Is There a Trade-Off between Environmental Conservation and Economic Growth?: Empirical Evidence from Thailand

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Abstract

This study examines the causal linkages between economic growth and two environmental indicators in the case of Thailand, carbon dioxide emission and energy use, in an attempt to examine whether there is a trade-off between environmental conservation and economic growth in Thailand. To do so, the Vector Autoregression and Granger Causality tests were employed to investigate the causality between economic growth as measured by real GDP, carbon dioxide emission, and energy use during 1961-2010. The findings indicate only a unidirectional and positive causality running from economic growth to carbon dioxide emission, whereas there was no evidence of causality from either carbon dioxide emission or energy use to economic growth. The findings remain unchanged as per capita variables were instead analyzed. As a result, there is no trade-off between environmental conservation and economic growth in Thailand since Thailand can implement policies to reduce carbon dioxide emission and energy use without harming economic growth or the well-being of its people.

Keywords: *Environmental Conservation, Economic Growth, Carbon Dioxide Emission, Energy Use*

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การอนุรักษ์สิ่งแวดล้อมและการเจริญเติบโตทางเศรษฐกิจเป็นการได้อย่างเสียอย่างหรือไม่: หลักฐานเชิงประจักษ์จากประเทศไทย

*ศุภเจตน์ จันทร์สาส์น**

บทคัดย่อ

งานวิจัยเรื่องนี้ทำการวิเคราะห์ความสัมพันธ์เชิงสาเหตุระหว่างการเจริญเติบโตทางเศรษฐกิจและตัวชี้วัดทางด้านสิ่งแวดล้อมในกรณีของประเทศไทยจำนวน 2 ตัวชี้วัด ได้แก่ การปล่อยก๊าซคาร์บอนไดออกไซด์และการใช้พลังงาน เพื่อศึกษาว่าการอนุรักษ์สิ่งแวดล้อมและการเจริญเติบโตทางเศรษฐกิจสามารถบรรลุได้พร้อมกันหรือไม่ โดยได้อาศัยการวิเคราะห์ Vector Autoregession และการทดสอบ Granger Causality เป็นเครื่องมือในการวิเคราะห์ความสัมพันธ์เชิงสาเหตุระหว่างการเจริญเติบโตทางเศรษฐกิจซึ่งวัดโดยมูลค่าผลิตภัณฑ์มวลรวมภายในประเทศแท้จริง ปริมาณการปล่อยก๊าซคาร์บอนไดออกไซด์ และปริมาณการใช้พลังงานในช่วงปี พ.ศ. 2504-2553 จากการศึกษา พบว่า การเจริญเติบโตทางเศรษฐกิจมีอิทธิพลในเชิงบวกต่อปริมาณการปล่อยก๊าซคาร์บอนไดออกไซด์ ในขณะที่ปริมาณการปล่อยก๊าซคาร์บอนไดออกไซด์และปริมาณการใช้พลังงานไม่มีอิทธิพลใด ๆ ต่อการเจริญเติบโตทางเศรษฐกิจ นอกจากนี้ เมื่อทำการวิเคราะห์ด้วยตัวแปรซึ่งคำนวณเป็นค่าต่อบุคคล พบว่า ผลการศึกษาไม่มีการเปลี่ยนแปลงแต่อย่างใด ดังนั้น จึงสรุปได้ว่าการอนุรักษ์สิ่งแวดล้อมและการเจริญเติบโตทางเศรษฐกิจในกรณีของประเทศไทยสามารถบรรลุได้พร้อมกัน เนื่องจากนโยบายเพื่อลดปริมาณการปล่อยก๊าซคาร์บอนไดออกไซด์และปริมาณการใช้พลังงานจะไม่ส่งผลกระทบเชิงลบใด ๆ ต่อการเจริญเติบโตทางเศรษฐกิจ

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Introduction

Thailand was very successful in implementing its first seven National Economic and Social Development Plans (1961-1996) to promote the economic growth of the nation, leading to the impressive average growth rate of the gross domestic product (GDP) during this period, which equalled 5.40 percent per year (World Bank, 2012). Unfortunately, such success has come with several environmental impacts, such as pollution, national resource depletion, environmental decadence, and deforestation (NESDB, 2010). Furthermore, real GDP per capita has been found to grow more slowly than carbon dioxide emission or energy consumption during the last three decades (Chansarn, 2013).

Based on Chansarn (2013), the average growth rate of real GDP per capita during 1971-1996 equalled 5.52 percent per year, where that of carbon dioxide emission per capita and energy use per capita equalled 7.57 and 4.64 percent per year, respectively. Moreover, considering the period 1997-2008, the average growth rate of real GDP per capita, carbon dioxide emission per capita, and energy use per capita equalled 1.77, 1.82, and 2.53 percent per year, respectively. These findings are not very surprising since Thailand's economic growth has been primarily driven by the labour-intensive manufacturing sector, which normally consumes high energy and emits a great deal of pollution. According to the NESDB (2013), the proportion of the real GDP of the manufacturing sector increased from 35.82 percent of total real GDP in 1993 to 46.52 percent in 2010. That is why such a situation came about.

