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Environmental Kuznets Curve in Thailand: Cointegration and Causality Analysis

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Abstract

The study is aim to explore the existence of environmental Kuznets curve (EKC) in case of Thailand over the period of 1971-2010. The EKC relationship posits that as economy grows, measured by per capita income, at the initial stage energy pollutants increase; but starts falling after a certain threshold income has been achieved. The postulated relation produces an inverted U-curve and has been empirically verified for many nations. The paper implements the ARDL bounds testing approach to cointegration in the presence of structural break for a long run relationship among the series; and the error correction mechanism for the short run dynamics. The results confirm cointegration among economic growth, energy consumption, trade openness, urbanization, and energy pollutants and vindicate the presence of an EKC for Thailand. Also, energy consumption and trade openness add to energy emissions while urbanization lowers it. This study provides new insights for policymakers looking for sustainable economic growth and clean environment through a comprehensive economic and environmental policy.

Keywords: Economic Growth, Energy Consumption, Environmental Kuznets Curve
JEL Codes: JEL classification: O13; Q25; Q53

Introduction

Global warming has become a major global concern. Recent evidence points to increased carbon dioxide (CO_2) emissions which is blamed the warming. In response to tackling this issue, several nations have committed to reduce CO_2 emissions at individual level. At the global level such awareness has led to the signing of the Kyoto Protocol which mandates lowering CO_2 emission to a certain level by the signatories. Unfortunately, it is set to expire in 2012. Over the past decade, Thailand, a developing country in East Asia, has been facing mounting challenge as she tries to contain CO_2 emissions and at the same time pursues sustainable economic growth.

Thai economy is primarily exports driven. The trade balance in 2010 was 342.3 billion Baht[1]. This was more than twice the average 154.9 billion Baht during the entire decade of 2001 to 2010 (NSO, 2011). This reflects on the significance of exports on Thai economic growth. Between 2002 and 2010, Thai gross domestic product (GDP) almost doubled from 5,450,643 to 10,104.8 billion Baht. In the 1990s, Thailand suffered severe economic collapse due to Asian flu. Following the crisis, imports of raw materials and capital have grown at pace with GDP. Some of other bright spots are, narrow down of the saving-investment gaps, decline in the ratio of public debt to GDP, and improvement in the current account balance. The recovery was very short-lived, however.

Thailand saw much political instability in 2006. As a result the economy suffered further, compounded by the global financial meltdown. Exports dropped substantially by 10%. The deep recession forced the Thai Government to implement various emergency rescue packages to restore the economy. In addition, the global food and energy crises over the past two years took its toll and even forced a revision in its 10^{th} National Economic and Social Development Plan (2007-2011). In

sum, national and global economic instabilities left immense impacts on Thai performance over the past decade. The 11th Plan (2012-16) which is under preparation places high priority on economic stability emphasizes on development of the country's self-reliance and resilience to external factors (ONEP, 2010).

Economic growth requires higher energy consumption which in turn boosts carbon emissions. From 2002 to 2010, total amount of energy consumption in Thailand, in terms of petroleum sales rose from 30.7 to 33.7 million liter (NSO, 2011). Energy sector the largest offender contributed about 70 % of the total 229 million tones CO_2 equivalent in 2000 and was the key emissions source in 2004 (78 % of 263 million ton CO_2 equivalent; ONEP, 2010). Given the need for economic growth, Thai government is exploring realistic approach to meet the standards for a low carbon society. In the same vein, the government is negotiating a new framework under the United Nations Framework Convention on Climate Change (UNFCCC) and the Kyoto Protocol. Currently, Thailand has crafted its 20 year (2011-2030) energy conservation plan in which the energy intensity, measured by energy use per unit of GDP, will be reduced from 16.2 ktoe/billion Thai Baht in 2005 to 12.1 ktoe/billion Thai Baht (25% decline) by the end of 2030. This will result in reduction of overall CO_2 emissions by 976 million tones (EPPO, 2011). The target is to reduce the use of fossil fuel and CO_2 emissions.

Urbanization plays a critical role in energy consumption, and thus CO_2 emission (Martínez-Zarzoso and Maruotti, 2011). Over the past decade, population growth in Thailand's has slowed down. Total Thai population is projected to increase from 63.4 million in 2008 to 71 million in 2028. The share of urban to the total population has also increased as a result of economic growth (ONEP, 2010), especially in the industrial areas, which has been the center of economic growth. This has further

contributed to the acceleration of urban population, and the expansion of cities. It is forecasted that approximately one-half of the Thai population will move to urban areas during the next 50 years (DPT, 2006). Per capita income in Thailand is still relatively low. Thai government likely will have to take extra efforts to boost economic growth to cater the needs of an exploding urban population. Higher urban population has implications for energy use and thus on environment.

Hossain, (2011) investigated the dynamic causal relationships between carbon dioxide emissions, energy consumption, economic growth, trade openness and urbanization for the panel of nine newly industrialized countries (NIC), namely Brazil, China, India, Malaysia, Mexico, Philippines, South Africa, Thailand and Turkey. The results found that over time higher energy consumption in the panel of newly industrialized countries gives rise to more CO_2 emissions as a result our environment will be polluted more. It is also found that the variables such as trade openness and urbanization have negative and significant impact on carbon emissions. Narayan and Narayan, (2010) tested the EKC hypothesis for 43 developing countries using both time series and panel data estimation techniques. They find that only data for the Middle Eastern and South Asian panels, emissions are lower in the long run compared to the short run, implying that CO_2 emission has fallen with a rise in income. Kukla-Gryz, (2009) analyzed the impact of economic growth and international trade on the level of air pollution by using the estimation of the structural equation model (SEM) with two factors describing the structure of economic activity and air pollution intensity. The results suggest that in the developing countries, both international trade and per capita income lead to changes in the structure of economic activity and – as a consequence – to the increase in air pollution. In addition, results indicate that the impact of economic growth on air

pollution intensity in the developing countries occurs through the change of the structure of economic activity.

