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Nexus between CO_2 Emission, Energy Consumption and Economic Growth in ASEAN Countries Plus China

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Abstract: This study mainly contributes to test the Environmental Kuznets Curve (EKC) hypothesis using panel data for the ASEAN (Malaysia, Indonesia, Thailand and Philippines) countries plus China. Empirical focus of the study is to examine the nexus between CO_2 emission, energy consumption and economic growth. While using panel data for 1971-2008 and applying panel co-integration techniques, the emergent findings of the study showed a positive relationship between per capita GDP and per capita CO_2 emission. Further, we found positive effect of energy consumption on CO_2 emission in long run. However, the study findings confirmed EKC inverted U-shape hypothesis for the ASEAN-china region after the inclusion of energy consumption. However, it did not hold once only quadratic relationship of per capita income was regressed with CO_2 emission. Our long-run Panel Ordinary Least Squares (POLS), Dynamic Ordinary Least Squares (DOLS) and Fully Modified Ordinary Least Squares (FMOLS) estimates also confirmed U-shaped EKC hypothesis for this sample of ASEAN4 countries plus China. The findings of the study suggest the countries under consideration should focus on increasing per capita income to sustain long term economic growth and to reduce pollutants and hence, CO_2 emission in the region.

Keywords: ASEAN, China, CO_2 Emission, Environmental Kuznets Curve, Energy Consumption, Panel Co-Integration

Introduction

The risk of global climate change resulted from increase in Greenhouse Gas (GHG) emission presents a profound concern for current economic growth and welfare of both developed and developing economies. According to an estimate, CO_2 emissions have increased more than ten-fold since the start of global economic and industrial revolution. Similarly as a result atmospheric concentrations of CO_2 have increased by 30% (Olivier *et al*., 2012). These global environmental concerns have motivated the world towards new environmental policies and reforms in order to substantially lower the CO_2 emissions. Currently, the main focus of sustainable development revolves around shifting entire development from simple economic growth to environmental friendly growth. Therefore, it is important to understand whether environmental reforms and economic growth can coincide or not. For this purpose, Environmental Kuznets Curve (EKC) is a hypothesized nexus between economic growth and environmental degradation indicators.

Basically there are two research strands in literature on the relationship between energy consumption, economic growth and environmental pollutants (Ozturk and Acaravci, 2010; Zhang and Cheng, 2009). The first strand which also validate the EKC hypothesis focuses on the relationship between environmental pollutants and economic growth. The second strand of the research is related to nexus between economic growth and energy consumption.

The Association of South East Asian Nations (ASEAN) countries' energy consumption increased by nearly 7.5% and economy grew by 5% a year from 1980 to 1999 (Karki *et al*., 2005). The ASEAN nations and countries such as India and China since the mid-1980s has proved pivot of the global economic growth. As per ASEAN Center for Energy, the region's economic growth had a significant increase in primary energy consumption which was 3.6% per annum with 339 Million Tons of Oil Equivalent (MTOE) to 511 MTOE from 1995 to 2007. Among the energy sources consumed in the region, coal had the fastest growth rate (13.0%) followed by natural gas (6.5%), geothermal energy (6.2%), hydro energy (4.8%) and "other energy" which is mostly biomass (0.9%) had the next fastest growth at 6.5% per annum increasing its share from 16.4-21.4%. However, oil's share declined from 31.4-10.6% while natural gas share increased from 16.4% to 21.4% from 1995 to 2007. Moreover, projections suggest that energy consumption in ASEAN would rise to about 583 MTOE in 2020. Thus, the ASEAN nations need as much as US$ 461 billion in investments in the energy sector from 2001 to 2020 to sustain economic growth.

The first strand, discussed above e.g., EKC, initially proposed by Kuznets (1955), is an inverted U shaped curve which shows a U-shaped relation between various indicators of environmental pollutants and per capita GDP. The EKC hypothesis further shows that initially per capita GDP and carbon emissions exhibit positive relationship but after a threshold level of per capita GDP this relation becomes reverse. This type of literature can be seen in a multi-country panel data framework (Hazama *et al*., 2011; Apergis and Payne, 2010) as well as some time series studies using time series econometrics (Begum *et al*., 2015; Shahbaz *et al*., 2015; 2013).