This fast-growing carbon dioxide emission and energy use has caused great concern regarding the sustainability of Thailand's economic and social development. The following definition is given to sustainable development by the Organization for Economic Co-operation and Development (OECD).

> *"Sustainable development can be defined in technical terms as a development path along which the maximisation of human well-being for today's generations does not lead to declines in future well-being."*
> – from Organization for Economic Co-operation and Development (2001)

Another definition is also given by the National Research Council.

"Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs." – from National Research Council (1999)

Based on these definitions, it seems that Thailand's current situation is very far from sustainable development since its development process is likely to cause an environmental problem and, of course, a detrimental impact on the well-being of future generations, who may have to live in a world without appropriate natural or environmental resources.

Accordingly, in order to achieve sustainable development, it is necessary for Thailand to find policies to reduce carbon dioxide emission and energy use. However, these environmental conservation policies may harm Thailand's economic growth since the reduction of carbon dioxide emission and energy use may cause the economic activity in manufacturing sector to decrease, leading to a trade-off between environmental conservation and economic growth. Consequently, this study aims to examine whether there is a trade-off between the environmental conservation and economic growth of Thailand. To do so, it utilized the Vector Autoregresion and Granger Causality tests to investigate the causal linkages between Thailand's economic growth and two environmental indicators, carbon dioxide emission and energy use, during 1961-2010, with the ultimate objective to prove that Thailand can formulate and implement policies to reduce carbon dioxide emission and energy use without affecting economic growth.

Literature Review

Based on the literature review, there have been several studies on the causal relationships between economic growth and environmental indicators, mostly in developing countries. For example, Sharma (2011) found that economic growth as measured by GDP determined carbon dioxide emission based on the data from 69 countries worldwide. In the case of China, Zhang and Cheng (2009) found that economic growth affected energy consumption but neither carbon dioxide emission nor energy consumption affected economic growth. However, Chang (2010) found that energy use as measured by natural gas and electricity consumption determined economic growth in China, whereas economic growth determined both carbon dioxide emission and energy use.

In addition, Li et al. (2011) and Wang et al. (2011) found an interrelationship between energy consumption and economic growth in China. Wang et al. (2011) and Xiumei et al. (2011) also found a unidirectional relationship running from economic growth to carbon dioxide emission. In India, Ghosh (2010) found bidirectional causality between carbon dioxide emission and economic growth, implying that reduction in carbon dioxide emission may cause economic growth to fall. However, Jafari et al. (2012) found that economic growth, carbon emission, and energy use were not cointegrated in Indonesia. In Malaysia, Azlina et al. (2012) found a unidirectional causality running from economic growth to energy consumption and from carbon dioxide emission to economic growth. These results contradict those of Saboori et al. (2012), who found that economic growth determined carbon dioxide emission.

Looking at the countries in Middle East and North Africa (MENA), Lotfalipour et al. (2010) found that economic growth determined carbon dioxide emission and energy use as measured by gas consumption determined economic growth in Iran. Arouri et al. (2012) also found that economic growth determined carbon dioxide emission in 12 MENA countries. In the case of other developing countries, Menyah and Wolde-Rufael (2010) found a unidirectional and positive causality running from carbon dioxide emission to economic growth and from energy consumption to economic growth, suggesting a trade-off between economic growth and environmental preservation in South Africa. However, Soytas and Sari (2009) and Ozturk and Acaravci (2010) found that neither carbon emission nor energy consumption caused economic growth in Turkey.

In the case of Thailand, Lean and Smyth (2010) found no causality running from economic growth to carbon dioxide emission. However, they found unidirectional causality from growth to carbon emission in Indonesia and Philippines. However, Narayan and Narayan (2010) found a unidirectional and positive causality running from economic growth to carbon dioxide emission in Thailand. Let us look at developed countries. Lee and Chang (2007) found that energy use positively determined economic growth only at a low level of energy use in Taiwan. However, Park and Hong (2013) found that carbon dioxide emission positively determined economic growth in South Korea. In Portugal, Pereira and Pereira (2010) found that energy consumption positively affected economic growth. Moreover, Acaravci and Ozturk (2010) found the positive influence of carbon emission on economic growth based on the data from 19 developed countries in the EU.

Based on the literature review, it is still difficult to clearly indicate the causal relationship between economic growth and carbon dioxide emission and energy use and the trade-off between environmental conservation and economic growth since the findings are different among different countries. Additionally, in the case of Thailand, the findings from two different studies are also different. This problem causes difficulty regarding policy formulation and implementation in terms of reducing carbon emission and energy use and promoting environmental conservation for Thailand without harming Thailand's economic growth or the Thai people's well-being. Consequently, the investigation of the causal relationship between economic growth and carbon dioxide emission and energy use in Thailand is still interesting and important.