Although there are a number of studies that examined the existence of EKC in case of Thailand, e.g. Hossain, (2011); Narayan and Narayan, (2010) and Kukla-Gryz, (2009); all of them accounted it as one of comparative countries only. This shows that applications devoted for Thailand and use single country-specific time series of multiple causalities–economic growth, energy consumption, urbanization, international trade, and CO_2 emissions- seems to be never carried out. This study contributes in existing energy literature by four ways: (i) it's first comprehensive effort to explore the relationship between economic growth, energy consumption and CO_2 emissions by incorporating trade openness and urbanization in CO_2 emissions function for case of Thailand, (ii) Zivot-Andrews (ZA) structural break unit root test is applied to test the order of integration of the variables, (iii), dummy is used to accommodate structural break while applying the ARDL bounds testing long run relationship between the variables and, (iv) the VECM is used to detect the direction of causality between the variables. Our results found cointegration between the variables and EKC is found in case of Thailand which is further confirmed by unidirectional causality running from economic growth to CO_2 emissions.

The rest of study is balances as following: section-II reviews the relevant literature, modelling and estimation strategy is explained in section-III. Section-IV interprets the results and conclusion and policy implication are drawn in section-V.

II. Review of Literature

As an outgrowth of the literature on the link among energy consumption, economic growth and environmental degradation, the Environmental Kuznets Curve (EKC) has gained significant popularity. The EKC relationship posits that as economic growth, measured by per capita, rises at the initial stage energy pollutants increase; but after a certain threshold income have been reached pollutants start falling. This produces an inverted U-curve. Researchers have examined the validity of EKC both for individuals as well as a group of nations. The conceptual framework owes much to the work of Grossmann and Krueger, (1991). Since then a burgeoning literature has emerged (Wang et al. 2011). And yet no clear consensus emerged. Using cross-national panel data, Selden and Song, (1994) examined the relationship between economic growth and environmental degradation. They considered four air pollutants: particulate matter, sulfur dioxide, nitrogen oxides, and carbon monoxide. They found inverted-U relationship between emissions and per capita GDP.

Cole et al. (1997) examined the relationship between per capita income and a wide range of environmental indicators using cross-country panel data to test for the existence of the EKC. The results suggest that EKC is found for local air pollutants even as indicators with a more global, or indirectly, impact either increase monotonically with income or else have predicted turning points at high per capita income levels. These findings offer valuable insight for crafting sustainable environmental policy. The inverted-U relationship between economic growth and CO_2 emissions estimated from panel data need not hold for specific individual countries over time (de Bruyn et al. 1998). They found that the time patterns for air pollutants and CO_2 emissions correlate positively with economic growth and that emissions reduction requires structural and technological changes in the economy. They point out that “sustainable growth” implies the rate of economic growth which

does not further aggravate pollute. Concern about climate change has prompted several analysts to examine the relation between economic activity and energy consumption and/or carbon emissions, e.g. Halicioglu, (2009); Apergis and Payne, (2009). Holtz-Eakin and Selden, (1995) were the first to explore the relationship between economic growth and CO_2 emissions. Estimates derived from global panel data (130 countries) suggest a diminishing marginal propensity to emit (MPE) CO_2 as GDP per capita rises. The relationship exhibited a monotonic, not inverted-U type.

Various studies investigated the relationship between economic growth, energy consumption and CO2 emissions and confirmed the existence of the environmental Kuznets curve. For example, Pao and Tsai, (2010) for BRIC; Ozturk and Acaravci, (2010) for Turkey; Acaravci and Ozturk, (2010) for Europe; Nasir and Rehman, (2011) and Shahbaz et al. (2012) in Pakistan; Iwata, (2011) in 28 developed and developing countries; Saboori et al. (2011) in Indonesia; Saboori et al. (2012) in Malaysia; Shahbaz et al. (2013) for Romania and Tiwari et al. (2013) for India validated the presence of the EKC.

Much of the earlier studies of EKC have applied bi-variate model in case of Thailand, and thus potentially suffer from the problem of omitted variables bias. Stern, (2004) pointed out that the EKC results have a very flimsy statistical foundation. In particular, he argues that a new generation of decomposition and efficient frontier models might help disentangle the true relations between the series which may even lead to the demise of the EKC. Contemporary approaches that have succeeded in avoiding the pitfalls include cointegration and Granger causality within a multivariate framework. With the advent of alternative statistical models like autoregressive distributed lag

procedure (ARDL) the research has been extended to several nations. The models have been implemented in both single and groups of developing countries.