Most of the past researches have not taken into consideration the various income levels across nations. Hence, proposed study is an attempt to fill the research gap by taking into account on comparing the nexus between per capita CO_2 emission, economic growth and energy use by taking into consideration for development level. Also, previous studies made efforts for confirmation of EKC hypothesis through various approaches such as; parametric, semi and non-parametric, fuzzy and linear model. They took different environmental pollutants, NH_4, SO_2, CO_2, etc. While using numerous kinds of data as primary, time series and panel however, the true nature of the models remained confused and the outcomes of these approaches remained mixed. Our study explained the question of the presence of an EKC hypothesis by utilizing the panel data. Determining the presence of EKC hypothesis for per capita CO_2 emission as a global pollutant is vital. It is important in the sense that the global pollutant can be lowered through financial support and international cooperation if developing nations exhibit U-shape curve. Hence, proposed study shed the light on the presence of the EKC for ASEAN4 (Malaysia, Philippine, Thailand and Indonesia) plus China countries.

The existing and regional social inequities combined with increased population and rapid economic growth among the ASEAN nations have essentially put huge pressures on the regional natural resources. The competition among different ASEAN for limited resources leads to trans-boundary as well as local environmental issues including depletion of natural resources, diminishing biological diversity, urban environmental degradation, different kinds of trans-boundary pollution (haze, water, land and air). Further, economic competition among ASEAN nation also created problem of increase wastes and increased consumption of resources, resulting in unsustainable development and economic growth. Therefore, ASEAN countries are struggling to keep balance between economic development and use of environmental resources (ASEAN Cooperation, 2009).

Recognizing the significance of environmental cooperation for sustainable development and regional integration, since 1977, ASEAN has a consensus to cooperate closely to promote environmental cooperation among its member nations. As reflected in the Blueprint for the ASEAN Socio-Cultural Community (ASCC Blueprint) 2009-2015 currently ASEAN environmental cooperation focuses on ten priority areas of regional importance. Out of these ten priority areas, clean environment is most important. For this purpose they are promoting Environmentally Sound Technologies (ESTs), cleaner production and environmental labeling is also one of the priority zones marked in the "ASEAN-China Environmental Cooperation Action Plan 2011-2013" and "ASEAN-China Strategy on Environmental Protection Cooperation 2009-2015". The targets of the cooperation are to enhance the use of recycled materials and the efficient use of raw materials to promote cooperation in cleaner production and environmental labeling and facilitate the development and transfer of ESTs. Among others the core activities include, feasibility study on mutual recognition of environmental labeling, the development of environmentally sound technology pilot projects and hence, the establishment of ASEAN-China environmental industry cooperation network. To implement the Action Plan and Strategy, ASEAN nations and China are now in the process of developing the draft of ASEAN-China Cooperation Framework for Environmentally Sound Technology and Industry, to give more detailed mechanism and guidance for ASEAN-China cooperation on the said subject area (ASEAN Cooperation, 2009).

Due to the fact that pollutants like oxides of nitrogen or Sulphur oxides may have more regional effect on the quality of the environment, it has been recognized in the literature that CO_2 emission is a key reason of global warming through its greenhouse process. Another reason for studying CO_2 emissions is that it has a central role to play in the current debate on environment protection and sustainable development. Also, inclusion of CO_2 emission in this study is that it directly related to the energy consumption which then use for production and consumption. Also, due ASEAN region's highly liberalized economic policies and rich natural have attracted many foreign investors which made this region one of the fastest growing economies in the world (Yu, 2003). Some of the member countries, i.e., Thailand, Singapore and Malaysian, are greatly involved in information technology and electronics export business, whereas Indonesia, Malaysia and Brunei export liquid natural gas and crude oil (Karki *et al*., 2005). Many countries in Asia-Pacific region have faced serious environmental issues such as land poverty and deforestation in line with conventional growth path. Hence, this region have initiated to investigate for the new path shifting from conventional development patterns to sustainable development because of these environmental issues (Luukkanen and Kaivo-oja, 2002). Also, ASEAN nations worry about the negative effect of restricted conventional development on economic growth. Although growth rates and energy resources in ASEAN countries as a whole are high level, there are no enough studies that examine environment-growth-energy consumption nexus. Therefore, the link between economic growth and per capita CO_2 emissions has very significance implications for environmental and economic policies. Taking the EKC hypothesis, this study investigates the nexus between the per capita CO_2 emission, economic growth and energy consumption in ASEAN4 plus China.