Econometric Models

According to the literature review, the test of a causal relationship between the two variables has been popularly performed by the Vector Autoregression (VAR) and Granger Causality tests. Although the stationarity of variables is not required for the VAR model (Sims, 1980), it is important for the Granger Causality test. Consequently, pre-testing all variables is required to test whether they are stationary. More clearly, this study will begin with the unit root (stationarity) test by employing the Augmented Dickey-Fuller (ADF) test (Wooldridge, 2003).

The general form of the ADF test with constant term and trend can be expressed as the following:

$$\Delta y_t = \alpha + \beta t + \theta y_{t-1} + \sum_{i=1}^{k} \gamma_k \Delta y_{t-i} + e_t \text{, where } \theta = \rho - 1 \tag{1}$$

where ρ = correlation coefficient. The null and alternative hypotheses are as follows:

H_0: $\theta = 0$ that is, $\rho = 1$ (the variable is non-stationary, implying integrated of order 1)

H_1: $\theta \neq 0$ that is, $\rho \neq 1$ (the variable is stationary, implying integrated of order 0)

If the variables are non-stationary, they will be transformed into growth forms to eliminate the unit roots.

The ADF test presented above allows for the serial correlation in the residual terms by including lagged autoregressive terms (Δy_{t-i}). The optimal number of lags was chosen by utilizing Akaike's Information Criterion (AIC) (Akaike, 1974), Hannan–Quinn Information Criterion (HQIC) (Hannan and Quinn, 1979), and Schwarz's Baysian Information Criterion (SBIC) (Schwarz, 1978). These three criteria can be stated as the following:

$$AIC = \left[\frac{2n}{n-k-1}\right]k - 2\ln[L_{max}] \tag{2}$$

$$HQIC = 2\ln[\ln(n)]k - 2\ln[L_{max}] \tag{3}$$

$$SBIC = \ln[n]k - 2\ln[L_{max}] \tag{4}$$

where n = number of observations, k = number of parameters to be estimated and L_{max} = the maximized value of the log-Likelihood for the estimated model.

After the test and the treatments of unit roots, the Vector Autoregression (VAR) model will be analyzed. VAR, introduced by Sims (1980), is the regression model which includes the lagged autoregressive terms of all variables in the analysis in order to capture the dynamic reactions of each variable. The objective of VAR is to test whether the past values of each variable have influences on its current value and/or the current values of the other variables.

VAR models for examining the causal linkage between economic growth and carbon dioxide emission can be stated as follows.

$$GDP_t = \alpha_0 + \sum_{i=1}^{n} \alpha_i GDP_{t-i} + \sum_{i=1}^{n} \beta_i CO2_{t-i} + \mu_{1t} \quad (5)$$

$$CO2_t = \lambda_0 + \sum_{i=1}^{n} \lambda_i GDP_{t-i} + \sum_{i=1}^{n} \delta_i CO2_{t-i} + \mu_{2t} \quad (6)$$

Moreover, VAR models for examining the causal linkage between economic growth and energy use can be stated as the following:

$$GDP_t = \gamma_0 + \sum_{j=1}^{k} \gamma_j GDP_{t-j} + \sum_{j=1}^{k} \omega_j EN_{t-j} + \varepsilon_{1t} \quad (7)$$

$$EN_t = \phi_0 + \sum_{i=1}^{n} \phi_i GDP_{t-j} + \sum_{i=1}^{n} \varphi_i EN_{t-j} + \varepsilon_{2t} \quad (8)$$

where GDP = economic growth is measured by real GDP growth rate, CO2 = carbon dioxide emission growth rate and EN = energy use growth rate. The AIC, HQIC, and SBIC will be utilized in order to select the optimal number of lags for each VAR model in the same manner as described above.

Thereafter, the Granger Causality test will be performed in order to examine whether one variable Granger causes the other variables (Granger, 1969). In other words, it tests whether one variable can predict the other variable. Based on the VAR models, the Granger Causality between two variables can be examined using the F test.

Causality from carbon dioxide emission to economic growth exists (carbon dioxide emission Granger causes economic growth) if the estimated coefficients on the lagged CO2 in (5) are statistically different from zero as a group ($\sum \beta_i \neq 0$), and causality from economic growth to carbon dioxide emission exists (economic growth Granger causes carbon dioxide emission) if the estimated coefficients on the lagged GDP in (6) are statistically different from zero as a group ($\sum \lambda_i \neq 0$). Likewise, causality from energy use to economic growth exists (energy use Granger causes economic growth) if the estimated coefficients on the lagged EN in (7) are statistically different from zero as a group ($\sum \omega_j \neq 0$), and causality from economic growth to energy use exists (economic growth Granger causes energy use) if the estimated coefficients on the lagged GDP in (8) are statistically different from zero as a group ($\sum \phi_j \neq 0$).