III. The Data, Modeling and Methodology

Data for the study cover the period of 1971-2010 and has been taken from the world development indicators (CD-ROM, 2011). The series are: energy consumption (kg of oil equivalent) per capita, real GDP per capita, trade openness [(exports + imports)/GDP] per capita, urbanization per capita and CO_2 emissions (in kt) per capita. We follow the empirical model of Ang, (2007, 2008); Soytas et al. (2007); Jalil and Mahmud, (2009); Halicioglu, (2009) and Shahbaz et al. (2012). We extended their work by incorporating urbanization. Its inclusion appears a well justified on theoretical ground for the EKC relationship in the case of Thailand. The general form of the equation is:

$$C_t = f(Y_t, Y_t^2, E_t, T_t, U_t) \qquad (1)$$

We use a non-linear functional form (in variables) to specify the relation. All series are transformed into logarithms. The estimable equation thus takes the following form:

$$\ln C_t = \beta_1 + \beta_Y \ln Y_t + \beta_{Y^2} \ln Y_t^2 + \beta_E \ln E_t + \beta_T \ln T_t + \beta_U \ln U_t + \mu_t \qquad (2)$$

Where, C refers to carbon emissions per capita; E is energy consumption per capita; Y and (Y^2) refer to real GDP per capita and its square; T is trade openness per capita; and U is urban population as share of total population; μ is a random error term, obeying the standard assumptions. The EKC hypothesis requires that $\beta_Y > 0$ and $\beta_{Y^2} < 0$. We expect energy use to increase pollutants, $\beta_E > 0$. The

sign of the coefficient of T can go either way. If β_T < 0, pollution is reduced due to strict environmental laws and helped by import of capital and technology that favor the environmental. Grossman and Krueger (1991, 1993) and Halicioglu (2009) argue that if β_T > 0 then polluting industries in developing economies might be shifting production that generate more emissions; as would be consistent with the safe haven hypothesis. Urbanization leads to higher demands for energy and thus environmental degradation. We expect β_U > 0.

We use the Autoregressive Distributive Lag (ARDL**)** bounds test approach to examine cointegration among the series developed by Pesaran et al. (2001). The ARDL model applies regardless of the order of integration (Pesaran and Pesaran, 1997). Most macroeconomic variables are I(1). Haug, (2002) argues that the ARDL approach for cointegration is preferable due its better small sample properties compared to other methods. Also, the unrestricted error correction model (UECM) with appropriate lags captures the data generating process within the general-to-specific framework (Laurenceson and Chai, 2003). An appropriate modification of the orders of the ARDL model is sufficient to simultaneously correct for residual serial correlation and endogeneity problems (Pesaran and Shin, 1999). The following UECM is used to examine the long and short run relationships among the series.

$$\begin{aligned}\ln C_t = {} & \alpha_0 + \alpha_{DUM} DUM + \sum_{i=1}^{p} \beta_i \Delta \ln C_{t-1} + \sum_{i=0}^{q} \delta_i \Delta \ln Y_t + \sum_{i=0}^{r} \sigma_i \Delta \ln Y_t^2 + \sum_{i=0}^{u} \varepsilon_i \Delta \ln E_t \\ & + \sum_{i=0}^{v} \varpi_i \Delta \ln T_t + \sum_{i=0}^{s} \phi_i \Delta \ln U_t + \lambda_c \ln C_t + \lambda_Y \ln G_t + \lambda_{Y^2} \ln Y_t^2 + \lambda_E \ln E_t \\ & + \lambda_T \ln T_t + \lambda_U \ln U_t + \mu_t \end{aligned} \quad (3)$$

The first part of equation (3) $\beta, \delta, \varepsilon, \sigma$ and ω capture the short run parameters; while $\lambda_C, \lambda_Y, \lambda_{Y^2}, \lambda_E, \lambda_T$ and λ_U capture the long run relation among the series and DUM is dummy variable[2]. The hypothesis of no cointegration: $H_0 : \lambda_C = \lambda_Y = \lambda_{Y^2} = \lambda_E = \lambda_T = \lambda_U = 0$ is tested against the alternate of cointegration i.e. $H_a : \lambda_C \neq \lambda_Y \neq \lambda_{Y^2} \neq \lambda_E \neq \lambda_T \neq \lambda_U = 0$. The decision about cointegration is taken based on the critical bounds tabulated by Pesaran et al. (2001) against the computed F-statistic. The upper critical bound (UCB) assumes that the variables are integrated at I(1) and the lower critical bounds (LCB) assumes they are I(0). If UCB is less than the F-statistic, the decision favors a long run relationship among the variables. If the F-statistic is less than LCB, there is no cointegration. The decision about cointegration will be inconclusive if the F-statistic lies between UCB and LCB[3].

After establishing cointegration is among the series, we turn to test the direction of causality between the pairs of economic growth, energy consumption, trade openness, urbanisation and carbon emissions. The vector error correction method (VECM) is suitable for causal relation between the variables if the series are found to be stationary at I(1) (Granger, 1969). All the series are endogenous in the system of vector error correction model (ECM) which shows that the response variable is explained both by its own lags, and lags of independent variables as well as the error correction term and (residual term). The VECM in five variables case can be written as follows:

$$\Delta \ln C_t = \alpha_{\circ 1} + \sum_{i=1}^{l} \alpha_{11} \Delta \ln C_{t-i} + \sum_{j=0}^{m} \alpha_{22} \Delta \ln Y_{t-j} + \sum_{k=0}^{n} \alpha_{33} \Delta \ln Y_{t-k}^2 + \sum_{r=0}^{o} \alpha_{44} \Delta \ln E_{t-r} + \sum_{s=0}^{p} \alpha_{55} \Delta \ln T_{t-s} + \sum_{u=0}^{q} \alpha_{66} \Delta \ln U_{t-u} + \eta_1 ECT_{t-1} + \mu_{1i} \quad (4)$$

