing income level was observed. Population exhibited a linear effect to CO_2; 1% change in population would increase CO_2 by 1.3 %. Energy efficiency showed a negative coefficient, as countries shift to high-tech,

less energy intensive and environmental friendly technologies emission will decline by 0.84 %.

Table 4. Estimation on the Environmental Kuznets Curve, in logarithms by income group, Asia, 1980-2004.

		Country Classification		
	Asia			
Variables	Estimated Coefficients[b]	low Income (LI)[b]	middle income (MI)[b]	high income (HI)[b]
Intercept	-39.426*	-3.821*	-0.280*	11.378*
	(1.925)	(4.177)	(2.566)	(7.797)
Population	1.307*	0.117*	0.204*	0.175*
	(0.035)	(0.050)	(0.034)	(0.070)
GDP per capita	3.707*	1.537*	0.529*	2.063*
	(0.321)	(0.362)	(0.191)	(0.597)
GDP per capita^2	-0.207*	-0.033*	-0.0005^{ns}	-0.042*
	(0.022)	(0.008)	(0.004)	(0.012)
Energy efficiency	-0.844*	0.951*	0.416*	0.806*
	(0.338)	(0.036)	(0.038)	(0.077)
$\overline{R}^2$	0.973	0.991	0.996	0.970
Number of countries	43	13	16	14

* significance at $p<0.05$ ^{ns} not significant at $p<0.05$

[b] Adjusted for autocorrelation using Maximum Likelihood Estimation.

The results of the EKC were not that good when sample countries within income groups. Result of the analysis is shown in Table 4. While the result showed the existence of EKC within the income groups. The result appeared to be nonsense, the sign of the energy efficiency was positive. The inverted U-shaped relationship of emission and GDP per capita generated in the study is shown in Figure 5. It shows that income growth is accompanied by growth in carbon dioxide emission at low income levels, but as income grows the demand for environmental protection also tends to increase, leading to a development path characterized by both economic growth and environmental quality improvement.

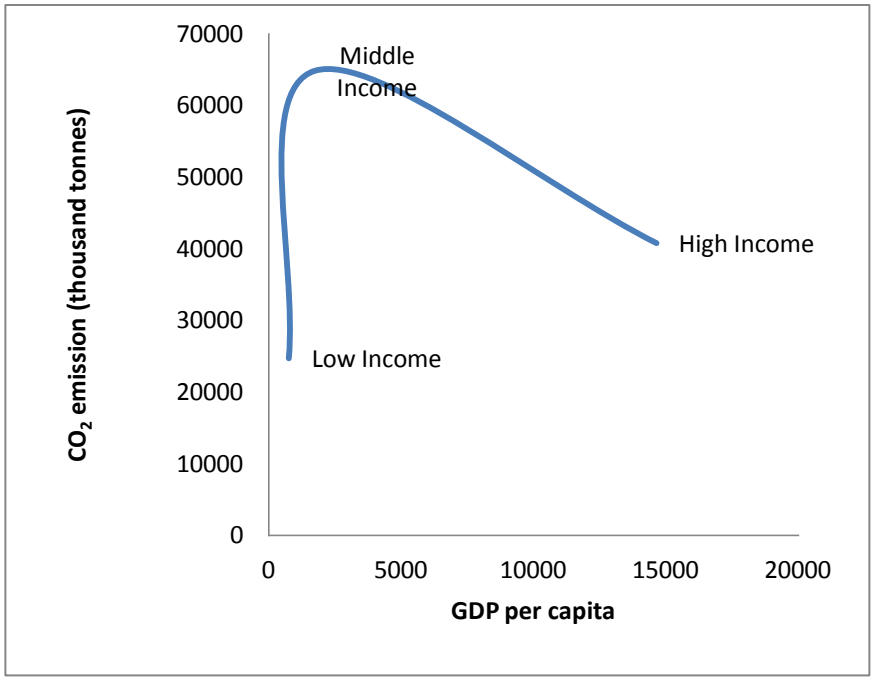

Figure 5. The Environmental Kuznets Curve, 1980-2004, Asia.

In the higher level of income, environmental quality becomes a luxury good. Increasing income enable interest groups to demand action from political actors, however, in low income countries it is crucial to say that environmental improvements may not happen automatically, even with economic growth. The improvement will be trigger with the legal and political institutions and functioning market.

CONCLUSION AND RECOMMENDATION

Conclusion

The result of the study leads to a conclusion that anthropogenic carbon dioxide emissions in Asia is increasing and has more than double from its 1980 level and its continuing to increase until the present. This increasing level is highly affected by (1) population, (2) income level, but with poor demand for environmental quality, and (3) Technology use in producing goods and (4) the sources of energy used by countries. The study confirmed the presence of the EKC in the Asian economy, within the sample it only showed a monotonically upward trend in emissions with increasing income level is discovered. It shows that low income countries are in a state that needs for technological assistance. Technological improvement of this country would decrease emissions in

significant amount. Shifting to less energy intensive technologies would be needed to change the current trend of the emissions. Investing in less energy intensive technology will change the current direction of CO_2 emissions.

Recommendation

The result of the study suggests the following:

(1) Stabilize human population sooner rather than later will help reduce future emissions.

(2) Changes in industrial sectors and other sectors that utilize energy to reduce emission using readily available technology. Shifting to wind, solar and geothermal power for all electricity generation could greatly reduce the use of fossil fuels.

(3) Increased appliance and machinery efficiency could lower industrial and residential energy use. In the short term, shifts away from personal vehicles toward mass transit, along with increases in fuel efficiency, can reduce transportation emissions. And in the longer term, use of hydrogen-fueled cars and buses could cut emissions even further.

(4) Finally, increasing funding for further research and development of clean energy technologies can also help move the world from a carbon-based and toward a hydrogen-based energy system.

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