Besides the VAR and Granger Causality tests, the impulse response function (IRF) will be analyzed in order to track the impact of any variable on the VAR system. In other words, the IRF examines the impacts of a unit shock in any endogenous variable on the future values of all endogenous variables in the VAR system (Hamilton, 1994). The general form of the IRF can be expressed as follows:

$$y_t = \mu + \varepsilon_t + \sum_{i=1}^{\infty} \psi_i \varepsilon_{t-i} = \mu + \psi(L)\varepsilon_t \tag{9}$$

where $\psi(L)$ denotes the infinite-degree lag operator polynomial $(1 + \psi_1 L + \psi_2 L^2 + \ldots + \psi_p L^p)$

The coefficientsare called “dynamic multipliers.” As a result, the coefficient ψ_s indicates a change in y_{t+s} due to a one unit change in ε_t. That is,

$$\psi_s = \frac{\partial y_{t+s}}{\partial \varepsilon_t} \tag{10}$$

The series $\{\psi_i\}$ indicates the change in the future value of y_{t+i} due to a one unit impulse in the innovation ε_t, without other changes in future innovations (ε_{t+i}). Consequently, the series $\{\psi_i\}$ is called the “impulse response function.”

To analyze the effects of one unit impulse in economic growth and carbon dioxide emission, the following models were estimated.

$$GDP_t = \mu_1 + \sum_{i=1}^{\infty} \psi_{11,i} \varepsilon_{GDP,t-i} + \sum_{i=1}^{\infty} \psi_{12,i} \varepsilon_{CO2,t-i} \tag{11}$$

$$CO2_t = \mu_2 + \sum_{i=1}^{\infty} \psi_{21,i} \varepsilon_{GDP,t-i} + \sum_{i=1}^{\infty} \psi_{22,i} \varepsilon_{CO2,t-i} \tag{12}$$

Based on (11) and (12) $\psi_{11,i}, \psi_{12,i}, \psi_{21,i}$ and $\psi_{22,i}$ indicate the effect of one unit impulse in either $\varepsilon_{GDP,t-i}$ or $\varepsilon_{CO2,t-i}$ on GDP_t and $CO2_t$.

Likewise, to analyze the effects of one unit impulse in economic growth and energy use, the following models are estimated.

$$GDP_t = \mu_3 + \sum_{i=1}^{\infty} \psi_{31,i} \varepsilon_{GDP,t-i} + \sum_{i=1}^{\infty} \psi_{32,i} \varepsilon_{EN,t-i} \quad (13)$$

$$EN_t = \mu_4 + \sum_{i=1}^{\infty} \psi_{41,i} \varepsilon_{GDP,t-i} + \sum_{i=1}^{\infty} \psi_{42,i} \varepsilon_{EN,t-i} \quad (14)$$

Similarly $\psi_{31,i}$, $\psi_{32,i}$, $\psi_{41,i}$ and $\psi_{42,i}$ indicate the effect of one unit impulse in either $\varepsilon_{GDP,t-i}$ or $\varepsilon_{EN,t-i}$ on GDP_t and EN_t.

In addition, the analytical method as described above was repeated in order to check the robustness of the study results, only this time, all of the variables in the analysis were transformed into per capita terms.

Data and Sources

This study relies on the time series data in the annual format of Thailand during 1961-2010. All data were obtained from the World Bank's World Development Indicators. They include real GDP per capita (million 2000 US dollars), carbon dioxide emission (metric tons), energy use (kilograms of oil equivalent), real GDP per capita (2000 US dollars), carbon dioxide emission per capita (metric tons), and energy use per capita (kilograms of oil equivalent).

Empirical Results

Table 1 summarizes the descriptive statistics of all the variables in this study. The interesting results found in this table were that, during the study period, carbon dioxide emission grew far faster than economic growth. That is, real GDP grew on average by 6.007 percent per year; however, carbon dioxide emission grew, on average, by 8.760 percent per year. In terms of energy use, although it grew more slowly than economic growth, the differences were very small. That is, real GDP per capita, on average, grew by 4.176 percent per year but energy use, on average, grew by 3.977 percent per year.

Table 1: Descriptive Statistics

Variable	Period	Observations	Mean (%)	Std. Dev. (%)
Real GDP Growth Rate	1961-2011	51	6.007	3.861
CO_2 Emission Growth Rate	1961-2009	49	8.760	9.706
Energy Use Growth Rate	1972-2010	39	5.511	4.766
Real GDP per Capita Growth Rate	1961-2011	51	4.176	3.673
CO_2 Emission per Capita Growth Rate	1961-2009	49	6.878	9.480
Energy Use per Capita Growth Rate	1972-2010	39	3.977	4.816

Remarks: Column 4 and 5 present the mean value and standard deviation of the annual growth rates of real GDP, carbon dioxide emission, energy use, real GDP per capita, carbon dioxide emission per capita and energy use per capita.