$$\Delta \ln Y_t = \beta_{\circ 1} + \sum_{i=1}^{l} \beta_{11} \Delta \ln Y_{t-i} + \sum_{j=0}^{m} \beta_{22} \Delta \ln C_{t-j} + \sum_{k=0}^{n} \beta_{33} \Delta \ln Y_{t-k}^2 + \sum_{r=0}^{o} \beta_{44} \Delta \ln E_{t-r} + \sum_{s=0}^{p} \beta_{55} \Delta \ln T_{t-s} + \sum_{u=0}^{q} \beta_{66} \Delta \ln U_{t-u} + \eta_1 ECT_{t-1} + \mu_{1i} \quad (5)$$

$$\Delta \ln Y_t^2 = \phi_{\circ 1} + \sum_{i=1}^{l} \phi_{11} \Delta \ln Y_{t-i}^2 + \sum_{j=0}^{m} \phi_{22} \Delta \ln C_{t-j} + \sum_{k=0}^{n} \phi_{33} \Delta \ln Y_{t-k} + \sum_{r=0}^{o} \phi_{44} \Delta \ln E_{t-r} + \sum_{s=0}^{P} \phi_{55} \Delta \ln T_{t-s} + \sum_{u=0}^{q} \phi_{55} \Delta \ln U_{t-u} + \eta_3 ECT_{t-1} + \mu_{3i} \quad (6)$$

$$\Delta \ln E_t = \varphi_{\circ 1} + \sum_{i=1}^{l} \varphi_{11} \Delta \ln C_{t-i} + \sum_{j=0}^{m} \varphi_{22} \Delta \ln Y_{t-j} + \sum_{k=0}^{n} \varphi_{33} \Delta \ln Y_{t-k}^2 + \sum_{r=0}^{o} \varphi_{44} \Delta \ln E_{t-r} + \sum_{s=0}^{p} \varphi_{55} \Delta \ln T_{t-s} + \sum_{u=0}^{p} \varphi_{55} \Delta \ln U_{t-u} + \eta_4 ECT_{t-1} + \mu_{4i} \quad (7)$$

$$\Delta \ln TR_t = \delta_{\circ 1} + \sum_{i=1}^{l} \delta_{11} \Delta \ln TR_{t-i} + \sum_{j=0}^{m} \delta_{22} \Delta \ln C_{t-j} + \sum_{k=0}^{n} \delta_{33} \Delta \ln G_{t-k} + \sum_{r=0}^{o} \delta_{44} \Delta \ln G_{t-r}^2 + \sum_{s=0}^{p} \delta_{55} \Delta \ln E_{t-s} + \sum_{u=0}^{p} \delta_{55} \Delta \ln U_{t-u} + \eta_4 ECT_{t-1} + \mu_{5i} \quad (8)$$

$$\Delta \ln U_t = \vartheta_{\circ 1} + \sum_{i=1}^{l} \vartheta_{11} \Delta \ln U_{t-i} + \sum_{j=0}^{m} \vartheta_{22} \Delta \ln C_{t-j} + \sum_{k=0}^{n} \vartheta_{33} \Delta \ln Y_{t-k} + \sum_{r=0}^{o} \vartheta_{44} \Delta \ln Y_{t-r}^2 + \sum_{s=0}^{p} \vartheta_{55} \Delta \ln E_{t-s} + \sum_{u=0}^{p} \vartheta_{55} \Delta \ln T_{t-u} + \eta_4 ECT_{t-1} + \mu_{6i} \quad (9)$$

Where u_{it} are error terms and assumed to be identically, independently and normally distributed (N~(iid)). The statistical significance of lagged error term i.e. ECT_{t-1} further validates a long run

relationship between the series. The estimated ECT_{t-1} also shows the speed of convergence from the short run towards the long run equilibrium path. The VECM helps to test the causal relation once series are found to be cointegrated. In such case, causality must be present at least from one direction. Also, the VECM can distinguish short- from the and-long run causal relationships; and detect causality in long run, short run or both (Shahbaz et al. 2011).

A statistically significant t-statistic on estimated lagged error term i.e. ECT_{t-1} with negative sign confirms the existence of long run causal relation. Short run causality is indicated by the joint χ^2 test on estimated first differenced lagged independent variables. For example, a significant $\alpha_{22,i} \neq 0 \forall_i$ implies that economic growth Granger-causes CO_2 emissions and causality runs from latter to the former. The similar inference can be drawn about other causality hypotheses. Finally, we use Wald or F-test to test the joint significance of estimated lagged terms of independent variables and error correction term which further confirms the existence of short-and-long run causality, known to measure strong Granger-causality (Oh and Lee, 2004). In addition to sensitivity analysis, parameter stability and goodness of fit for the ARDL model is checked by cumulative sum of recursive residuals (CUSUM) and cumulative sum of squares of recursive residuals ($CUSUM_{SQ}$).

IV. Results and Empirical Discussions

While not necessary, the first step is to find out the order of integration of the variables prior to applying the ARDL bounds testing for long run relationship between the series. This is needed to insure that none of the series is I(2). In the literature, various tests are available to test the stationarity properties of the variables such as ADF by Dikey-Fuller (1979), DF-GLS by Elliot et al. (1996), Ng-Perron by Ng and Perron (2001) etc. The results of these tests imply that the variables

are integrated at I(1)[4]. Baum, (2004) points out that these above tests may be biased in the presence of structural break. To overcome this issue, we use Zivot-Andrews, (1992) structural break unit root test. The Zivot-Andrews, (1996) allows information about one structural break in the series to have one structural break point. The results are robust with the findings of ADF, DF-GLS and Ng-Perron. The results reported in Table-1 suggest that the variables are 1st difference stationary with intercept and trend i.e. I(1). This sets the stage for applying the ARDL bounds testing approach to cointegration for a long run relationship among the variables for Thailand over the period 1971-2010.