Based on previous discussion the proposed study makes several contributions to the current literature. Firstly, by including energy consumption for the first time in the literature this study analyses the economic growth-environment nexus and hence, the EKC hypothesis which is important for empirical contribution. Even though the link between two or three of them is separately investigated in different literatures such as environment-growth-population literature, growth-tourism literature and growth-energy literature. Secondly, this study focuses on the panel study of selected countries from ASEAN nations plus China because the selected region has a key role in energy sector and produce a significant share of the gas emissions and world GDP. Thirdly, the ASEAN region is becoming an important player in the world economy, which is the most dynamic regions of the world. Also, region has many environmental clean projects and blueprints discussed above with China which is the second largest economy and energy consumption in the world. This led to revisit the EKC curve for these countries although individually EKC has testified for these countries. Lastly, as methodological contributions, this study uses unit root tests (LLC, Breitung, IPS, ADF, PP panel unit root tests) and the cointegration test (the Lagrange multiplier bootstrap panel co-integration test) that take into consideration for cross-sectional dependence problem since Pesaran's CD test (Pesaran, 2004) shows that disturbances in each panel time-series data are cross sectionally dependent. This is important because refusing to recognize the problem of cross-sectional dependence can result in unreliable results and cause econometrically dangerous consequences. Further, we employed the Fully Modified Ordinary Least Square (FMOLS), Dynamic Ordinary Least Squares (DOLS) and Dynamic Ordinary Least Squares (DOLS) technique which are considered as a second-generation estimator to reveal the coefficient estimates.

The rest of the paper is as followed; in the second part of the study detailed literature is discussed especially in case time series and panel data which confirm/disconfirm EKC, in third section we shed a light on panel unit root test, co-integration tests and long term relationship among stated variables, forth part is about results and discussion and fifth part concludes the paper with some policy recommendations.

Literature Review

Kuznets (1955) has intuited a link between income inequality and per capita income as an inverted-U-shaped curve. Simply, he stated that with the rise in the income per capita, the income inequality also rises but starts dropping after a threshold level. On the basis of this idea, many authors have executed a new hypothesis: the existence of an inverted U-shaped relationship between measures of environmental degradation and per capita GDP (Grossman and Krueger, 1991; 1995; Koop, 1998; Panayotou, 2000; Selden and Song, 1994; Stern, 2004; Panayotou, 1993; Taylor and Copeland, 2004; Hettige *et al*., 1992; Shafik and Bandyopadhyay, 1992). Afterward, this curve has been labelled as Environmental Kuznets Curve (EKC).

Various studies (e.g., Jalil and Feridun, 2011; Sadorsky, 2010; Jensen, 1996) examined the factors of the EKC, such as energy consumption, economic growth, CO_2 emissions and financial development. Besides of a vast pool of research on EKC in the world, , there is very limited literature (e.g., Begum *et al*., 2015; Hazama *et al*., 2011) is available on EKC in case of ASEAN countries. For instance, Hazama *et al*. (2011) analyzed the environment-trade interaction in the ASEAN region employing extended EKC by utilizing panel data. Further, they extended their analysis by including trade with Japan and its relationship with carbon emission in ASEAN countries. While Begum *et al*. (2015) analyzed EKC by focusing the emerging impacts of energy consumption, output growth and population on CO_2 emission using econometric models for Malaysia. From Chinese perspective, Dhakal (2009) explored the nexus between CO_2 emissions and urbanization in China.

In sum, it is not easy to find an inverted-U form relation for the carbon emission. A number of studies working on CO_2 emissions find a significant positive correlation between economic growth and carbon emission (Pao and Tsai, 2010) for Russia, (Chang, 2010), China and Turkey (Ozturk and Acaravci, 2010). On other hand, however, various other studies (for example, Apergis and Payne, 2010; Galeotti *et al*., 2006; Martinez-Zarzoso and Bengochea-Morancho, 2003; Vollebergh *et al*., 2005) employed traditional panel methods and reported an inverted U-shaped function for CO_2 emissions.

In addition, the significant role of energy consumption in CO_2 emissions should not be abandoned while analyzing economic growth and environmental performance nexus. A sizeable volume of investigation has been allocated towards analyzing economic growth and energy consumption (Ozturk, 2010). Further, literature has suggested to analyse economic growth and energy consumption simultaneously in a single multivariate fashion. Apergis and Payne (2010) adopted this approach to test both nexus in a single econometric framework.

The paper treats the link between energy consumption, economic growth and CO_2 emissions, in case of ASEAN4 plus China. The major motivation behind this approach is to focus on the testing the hypothesis of environmental Kuznets curve for ASEAN-china region for the period of 1971-2008. Unfortunately, a limited literature is available focusing specifically on ASEAN4-China region. Keeping its significance, the main objective of this study is to fill the existing research gap.

Materials and Methods

This study used the standard panel data and econometric modelling for the empirical analysis of the study. First we illustrated the standard time series procedures in panel context then we specified our empirical model for estimation.

Unit Root and Stationary Tests

For empirical analysis, we need to test GDP per capita and per capita CO_2 emission for the unit root tests. The use of unit roots is performed due to the fact that individual tests have generally low power when they are utilized to short series, while panel tests escalate the power of contrasts (Perman and Stern, 1999). Also, Levin *et al*. (1992) showed that panel approach substantively increases the power of the test compared to the time series ADF tests. We can test the unit roots by applying Breitung, LLC, IPS, ADF, PP panel type unit root tests. Thus, if the null hypothesis of non-stationary cannot be rejected, the variables have to be differenced until they become stationary at I(1), that is until the existence of a unit root is rejected, before proceeding to the empirics of co-integration.