Table 2 presents the Augmented Dickey-Fuller (ADF) test statistics for the unit root test for growth and level terms of all variables. Based on the ADF test statistics, all of the variables in level terms seemed to be non-stationary as they contained unit roots, indicating that they were integrated of order 1. To fix these problems, all of the variables were calculated into growth terms. The ADF test statistics clearly showed that the growth rates of all the variables were integrated of order 0, implying the stationarity of these variables.

Table 2: ADF Test for Stationarity

Variable	Period	Stationarity (Growth Term)	Stationarity (Level Term)
Real GDP	1961-2011	-4.023* (1)	-1.805 (2)
CO_2 Emission	1961-2009	-6.386* (0)	-1.756 (3)
Energy Use	1972-2010	-3.208*** (1)	-1.327 (1)
Real GDP per Capita	1961-2011	-3.917** (1)	-2.184 (2)
CO_2 Emission per Capita	1961-2009	-6.321* (0)	-2.078 (2)
Energy Use per Capita	1972-2010	-3.141*** (1)	-1.683 (1)

Remarks: Column 3 and 4 present the Augmented Dickey-Fuller test statistics for the unit root test for growth and level terms of real GDP, carbon dioxide emission, energy use, real GDP per capita, carbon dioxide emission per capita and energy use per capita. The number of lags is presented in parentheses. Akaike's Information Criterion (AIC), Han nan–Quinn Information Criterion (HQIC), and Schwarz's Baysian Information Criterion (SBIC) were employed to select the number of lags. Trend and constant terms were included in all test equations. The null hypothesis is that each variable is non-stationary. Moreover, *, ** and *** indicate the statistical significance (rejection of the null hypothesis) at the 1, 5 and 10 percent level, respectively.

Now, all of the variables are stationary and the VAR analysis and Granger Causality tests can be estimated. Before doing so, Akaike's Information Criterion, Hannan–Quinn Information Criterion, and Schwarz's Baysian Information Criterion were analyzed in order to choose the optimal lag lengths for each VAR model. The results are presented in Table 3. After considering AIC, HQIC and SBIC, two lag orders were selected for the VAR analysis of economic growth and carbon dioxide emission, while one lag order was selected for the VAR analysis of economic and energy use.

Table 3: Lag Length Selection for VAR Analysis Employing AIC, HQIC, and SBIC

Model	Akaike's Information Criterion (AIC)	Hannan-Quinn Information Criterion (HQIC)	Schwarz's Baysian Information Criterion (SBIC)	Optimal Lag Length Selection for VAR Analysis
GDP and CO2	2 (12.4021)	1 (12.5161)	1 (12.6672)	2
GDP and EN	1 (11.0934)	1 (11.1854)	0 (11.3042)	1
GDPC and CO2C	2 (12.3830)	1 (12.4865)	0 (12.5911)	2
GDPC and ENC	1 (11.0894)	1 (11.1815)	0 (11.2661)	1

Remarks: Column 2, 3 and 4 present the number of lags selected using Akaike's Information Criterion (AIC), Hannan–Quinn Information Criterion (HQIC), and Schwarz's Baysian Information Criterion (SBIC), respectively. The figures given in parentheses are the AIC, HQIC, and SBIC values. Column 5 presents the optimal number of lags selected for Vector Autoregression (VAR) analysis. It is the highest number of lags suggested by AIC, HQIC or SBIC. GDP = growth rate of real GDP, CO2 = growth rate of carbon dioxide emission, EN = growth rate of energy use, GDPC = growth rate of real GDP per capita, CO2C = growth rate of carbon dioxide emission per capita, ENC = growth rate of energy use per capita.

The results of the VAR analysis and Granger Causality test are presented in Table 4. The findings reveal that economic growth as measured by real GDP was determined by one year lagged real GDP and two year lagged carbon dioxide emission. That is, a one percent increase in real GDP growth rate in year t – 1 will lead to a 0.635 percent increase in real GDP growth rate in year t, whereas a one percent increase in carbon dioxide emission growth rate in year t – 2 will lead to a 0.116 percent increase in real GDP growth rate in year t. When looking at the carbon dioxide emission (CO2) equation, the findings revealed that carbon dioxide emission was affected by one year lagged economic growth. That is, a one percent increase in real GDP growth rate in year t – 1 will cause carbon dioxide emission to increase by 1.1 percent in year t. Now let us look at the causal relationship between economic growth and energy use. The finding revealed that economic growth did not cause energy use and energy use did not cause economic growth at any significant level.

The results remained unchanged as real GDP per capita, carbon dioxide emission per capita, and energy use per capita were analyzed. That is, economic growth as measured by real GDP per capita was determined by one year lagged real GDP per capital and two year lagged carbon dioxide emission per capita. Based on Table 3, the real GDP per capita growth rate will increase by 0.106 percent in year t if the carbon dioxide emission per capita growth rate increases by 1 percent in year t – 2. It will also increase by 0.607 percent in year t if the real GDP per capita growth rate increases by 1 percent in year t – 1. Additionally, carbon dioxide emission is clearly affected by economic growth since a one percent increase in real GDP per capita growth rate in year t – 1 will lead to a 1.012 percent increase in carbon dioxide emission per capita growth rate in year t. However, a causal relationship between economic growth and energy use was not found.