Table-1: Zivot-Andrews Structural Break Unit Root Test

Variable	**At Level**		**At 1st Difference**	
	T-statistic	Time Break	T-statistic	Time Break
$\ln C_t$	-2.917(1)	1990	-5.253(0)**	1987
$\ln Y_t$	-3.726 (1)	1988	-4.876(0)***	1997
$\ln Y_t^2$	-3.683 (1)	1988	-4.913 (0)***	1997
LE_t	-3.148 (1)	1989	-6.587 (0)*	1984
$\ln U_t$	-3.381 (0)	1988	-7.150 (0)*	1987
$\ln T_t$	-3.937 (1)	1976	-7.575 (0)*	1981
Note: *, ** and *** represent significant at 1%, 5% and 10% level of significance. Lag order is shown in parenthesis.				

The ARDL bounds test statistic is sensitive to the selection of lag length. Lütkepohl, (2006) documents that dynamic link among the series can be captured if proper lag is used. The selected lag length of 2, using AIC criteria as repoted in Table-2.

Table-2: Lag Length Criteria

VAR Lag Order Selection Criteria

Lag	LogL	LR	FPE	AIC	SC	HQ
0	236.0789	NA	2.22e-13	-12.1094	-11.8508	-12.0174
1	561.4300	530.8359	5.54e-20	-27.3384	-25.5284*	-26.6944*
2	602.0704	53.4742*	5.02e-20*	-27.5826*	-24.2212	-26.3867

* indicates lag order selected by the criterion

LR: sequential modified LR test statistic (each test at 5% level)

FPE: Final prediction error

AIC: Akaike information criterion

SC: Schwarz information criterion

HQ: Hannan-Quinn information criterion

The next step is to examine a long run relationship among the variables. The results of the ARDL bound testing approach to cointegration reported in Table-3. Our findings show that our calculated F-statistics i.e. 11.6357, 28.0861 and 7.4809 exceed upper critical bounds at the 1% and 10% levels of significance when CO_2 emissions, energy consumption and trade openness are used as predicted variables. Our sample consists of 40 observations (1971-2010) so, critical values from Pesaran[5] et al. (2001) are inappropriate. As such, we chose to use the lower and upper critical bounds generated by Narayan, (2005). We find three cointegration vectors and thus a long run relationship among

economic growth, energy consumption, trade openness, urbanization and CO_2 emissions for Thailand over the study period of 1971-2010.

Table-3: ARDL Cointegration Analysais

Variable	$\ln C_t$	$\ln Y_t$	$\ln Y_t^2$	$\ln E_t$	$\ln T_t$	$\ln U_t$
F-statistics	11.6375*	1.5483	1.5345	28.0861*	7.4809***	4.2474
Break Year	1990	1988	1988	1989	1976	1988
Critical values#	1 % level	5 % level	10 % level			
Lower bounds	10.150	7.135	5.950			
Upper bounds	11.130	7.980	6.680			
$Adj - R^2$	0.9703	0.9994	0.9994	0.9702	0.6410	0.9367
F-statistic	19.8202*	26.0811*	24.7990*	19.6792*	3.5003**	21.7236*

Note: *, ** and *** show significant at 1%, 5% and 10% level respectively. # Critical values bounds are from Narayan (2005) with unrestricted intercept and unrestricted trend.

In addition to the ARDL approach, we also implemented the Johansen cointegration approach to test the robustness of long run relationship. The results in Table-4 show two cointegration vectors, as confirmed by trace test statistics and maximum eigen values the at 1% and 5% level of significance. This validates a long run relationship which is robust in the long run results.

Table-4 Results of Johansen Cointegration Test

Hypothesis	Trace Statistic	Maximum Eigen Value
R = 0	161.0758*	79.2998*
R ≤ 1	81.7760*	37.0243**
R ≤ 2	44.7516	23.5707
R ≤ 3	21.1809	12.0915
R ≤ 4	9.0893	9.0821
R ≤ 5	0.0072	0.0072
Note: *, ** and *** show significant at 1%, 5% and 10% level respectively.		

We now discuss the marginal impacts of economic growth, energy consumption, trade openness and urbanization on CO_2 emissions in the long run as well as in the short run. The long run results reported in Table-5 indicate that both linear and non-linear terms of real GDP per capita confirm an inverted-U relationship between economic growth and CO_2 emissions. The results suggest that 1 percent rise in real GDP per capita will raise CO_2 emissions per capita by 7.2369 percent while negative sign of estimate i.e. -0.3057 of squared term establishes the inverted relationship between CO_2 emissions and real GDP per capita. This evidence confirms that CO_2 emissions increase at initial stage of economic growth and decline after a threshold point i.e. EKC exists. In other words, GDP influences the efficient consumption of energy resulting in reduction of CO_2 emissions. This implies that energy demand-side-management policies should be launched by applying energy-efficient technology by public organizations to reduce energy consumptions. The use of energy efficient machines and appliances helped to achieve the goal, something which can be potentially