Co-Integration Analysis

While a number of co-integration tests are documented in the time series literature, there are few co-integration tests developed in panel data such as: Kao (1999) Test, Pedroni (2000; 2004) Test and Larsson *et al*. (2001).

Kao proposed an extension of the Engle and Granger (1987) co-integration test from individual time series to a panel. Basic idea is to scrutinize two I(1) series and check if the residuals of the spurious regression involving these I(1) series are I(0) as: If this is so, then the series are co-integrated and if the series are I(1) then the variables are not co-integrated. A test for the null hypothesis of no co-integration can be based on an ADF-type unit root test based on the residuals.

However, the panel regression model that Pedroni proposed:

$$Y_{it} = a_i + \delta_t + \sum_{m=1}^{M} \beta_{mi} X_{mi,t} + u_{it} \tag{1}$$

Seven different co-integration statistics are offered to capture the within (pooled) and between (group mean) effects-classified into two categories.

Larsson *et al*. (2001) proposed a likelihood-based (LR) panel test of co-integration rank in heterogeneous panel models based on the average of the individual rank trace statistics introduced by Johansen (1988). In Monte Carlo simulation, they investigated the small sample properties of the standardized LR statistic. The LR test requires a large time-series dimension and even if the panel has a large cross-sectional dimension, the size of the test will be sternly biased.

Specification of Environmental Kuznets Curve

To investigate the co-movement between economic growth and carbon emission which is a synthesis of the EKC and to perform our empirical analysis, we need to estimate the following two models based on above mentioned variables for ASEAN4 plus China:

$$LCO_{2it} = \beta_1 + \beta_2 LGDP_{it} + \beta_3 LGDP^2{}_{it} + \varepsilon_{it} \tag{2}$$

$$LCO_{2it} = \beta_1 + \beta_2 LGDP_{it} + \beta_3 LGDP^2{}_{it} + \beta_4 LENUSE_{it} + \varepsilon_{it} \tag{3}$$

where, GDP per capita is used as a measure for economic activity for ASEAN plus China and is the carbon emission per capita indicating environmental quality in a given time period.

In order to check the existence of EKC, the given Equation 2 and 3 which will be derived from the relationship between GDP and pollution level will be used. For EKC to hold, it is expected that pollution levels escalates with increasing income up to a limit beyond which pollution levels are likely to fall with higher levels of income. Hence, if coefficient of GDP will be positive and that of coefficient of GDP^2 will be negative, then it indicates the inverted U-shaped link amid GDP per capita and CO_2 emission.

Data

The present study utilize balance panel data of ASEAN4-China for the time period of 1971-2008 on CO_2 emissions, real GDP and energy use. CO_2 emissions (CO_2) are represented by carbon dioxide emissions evaluated in metric tons per capita while (real) GDP per capita (GDP) is a measure of economic development or level of income. The GDP is in constant 2000 US dollar. We utilize the energy use (kg of oil equivalent per capita) as a measure of Energy Consumption (EC). Data on CO_2 emissions, real GDP and energy use are sourced from World Development Indicators (WDI). Starting from year 1971 is important as in this era, the use of technology increased due to the Green Revolution in 1960 s whereas the fully use of technology initiated the environmental problems.

Results and Discussion

Results of the Unit Root and Panel Co-Integration Tests

In this study, we applied the Levin-Lin-Chu (LLC), Breitung, Im-Pesaran-Shin (IPS), ADF and PP test. The results are given in Table 2 and 3. The LLC, Breitung, IPS and ADF statistics for level of per capita GDP, energy use per capita and carbon emission per capita measured in kilotons unable to reject the null hypothesis of the unit root. But once we took first difference I(1), all variables become stationary. After making the series as stationary, we can now proceed to panel co-integration tests. We also presented descriptive statistics of the variables as shown in Table 1. Mean of CO_2, GDP and energy use found to be 0.4023, 6.8541 and 6.5358, respectively.

Furthermore, to check the long term co-movement between the given variables, we can use KAO and/or Pedroni co-integration test. We applied the Kao co-integration test and we rejected the null of no co-integration at 10% level of significance when association is checked for GDP and carbon emission. Further, once we applied the Pedroni co-integration test including all three variables with no intercept and no trend the results showed that 4 out of seven statistics are statistically significant indicating that co-integration exist among the variables.