The Granger Causality test statistics are also presented in Table 4. The findings revealed that only the estimated coefficients on the lagged real GDP in the carbon dioxide emission equation were statistically different from zero as a group. The results remained the same in the case of the equation of carbon dioxide emission per capita. That is, the estimated coefficients on the lagged real GDP per capita in carbon dioxide emission per capita equation were statistically different from zero as a group. However, the coefficients of the lagged carbon dioxide emission in real GDP equation were not statistically different from zero as a group. Consequently, it is sensible to conclude that there is a unidirectional causality running from economic growth to carbon dioxide emission. In other words, economic growth Granger causes carbon dioxide emission.

Table 4: Results from VAR Analysis and Granger Causality Tests

		Endogenous Variables				Granger Causality Test	
VAR Model	**Equation**	**GDP_{t-1}**	**GDP_{t-2}**	**$CO2_{t-1}$**	**$CO2_{t-2}$**	**F-Stat**	**Granger Causality**
GDP and CO2	GDP	0.635*	-0.268	-0.016	0.116**	1.780	CO2 $\nrightarrow$ GDP
		(0.000)	0.114	(0.776)	0.038)	(0.181)	
	CO2	1.100**	0.322	-0.095	-0.041	4.090**	GDP $\rightarrow$ CO2
		(0.012)	0.490	(0.544)	0.789)	(0.024)	
VAR Model	**Equation**	**GDP_{t-1}**	**GDP_{t-2}**	**EN_{t-1}**	**EN_{t-2}**	**F-Stat**	**Granger Causality**
GDP and EN	GDP	0.473**	-	0.001	-	0.030	EN $\nrightarrow$ GDP
		(0.015)		(0.997)		(0.873)	
	EN	0.156	-	0.207	-	0.380	GDP $\nrightarrow$ EN
		(0.521)		(0.327)		(0.542)	
VAR Model	**Equation**	**$GDPC_{t-1}$**	**$GDPC_{t-2}$**	**$CO2C_{t-1}$**	**$CO2C_{t-2}$**	**F-Stat**	**Granger Causality**
GDPC and CO2C	GDPC	0.607*	-0.279	-0.023	0.106***	1.540	CO2C $\nrightarrow$ GDPC
		(0.000)	0.089	(0.675)	(0.053)	(0.227)	
	CO2C	1.012**	0.224	-0.079	-0.033	3.190***	GDPC $\rightarrow$ CO2C
		(0.022)	0.629	(0.612)	(0.832)	(0.051)	
VAR Model	**Equation**	**$GDPC_{t-1}$**	**$GDPC_{t-2}$**	**ENC_{t-1}**	**ENC_{t-2}**	**F-Stat**	**Granger Causality**
GDPC and ENC	GDPC	0.431**	-	0.014	-	0.010	ENC $\nrightarrow$ GDPC
		(0.029)		(0.934)		(0.935)	
	ENC	0.136	-	0.234	-	0.270	GDPC $\nrightarrow$ ENC
		(0.588)		(0.267)		(0.606)	

Remarks: Columns 3 to 6 present the regression coefficients of the lag values of endogenous variables in each VAR model. Column 7 presents the F-stat for Granger Causality test. The null hypothesis is that there is no Granger Causality between two endogenous variables. Moreover, *, ** and *** indicate a statistical significance (indicating Granger Causality between two endogenously variables) at the 1, 5 and 10 percent level, respectively. The figures in the parentheses are P-Values. Column 8 summarizes the Granger Causality between two endogenous variables.

Furthermore, since the estimated coefficients on the lagged energy use in the real GDP equation and the estimated coefficients on the lagged real GDP in energy use equation were not statistically different from zero as a group, there was no causal relationship between energy use and economic growth. In other words, these two variables are considered independent in the case of Thailand.

Figure 1 and Figure 2 illustrate the impulse response functions showing the effects of economic growth shock and carbon dioxide emission shock. Note that economic growth was measured by real GDP in Figure 1 but measured by real GDP per capita in Figure 2. The findings from these two figures are very similar. Based on these two figures, a one unit shock in carbon dioxide emission seemed to have no effect on economic growth in the later periods. It did not have any effect even on carbon dioxide emission in the later periods. In contrast, the figures clearly show that a one unit shock in economic growth had a positive impact on carbon dioxide emission in the later periods. That is, the economic impulse in the current year will cause carbon dioxide emission to increase in the next year. Thereafter, carbon dioxide emission tends to decrease in the following periods before the shock dies out at around four years.