achieved at higher levels of income. These findings are consistent with those of Song et al. (2008); Halicioglu, (2009); Fodha and Zaghdoud, (2010); Lean and Smyth, (2010); Shahbaz et al. (2012), Shahbaz et al. (2013) and Tiwari et al. (2013). The impact of energy consumption on energy pollutants is positive and statistically significant at 1% level. We find that a 0.6424 percent increase in CO_2 emissions is linked with 1 percent increase in energy consumption. Energy consumption is a major contributor to environmental degradation. CO_2 emissions have increased from power generation and industrial sectors that are using more natural gas and lignite/coal. In 2011, total lignite/coal consumption was 19 million tons, a rise by 5.5 percent from 2010 (based on the heating value); while natural gas consumption in 2011 increased by 2.6 percent compared to that in 2010 (EPPO, 2012). Although air pollution emissions control technologies for these fuels are in place, the desired reduction in CO_2 emission remains unsatisfactory. The dilemma for Thailand is to balance the needs of economic growth with energy consumption and greenhouse gas emissions in the long-run. It is forecasted that natural gas demand in 2011 (excluding the use as feedstock in gas separation plants) will increase by 6.1 percent compared with that in 2010.

Table-5: Long-and-Short Runs Analysis

Dependent Variable: $\ln C_t$			
Long Run Results			
Variable	Coefficient	Std. Error	t-Statistic
Constant	-40.3455	7.5585	-5.3377*
$\ln Y_t$	7.2369	1.5350	4.7144*
$\ln Y_t^2$	-0.3057	0.0772	-3.9580*

$\ln E_t$	0.6424	0.1634	3.9292*
$\ln T_t$	0.1699	0.0972	1.7477***
$\ln U_t$	-2.1404	0.4031	-5.3090*
Short Run Results			
Variable	Coefficient	Std. Error	t-Statistic
Constant	0.0201	0.0135	1.4921
$\ln Y_t$	7.0400	3.3750	2.0859**
$\ln Y_t^2$	-0.3005	0.1601	-1.8763***
$\ln E_t$	0.4182	0.1638	2.5525*
$\ln T_t$	0.0962	0.0728	1.3219
$\ln U_t$	-2.3064	1.1179	-2.0630*
ECM_{t-1}	-0.6136	0.1473	-4.1656*
R^2	0.7880		
$Adj - R^2$	0.7456		
F-statistic	18.5899*		
Diagnostic Test	F-statistic	Prob. value	
$\chi^2 NORMAL$	0.0357	0.9822	
$\chi^2 SERIAL$	1.2763	0.2948	
$\chi^2 ARCH$	0.7092	0.7046	
$\chi^2 WHITE$	1.1725	0.3470	
$\chi^2 REMSAY$	0.7594	0.4537	

Note: *, ** and *** show significant at 1%, 5% and 10% level respectively.

We find positive relationship between trade openness and environmental degradation. A 1 percent increase in trade openness is expected to raise CO_2 emissions by 0.1699 percent, all else same. One may conclude that trade openness stimulates economic growth i.e. income per capita which in turn impedes environmental quality in Thailand by increasing CO_2 emissions. Thailand has established the Board of Investment of Thailand (BOI) under the Ministry of Industry to encourage foreign investors to set up operation in the country. This includes an attractive and competitive package of tax incentives; no foreign equity restrictions on manufacturing activities or some services; and waiver of restrictions on land ownership by foreign entities; but none to support climate-friendly activities. These findings are consistent with Khalil and Inam, (2006) for Pakistan and Halicioglu, (2009) for Turkey. They reported that trade openness increases CO_2 emissions.

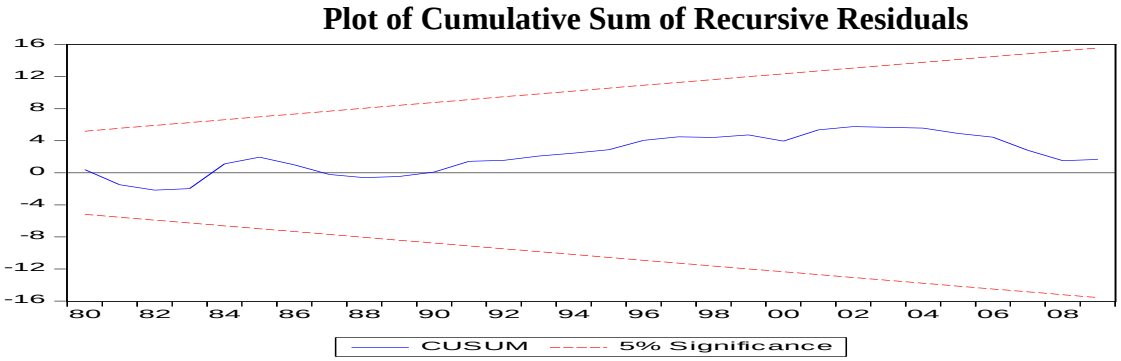
The effect of urbanization on CO_2 emissions is negative and statistically significant at the 1 percent level. A 1 percent increase in urbanisation lowers CO_2 emissions by 2.1404 percent by keeping other things constant. Urbanisation is major contributor to save environment from degradation in case of Thailand. Urbanization in Thailand has moved hand in hand with industrialization. Thailand has promoted itself as an industrial manufacturing hub in the Southeast Asia. As a result industrial estates can be found all over the country expanding in to the residential and commercial areas. A planned urbanization can lower air pollution and greenhouse gases emissions, especially in transport sector. Mass public transport can be helpful. Well-planned compact cities can induce shorter commute distance (Dulal et al. 2011).