Results of the Empirical Models

In next step, we estimated the long run coefficients of the panel model. First, we estimated the pooled OLS model and selected an appropriate model between pooled OLS and random effect model. Chi square value on the basis of Breusch and Pagan LM test found highly significant favoring random effect model. Secondly, we estimated the fixed effect model and on the basis of Hausman test, we found that fixed effect model is more appropriate over random effect model because chi square value in former case is highly significant rejecting the null hypothesis of Cov(χ_i, χ_{it}) = 0. Thirdly, the diagnostic tests showed that model was suffering from serial correlation and heteroscedasticity. To correct the model from these problems, we applied robust standard error to adjust the standard error of model in order to get unbiased results. After estimating all above mentioned analysis and diagnostic tests, we estimated following long run equation:

$$\begin{aligned} LCO_{2it} &= 3.79 - 2.0199LGDP_{it} + 0.2193LGDP_{it}^2 \\ &\quad\ (1.60) \qquad (-2.77) \qquad\qquad (3.83) \end{aligned} \tag{4}$$

$$\begin{aligned} &LCO_{2it} \\ &= -8.3502 + 0.2970LGDP_{it} - 0.0111LGDP_{it}^2 + 1.1086LENUSE_{it} \\ &\quad (-7.52)\ (0.93) \qquad (-0.38) \qquad\qquad (6.26) \end{aligned} \tag{5}$$

Parenthesis values illustrated the t-statistics in Table 3. The values show that all coefficients of GDP per capita and its square are not statistically significant at 5 and 1%. First model disconfirm the EKC. Results are significant. It means countries are still need to improve the per capita GDP. However, in second model, the relationships between energy consumption, GDP per capita and CO_2 emissions exist. Importantly, the positive coefficient of energy consumption, indicate a sizeable effect of energy consumption on pollution. This result indicated that a 1% increase in energy use increases CO_2 emissions per capita by 110% in ASEAN4 plus china region. Thus, energy use leads towards environmental degradation. This can be simply elucidated by the realm that when the GDP is low, environmental concern is overshadowed by the pursuit of growth. This is common as in the case of the emerging and developing countries which should be the main objective of the economic policy. However, once income increases there may be succeeds in as second stage characterized by a relatively slower degradation of the environment. This act can be illustrated by here realization by middle income countries to bracket, the environmental issue. Also this kind of attentiveness can be helpful for financial efforts allocated to the grants or the creation of institutions, cleaning of air or water that handle these cases.

The objective of this study was to investigate the existence of environmental Kuznets curve for the given countries, using the panel unit root tests, panel co-integration and dynamic ordinary least squares as well as fully modified ordinary least squares. First, this study conducted the panel unit root and panel co-integration tests to analyze the long run movement between CO_2 emission and economic growth. After that, this study showed the Dynamic Ordinary Least Squares (DOLS) and Fully Modified Ordinary Least Squares (FMOLS) along with the traditional Panel Ordinary Least Squares (POLS) tests to analyze whether economic growth and energy use had an impact on CO_2 emission in the selected countries. The results are illustrated in Table 4 for the given two models corresponding to environmental Kuznets curve.

Table 1. Descriptive statistics

Variables	Observations	Mean	Std. Dev.	Min	Max
LCO_2	190	0.4023	0.7454	-1.1358	2.0245
LGDP	190	6.8541	0.8323	4.8465	8.5322
LENUSE	190	6.5358	0.5166	5.6656	7.8842

Table 2. Unit root tests

	LLC test H0: Unit root (Common unit root process)		Breitung test		IPS test H0: Unit root (individual unit root process)	
Variable	Constant without trend	Constant with trend	Constant without trend	Constant with trend	Constant without trend	Constant with trend
Level						
LCO_2	-0.0940	0.3273		-2148.0000	2.0449	-0.1683
	(0.4625)	(0.6283)		(0.415)	(0.9796)	(0.4332)
LGDPC	0.4426	-0.4695		-0.4266	2.0593	-0.2015
	(0.6710)	(0.3194)		(0.3348)	(0.9803)	(0.4202)
LENUSE	0.3074	1.7289		-1.1248	2.1377	1.4552
	(0.6207)	(0.9581)		(0.1303)	(0.9837)	(0.9272)
First difference						
LCO_2	-4.7819	-3.6257		-4.8661	-5.5767	-4.1426
	(0.0000)	(0.0001)		(0.0000)	(0.0000)	(0.0000)
LGDPC	-5.3846	-4.9843		-5.5397	-5.0749	-4.0284
	(0.0000)	(0.0000)		(0.0000)	(0.0000)	(0.0000)
LENUSE	-4.3725	-3.6886		-5.2698	-5.5169	-4.4339
	(0.0000)	(0.0001)		(0.0000)	(0.0000)	(0.0000)

Note: Probability values are given in parenthesis confirming that variables are stationary at I(1)