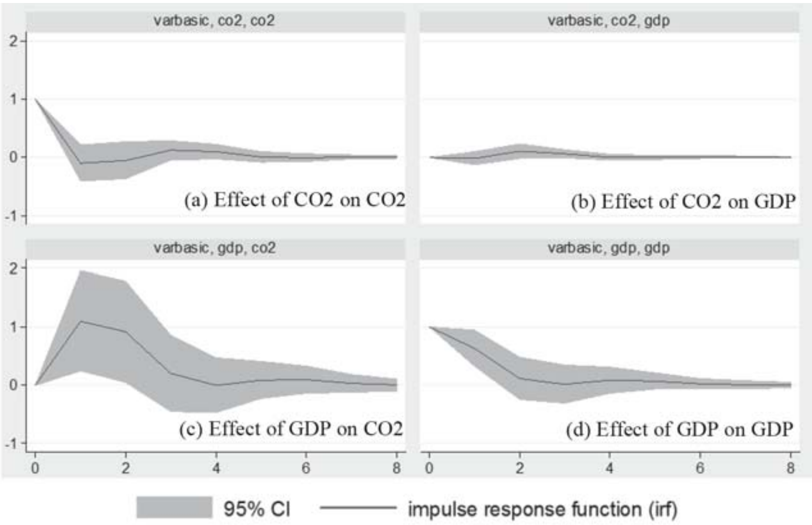

Figure 1: Impulse Response Functions Showing the Effect of Real GDP Shock and Carbon Dioxide Emission Shock

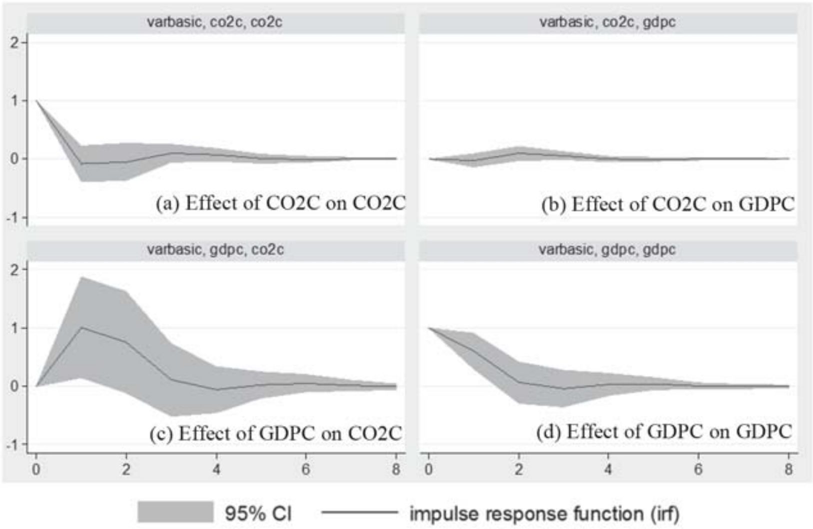

Figure 2: Impulse Response Functions Showing the Effect of Real GDP per Capita Shock and Carbon Dioxide Emission per Capita Shock

Figure 3 and Figure 4 present the impulse response functions showing the effects of economic growth shock and energy use shock. These two figures clearly support the Granger Causality test results, which indicate that there is no causality between economic growth and energy use. According to Figure 3 and Figure 4, a one unit shock in energy use seems to have no impact on economic growth in the later periods, whereas a one unit shock in economic growth seemed to have very little impact on energy use in the later periods. That is, the initial impulse in economic growth will lead to a very slight increase in energy use in the next year before the shock dies out at about two years.

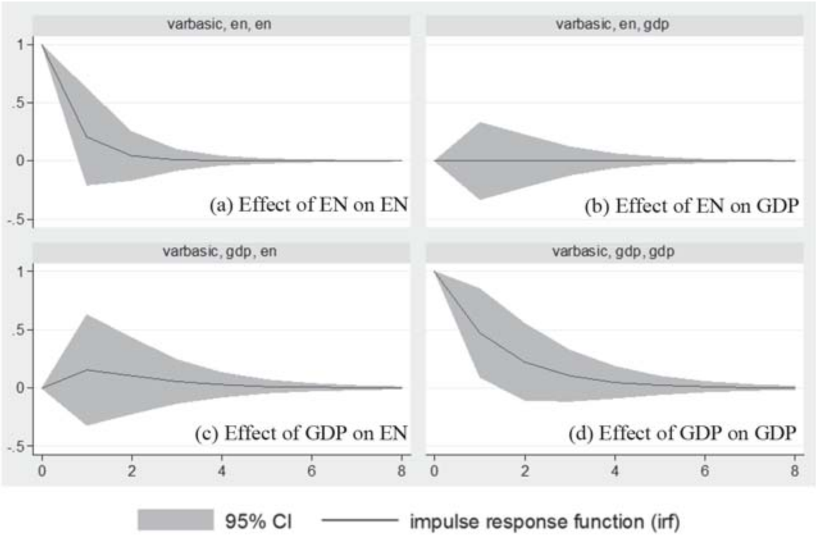

Figure 3: Impulse Response Functions Showing the Effect of Real GDP Shock and Energy Use Shock