The short run results indicate that the impact of linear (non-linear) term of real GDP per capita on CO_2 emissions is positive (negative) and it is statistically significant at the 5 (10) percent level. These findings again confirm the existence of environmental Kuznets curve (EKC) is the short run. The relationship between energy consumption and CO_2 emissions is positive and significant at the 1 percent level. All else is same, a 0.4182 percent increase in CO_2 emissions is linked with a 1 percent use (rise or fall) of energy. Impact of trade openness on CO_2 emissions is positive but it is not statistically significant. Finally, urbanization is inversely linked with CO_2 emissions. Keeping other things constant, a 1 percent increase in urbanization improves the environmental quality by 2.3064 percent at 1 percent level of significance. The significance of lagged error term i.e. ECM_{t-1} with negative sign further validates the existence of a long run relationship among the variables. The results reported in Table-5 show that estimate of lagged error term is -0.6136 and it is statistically significant at 1 percent level of significance. This suggests that deviations in CO_2 emissions from long run equilibrium are corrected by 61.36 percent every year. This implies that established long run relationship between the series is reliable and robust.

We applied the cumulative sum (CUSUM) and the cumulative sum of squares (CUSUMsq) tests to examine the stability of the long-and-short runs parameters. Based on the results in Figure 1 and 2, we may accept the hypothesis of correct specification of regression model, because the plots of CUSUM and CUSUMsq lie within critical bounds at 5 per cent level of significance (Bahmani-Oskooee and Nasir, 2004). The graph for CUSUM test statistics falls within critical lines i.e. red lines while statistics of CUSUMsq test appear to cross the bounds in years of 1984 and 1990 which reflect structural breaks in the series. Between 1980s and the first half of the 1990s the Thai economy experienced a period of rapid economic growth, hitting a peak of 13.29% in 1988.

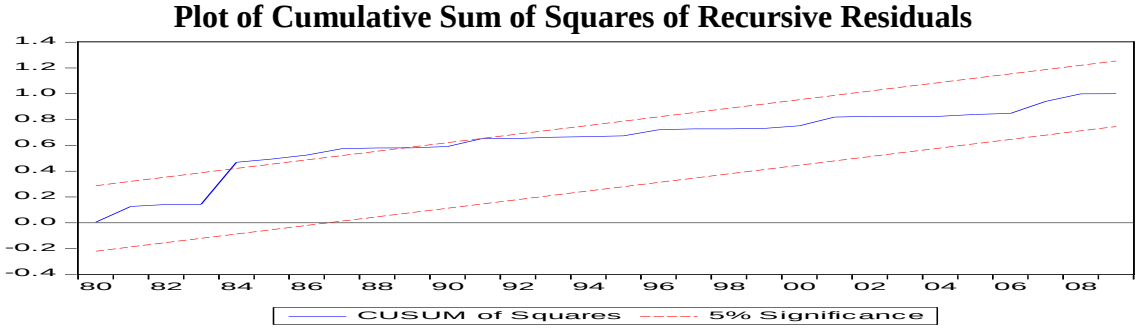
Thailand's GDP (constant price) remained relatively high, 12.19% in 1989 and 11.63% in 1990 and dropped to 8.11% in 1991 (International Monetary Fund, 2011). The period of rapid economic growth along with other attending factors may have influenced other break points during the period, i.e. urbanization in 1988, energy consumption in 1989, CO_2 emissions in 1990 and significant reduction in the incidence of poverty. The number of people living in poverty decreased substantially from nearly 18 million in 1988 to little less than 7 million in 1996 (ONEP, 2000). Average annual rate of change of urban population between 1985 and 1990 was 2.44 % (United Nations, 2011). The demand for energy in Thailand grew along with an expanding economy. During the period of rapid economic growth, energy consumption increased by 8-10 percent annually and added to CO_2 emission from about 165 Tg in 1990 to 202 Tg in 1994 (ONEP, 2000).

Figure-1



The straight lines represent critical bounds at 5% significance level.

Figure-2



The straight lines represent critical bounds at 5% significance level.

The CUSUM and CUSUMsq graphs is not always dependable so, Leow, (2004) suggests that we should apply Chow forecast test to check for structural breaks in a series. Therefore, we applied the test. The results reported in Table-6 indicate no evidence of structural break in Thai economy over the period of 1984-1990. The long-and-short runs parameters are stable and appear reliable for policy making purpose in Thailand.

Table-6: Chow Forecast Test

Chow Forecast Test	Value	Prob. value
F-statistic	0.9193	0.6169
Likelihood ratio	71.8695	0.0000

VECM Granger Causality Analysis

Given the existence of cointegration among the series, economic growth, trade openness, energy consumption, urbanization and CO_2 emissions, we now investigate causal relationship between them. Knowledge about the direction of causality between the series can help policy makers in crafting an integrated and sustainable environmental policy. Granger, (1969) suggested if the series are first difference stationary and cointegrated the VECM. The results are reported in Table-7.

Table-7 reveals that in the long span of time, there is bidirectional causality between CO_2 emissions and energy consumption; energy consumption and trade openness; and trade openness and CO_2 emissions. We find unidirectional causality from economic growth and urbanization to CO_2 emissions. The statistical significance of ECT_{t-1} implies the speed of adjustment in trade openness equation is (-0.7664) as compared to CO_2 emissions and energy consumption equations are (-0.6574) and (-0.6573) respectively.