Table 3. Unit root tests

	ADF-MWχ^2		PP-MWχ^2	
Variable	Constant without trend	Constant with trend	Constant without trend	Constant with trend
Level				
LCO_2	2.5047	9.5835	3.6828	6.9088
	(0.9908)	(0.4778)	(0.9605)	(0.7340)
LGDP	3.7067	8.3631	3.1904	6.9784
	(0.9596)	(0.5934)	(0.9766)	(0.7275)
LENUSE	4.0009	3.3402	4.3148	4.8799
	(0.9473)	(0.9722)	(0.9320)	(0.8991)
First difference				
LCO_2	50.2653	35.0532	91.9232	76.7266
	(0.0000)	(0.0001)	(0.0000)	(0.0000)
LGDP	45.1955	33.6300	58.8362	43.4344
	(0.0000)	(0.0002)	(0.0000)	(0.0000)
LENUSE	50.4231	38.2915	104.0050	100.9780
	(0.0000)	(0.0000)	(0.0000)	(0.0000)

Note: Probability values are given in parenthesis confirming that variables are stationary at I(1)

Table 4. Panel Least Squares (OLS), Dynamic Ordinary Least Squares (DOLS) and Fully Modified Least Squares (FMOLS) estimation results (Dependent variable: Log CO_2)

	Model 1			Model 2		
	OLS	DOLS	FMOLS	OLS	DOLS	FMOLS
Log GDPPC	2.1813***	5.0620***	5.0620***	1.8800***	5.2902***	2.1741***
	(-9.4987)	(-6.0594)	(-4.5784)	(-8.0723)	(-1.2356)	(-6.7496)
Log GDPC squared	-0.9506***	-1.6868***	-1.6866***	-0.9672***	-1.2715***	-1.0427***
	(-12.0560)	(-6.2248)	(-5.8026)	(-12.9976)	(-0.2609)	(-10.9762)
Log Energy use				0.4366***	-1.8990*	0.3206*
				(-3.5832)	(-0.9532)	(-1.8592)

Note: Figures in parentheses are t-statistics values while *, ** and *** represent significance levels at 10%, 5% and 1% respectively

The results of Panel Ordinary Least Squares (POLS) for the first model (column 2) and for the second model (column 5) showed that economic growth has a positive and significant impact on CO_2 emission, whereas increasing economic growth as measured by the squared of GDP per capita are significantly negatively affecting the CO_2 emission, indicating the existence of environmental Kuznets curve in these countries. As for as the impact of energy use on CO_2 emission is related, the estimated results reported a positive impact of energy use on CO_2 emission as indicated by OLS and FMOLS. Further, the estimated results of DOLS and FMOLS also supported the findings of panel OLS such that economic growth (increasing economic growth) is positively (negatively) affecting CO_2 emission while energy use is having a positive impact on CO_2 emission. Overall, it is concluded that economic growth is positively affecting CO_2 emission while improvement in economic development is negatively affecting CO_2 emission. Further, energy use is positively contributing towards CO_2 emission in these countries.

Knowing this fact, government or environmental agencies can put taxes according to the principle of "polluter payers" because environment is considered as luxury goods. Whatever its form, there should be efforts to decrease environmental degradations as this could be apparent by the above estimated equation. Overall, there is a positive association between CO_2 emissions and per capita real GDP and a negative relationship between CO_2 emissions and per capita real GDP confirming the quadratic form and hence EKC for ASEAN4 plus one countries: One percent increase in per capita real GDP increases per capita CO_2 emissions by 158% in the ASEAN4 plus China countries. Moreover, findings of the study are supportive of the Environmental Kuznets Curve hypothesis in the ASEAN4 plus one region: The level of CO_2 emissions first increases with income, stabilizes and then reduces. Thus, there appears to be an inverted U-shaped association between per capita real GDP and per capita CO_2 capita in the ASEAN4 plus one region once energy consumption is included in the model.

Conclusion

The question of sustainability of growth in ASEAN4 plus China has gain much attention of the policy makers which motivated us to do nexus between economic growth, energy use and environmental pollutants in ASEAN4 plus China region. This study had two main objectives. Firstly, existence of EKC was investigated in the ASEAN4 plus one China in the matter of per capita CO_2 emissions. Secondly, panel co-integration techniques were utilized to explore the nexus between real GDP per capita, energy consumption and per capita CO_2 emissions for 4 ASEAN nations plus China from 1971 to 2008.

In this study we confirmed EKC curve for stated countries. In order to explain dynamic of U shaped curve, three theoretical explanations can be provided: Firstly, growth impacts tastes of economic agents to a more friendly environmental production process and products, secondly, economic growth augments the set-up of capacities, institutions and organizations for deal with environmental issues and thirdly, technological and innovation change lead to utilize more friendly process and technologies following the market opportunities.