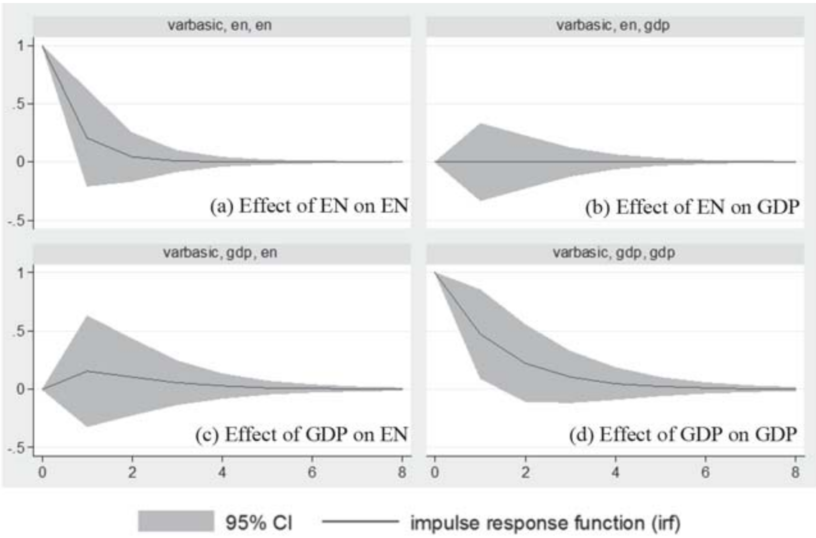

Figure 4: Impulse Response Functions Showing the Effect of Real GDP per Capita Shock and Energy Use per Capita Shock

Discussion

The findings from this study suggest a unidirectional causality running from economic growth to carbon dioxide emission in Thailand. That is, economic growth will lead to the increase in carbon dioxide emission in the nation. This finding complies with that of Acaravci and Ozturk (2010), Lotfalipour et al. (2010), Wang et al. (2011), Xiumei et al. (2011), Arouri et al. (2012), Saboori et al. (2012), and Park and Hong (2013). Additionally, this finding supports Narayan and Narayan (2010), who found unidirectional and positive causality running from economic growth to carbon dioxide emission in Thailand. It contradicts the work of Lean and Smyth (2010), however, who found no causality running from economic growth to carbon dioxide emission. Furthermore, this study also found that neither carbon dioxide emission nor energy use caused economic growth in Thailand. This finding also complies with that of Soytas and Sari (2009) and Ozturk and Acaravci (2010).

These findings imply that in Thailand, carbon dioxide is not mainly emitted by production, which is the primary economic activity for creating economic growth. Instead, it seems to be produced by consumption. This statement can be supported by the finding that economic growth positively determines carbon dioxide emission. This is because economic growth tends to improve the standard of living of people, leading to higher purchasing power, more consumption and, of course, higher carbon dioxide emission. Moreover, the findings also imply that energy use and economic growth are not relevant. Consequently, there is no trade-off between environmental conservation and economic growth in Thailand since it is possible for Thailand to formulate and implement a public policy to reduce carbon dioxide emission and energy use without forgoing the economic growth of the nation. In other words, environmental conservation and economic growth can be simultaneously achieved in Thailand.

Conclusion and Recommendations

This study investigated the causal relationship between economic growth as measured by real GDP and two environmental indicators, carbon dioxide emission and energy use, in Thailand during 1961-2010 by employing the Vector Autoregression and Granger Causality tests. The findings revealed that economic growth as measured by real GDP Granger caused carbon dioxide emission in Thailand. In other words, there is a unidirectional causality running from economic growth to carbon dioxide emission. Nevertheless, economic growth was found to have no effect on energy use. Additionally, neither carbon dioxide emission nor energy use had an impact on economic growth in Thailand. Consequently, there is no trade-off between environmental conservation and economic growth in Thailand.

Therefore, in order to reduce carbon dioxide emission and energy consumption, public policies and campaigns are necessary to encourage people to realize the necessity of natural resource conservation and environmental protection. Environmental laws and regulations must be carried out and strictly enforced. In addition, public policies to promote human capital in the nation are also recommended. The greater human capital will make the people of the nation more productive and more competitive, enabling them to have greater economic opportunity, higher income, and better access to social services. The community, society, and nation will eventually be strengthened as these people will realize the importance of natural resource conservation and environmental protection. Moreover, human capital will also enable Thailand to develop capital intensive industries which emit less carbon dioxide and consume less energy, and which enable businesses to employ more eco-friendly technology. With these policies, Thailand will have a good opportunity to achieve sustainable development and sustained economic growth in the long run.

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