Table-7: VECM Causality Analysis

Dependent Variable	Short Run						Long Run
	$\ln C_t$	$\ln Y_t$	$\ln Y_t^2$	$\ln E_t$	$\ln T_t$	$\ln U_t$	ECM_{t-1}
$\ln C_t$	…	2.7059*** [0.0871]	3.7464** [0.0384]	0.8874 [0.4248]	0.8958 [0.4258]	5.4765** [0.010]	-0.6574* [-3.8751]
$\ln Y_t$	4.7830** [0.0179]	…	3.0029** [0.0222]	0.8161 [0.4540]	0.2812 [0.7573]	3.8441** [0.0356]	
$\ln Y_t^2$	4.1918** [0.0275]	3.0008** [0.0229]	…	1.0611 [0.3617]	0.3668 [0.6967]	3.6399** [0.0416]	
$\ln E_t$	1.0491 [0.3657]	0.1160 [0.8909]	0.1568 [0.8557]	…	0.4417 [0.6480]	0.1054 [0.9004]	-0.6573* [-3.0071]
$\ln T_t$	0.1286 [0.8799]	1.0231 [0.3746]	1.1403 [0.3364]	0.0479 [0.9533]	…	0.0132 [0.9869]	-0.7664* [-2.9441]
$\ln U_t$	0.1047 [0.9010]	0.1154 [0.8944]	0.1086 [0.8975]	0.2746 [0.7622]	3.0177*** [0.0678]	…	…
Note: *, ** and *** show significant at 1%, 5% and 10% level respectively.							

In the short run, feedback hypothesis is found between economic growth and CO_2 emissions. Urbanization Granger causes CO_2 emissions and economic growth. The unidirectional causality is found from trade openness to urbanization. Overall, the results indicate that unidirectional causality runs from economic growth ($\ln Y_t$ and $\ln Y_t^2$) to CO_2 emissions ($\ln C_t$) in the long and the short run. This lends support to the existence of the environmental Kuznets curve (EKC). These findings are

consistent with Maddison and Rehdanz, (2008) for North America; Zhang and Cheng, (2009) and Jalil and Mahmud, (2009) for China; Ghosh, (2010) for India; Narayan and Narayan, (2010)) for developing economies; Nasir and Rehman, (2011) and Shahbaz et al. (2012) for Pakistan; Tiwari et al. (2013) for India.

V. Conclusions and Future Research

The paper examines the existence of EKC for Thailand over the period of 1971-2010 by implementing the ARDL bounds test approach in the presence of structural break stemming in the series to examine a long run relationship. The direction of causality between economic growth, energy consumption, trade openness, urbanization, and CO_2 emissions is investigated by employing the VECM Granger causality approach.

We find that the variables are cointegrated. The results indicate that energy consumption worsens environment via increasing CO_2 emissions. Trade openness also increases environmental pollutants, which may be due to pollution-haven hypothesis and poor local laws. Urbanization protects environment. The existence of EKC suggests that economic growth initially increases CO_2 emissions and then starts to decline it once threshold income level is achieved. The causality analysis shows bidirectional causality between energy consumption, trade openness, urbanization, and CO_2 emissions. Economic growth Granger causes CO_2 emissions further reaffirms the presence of ECK in Thailand. CO_2 emissions is also Granger-caused of urbanisation.

Our study suggests that any overuse of non-renewable energy, i.e., natural gas and coal/ lignite, contributes to greenhouse gas (GHG) emissions. Therefore, Thai government should turn to explore

renewable energy sources to sustain economic growth for long run but also save environment from degradation. A more focus is needed to adopt energy efficient and less pollutants emitting technology to accelerate domestic production and hence economic growth. In the context of trade openness, policy makers should craft policies that are “climate-friendly investment” and thus help to mitigate the adverse impact on environment from CO_2 and other GHG emissions. Continued urbanization appears to be helping in reducing CO_2 emission, perhaps due to use of public transport rather than private cars and use of fuel. The government should further support an efficient public and fuel efficient modes of transport. Incentives for the provision of such services, putting regulation in place and their effective enforcement, along with long term urban planning should be targeted.

The only use of trade openness and urbanisation variables in empirical models cannot the capture the true phenomenon of trade and urbanisation. That’s why we need a comprehensive study to investigate the impact of trade on energy consumption and hence on CO_2 emissions following Ghani, (2012) and, Cole and Elliott, (2003) in case of Thailand. Similarly, effect of urbanisation on energy consumption and environmental degradation can be investigated following Zhu et al. (2012) by applying semi-parametric approach. The impact of financial development and financial instability (finnacial crisis) on energy consumption and CO_2 emissions can also be examined in Thai economy following Shahbaz and Lean, (2012) and latter on Islam et al. (2013) and, Shahbaz, (2013) respectively.

Footnotes

1. 1 US$ = 30.5 Baht (Mar, 2012)
2. Dummy is based on ZA structural break unit root test
3. In such situation, we may have to rely on the lagged error correction term (ECM_t) for a long run relationship.
4. The results of ADF, DF-GLS and Ng-Perron are available from authors upon request.
5. The critical bounds generated by Pesaran et al. (2001) are suitable sample of size (T = 500 to T = 40, 000). Narayan and Narayan (2005) argue that the critical values from Pesaran et al. (2001) are significantly smaller, so may produce biased results. Narayan's (2005) values are more appropriate for small samples of size T = 30 to T = 80.

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