This study showed that energy use had a significantly positive effect on per capita CO_2 emissions in the long run. Energy consumption is likely to be a crucial factor effecting the quality of the environment if a country's income level is not high enough for it to care about the environment. Moreover, the country's economic development and energy usage had substantial effect on carbon dioxide emissions. Importantly, study showed that real GDP per capita did not exhibit a quadratic link with per capita CO_2 emissions as shown by insignificance of results in first model. Taken together, estimated results did not show an inverted U-shaped pattern associated with the EKC hypothesis for the ASEAN4 plus one region. However, it did hold after incorporation of energy usage with positive and significant effect on CO_2 emission. Hence, we recommend that countries under consideration should increase per capita income and impose tax for energy consumption for sustainable development and to reduce pollutants.

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Author's Contributions

Ghulam Mustafa: Corresponding author who conception and designed the paper, acquisition of data, analysis and interpretation of data. He also contributed in drafting the article and reviewed it critically for significant intellectual content, prepared original and final version and gave final approval.

Ismail Abd Latif: He helped in conception, designing, interpretation of analysis, reviewed the paper and its various version and paraphrasing of different versions. He contributed in drafting article and main author's supervisor in his PhD studies.

Said Zamin Shah: Provided technical help through results and discussions and its various versions, analysis and interpretation and paraphrasing the manuscript.

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Ethics

This article is original and never published before. This was the individual class assignment for advance econometrics which is never published in any journal or elsewhere.

References

Apergis, N. and J.E. Payne, 2010. The emissions, energy consumption and growth nexus: Evidence from the commonwealth of independent states. Energy Policy, 38: 650-655. DOI: 10.1016/j.enpol.2009.08.029

ASEAN Cooperation, 2009. ASEAN Cooperation on Environmentally Sound Technologies (EST).

Begum, R.A., K. Sohag, S.M.S. Abdullah and M. Jaafar, 2015. CO_2 emissions, energy consumption, economic and population growth in Malaysia. Renewable Sustainable Energy Rev., 41: 594-601. DOI: 10.1016/j.rser.2014.07.205

Chang, C.C., 2010. A multivariate causality test of carbon dioxide emissions, energy consumption and economic growth in China. Applied Energy, 87: 3533-3537. DOI: 10.1016/j.apenergy.2010.05.004

Dhakal, S., 2009. Urban energy use and carbon emissions from cities in China and policy implications. Energy Policy, 37: 4208-4219. DOI: 10.1016/j.enpol.2009.05.020

Engle, R.F. and C.W.J. Granger, 1987. Co-integration and error correction: Representation, estimation and testing. Econometrica, 55: 251-76. DOI: 10.2307/1913236

Galeotti, M., A. Lanza and F. Pauli, 2006. Reassessing the environmental Kuznets curve for CO_2 emissions: A robustness exercise. Ecol. Econom., 57: 152-163. DOI: 10.1016/j.ecolecon.2005.03.031

Grossman, G.M. and A.B. Krueger, 1991. Environmental impacts of a North American free trade agreement. National Bureau Economic Research Working Paper Series, 3914: 1-57.

Grossman, G.M. and A.B. Krueger, 1995. Economic growth and the environment. Q. J. Econom., 110: 353-377.

Hazama, Y., M. Kojima, T. Machikita, K. Murakami and S. Suzuki, 2011. Trade liberalization and environmental interaction in Japan and ASEAN: An extended environmental Kuznets Curve with panel data. ECONBIZ Find Economic Literature.

Hettige, H., R.E. Lucas and D. Wheeler, 1992. The toxic intensity of industrial production: Global patterns, trends and trade policy. American Economic Rev., 82: 478-481.

Jalil, A. and M. Feridun, 2011. The impact of growth, energy and financial development on the environment in China: A cointegration analysis. Energy Econom., 33: 284-291. DOI: 10.1016/j.eneco.2010.10.003

Jensen, V.M., 1996. Trade and environment: The pollution haven hypothesis and the industrial flight hypothesis; some perspectives on theory and empirics. University of Oslo.

Johansen, S., 1988. Statistical analysis of cointegration vectors. J. Econom. Dynam. Control, 12: 231-254. DOI: 10.1016/0165-1889(88)90041-3

Kao, C., 1999. Spurious regression and residual-based tests for cointegration in panel data. J. Econometr., 90: 1-44. DOI: 10.1016/S0304-4076(98)00023-2

Karki, S.K., M.D. Mann and H. Salehfar, 2005. Energy and environment in the ASEAN: Challenges and opportunities. Energy Policy, 33: 499-509. DOI: 10.1016/j.enpol.2003.08.014

Koop, G., 1998. Carbon dioxide emissions and economic growth: A structural approach. J. Applied Stat., 25: 489-515. DOI: 10.1080/02664769822972

Kuznets, S., 1955. Economic growth and income inequality. Am. Economic Rev., 45: 1-28.

Larsson, R., J. Lyhagen and M. Löthgren, 2001. Likelihood-based cointegration tests in heterogeneous panels. Econometr. J., 14: 109-142. DOI: 10.1111/1368-423X.00059

Levin, A., C.F. Lin and C. Chu, 2002. Unit root tests in panel data: Asymptotic and finite-sample properties. J. Econometr., 108: 1-24.

Luukkanen, J. and J. Kaivo-oja, 2002. ASEAN tigers and sustainability of energy use-decomposition analysis of energy and CO_2 efficiency dynamics. Energy Policy, 30: 281-292. DOI: 10.1016/S0301-4215(01)00091-X

Martinez-Zarzoso, I. and A. Bengochea-Morancho, 2003. Testing for an environmental Kuznets curve in latin-american countries. Revista de Análisis Económico, 18: 3-26.

Olivier, J.G., G. Janssens-Maenhout and J.A. Peters, 2012. Trends in global CO_2 emissions: 2012 report. PBL Netherlands Environmental Assessment Agency the Hague.

Ozturk, I., 2010. A literature survey on energy–growth nexus. Energy Policy, 38: 340-349. DOI: 10.1016/j.enpol.2009.09.024

Ozturk, I. and A. Acaravci, 2010. CO_2 emissions, energy consumption and economic growth in Turkey. Renewable Sustainable Energy Rev., 14: 3220-3225. DOI: 10.1016/j.rser.2010.07.005

Panayotou, T., 2000. Economic growth and the environment. Q. J. Econom., 110: 353-378. DOI: 10.3386/w4634

Panayotou, P., 1993. Empirical tests and policy analysis of environmental degradation at different stages of economic development. ILO Working Papers.

Pao, H. and C. Tsai, 2010. CO_2 emissions, energy consumption and economic growth in BRIC countries. Energy Policy, 38: 7850-7860. DOI: 10.1016/j.enpol.2010.08.045

Pedroni, P., 2000. Fully modified OLS for heterogeneous cointegrated panels. Adv. Econometr., 15: 93-130.

Pedroni, P., 2004. Panel cointegration; asymptotic and finite sample properties of pooled time series tests, with an application to the PPP hypothesis. Econometric Theory, 20: 597-627. DOI: 10.1017/S0266466604203073

Perman, R. and D.I. Stern, 1999. The environmental Kuznets Curve: Implications of non-stationarity. The Australian National University.

Pesaran, M.H., 2004. General diagnostic tests for cross section dependence in panels.

Sadorsky, P., 2010. The impact of financial development on energy consumption in emerging economies. Energy Policy, 38: 2528-2535. DOI: 10.1016/j.enpol.2009.12.048

Selden, T.M. and D. Song, 1994. Environmental quality and development: Is there a Kuznets curve for air pollution emissions? J. Environ. Econom. Manage., 27: 147-162. DOI: 10.1006/jeem.1994.1031

Shafik, N. and S. Bandyopadhyay, 1992. Economic growth and environmental quality: Time-series and cross-country evidence. World Bank Publications.

Shahbaz, M., M.S. Shabbir and M.S. Butt, 2013. Effect of financial development on agricultural growth in Pakistan: New extensions from bounds test to level relationships and Granger causality tests. Int. J. Social Econom., 40: 707-728. DOI: 10.1108/IJSE-01-2012-0002

Shahbaz, M., S. Dube, I. Ozturk and A. Jalil, 2015. Testing the environmental Kuznets curve hypothesis in Portugal. Int. J. Energy Economi. Policy, 5: 475-481.

Stern, D.I., 2004. The rise and fall of the environmental Kuznets curve. World Develop., 32: 1419-1439. DOI: 10.1016/j.worlddev.2004.03.004

Taylor, M.S. and B.R. Copeland, 2004. Trade, growth and the environment. J. Econom. Literature, 42: 7-71. DOI: 10.1257/002205104773558047

Vollebergh, H.R.J., E. Dijkgraaf and B. Melenberg, 2005. Environmental Kuznets curve for CO_2: Heterogeneity versus homogeneity. SSRN Electronic J. DOI: 10.2139/ssrn.683109

Yu, X., 2003. Regional cooperation and energy development in the Greater Mekong Sub-region. Energy Policy, 31: 1221-1234. DOI: 10.1016/S0301-4215(02)00182-9

Zhang, X.P. and X.M. Cheng, 2009. Energy consumption, carbon emissions and economic growth in China. Ecol. Econom., 68: 2706-2712. DOI: 10.1016/j.ecolecon.2009.05.011