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CO_2 Emissions, Energy Consumption, Economic Growth and Agricultural Development in ASEAN's Developing Members

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Abstract: This paper investigates the dynamic causal relationships among environmental degradation, economic growth, energy consumption and agricultural development in Association of South East Asian Nations' (ASEAN) five members. This panel sample shows evidence that supports the Environmental Kuznets Curve (EKC), and that CO_2 emissions begin to decline when income level reaches to 8.602 (in logarithms). Applying Granger causality test, we find the existence of causality nexuses among these variables. The estimated results support feedback hypothesis, and these members as a whole seem to loosen their environmental protection regulations to reach their economic goals. A cut in CO_2 emissions thus will hurt their growth. Furthermore, the results suggest implication that economic development promotes ASEAN developing countries' agricultural productivity growth. This also partially supports evidence of these countries firms' investment transition to agricultural sector, after gaining benefits of industrialization and modernization within these countries. On the other hand, any negative shocks to their economies will adversely affect their agricultural development.

Keywords: ASEAN, EKC curve, Granger Causality, Agricultural Development, Energy Consumption, CO_2 Emissions

JEL Classification Number: C33, O44, O53

1. Introduction

Energy consumption is one of the important engines of economic development, and the usage of energy is associated with an increase in carbon dioxide (CO_2) emissions. Current literature has focused on the causality relationships among energy, economic growth and environmental degradation, as well as connected them with other indicators such as financial development, foreign direct investment (FDI) or trade openness (Keppler and Mansanet-Bataller, 2010; Pao and Tsai, 2011 and Ozturk and Acaravci, 2013).

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Meanwhile, agriculture is always an important determinant of the economies, in both the developed and developing countries. Chenery and Syrquin (1975) find that agriculture contributes to economic growth by releasing resources (labor and savings) for using in other sectors. Go further, Mellor (2000) states that agriculture's role is more important in reducing poverty and encouraging domestic demand. Applying this consideration to industrialized countries, Johnson (1997) recognizes that the growth of total factor productivity in the OECD countries in agriculture has been greater than in manufacturing during the past quarter century or more. The increase in agricultural productivity still constitutes an important source of the high income economies, which largely driven by the spread of information and communication technology (ICT), and by the investment in human and physical capital, *among others* (OECD, 2013). In another aspect in South East Asian developing countries such as Indonesia, Malaysia, Philippines or Vietnam, the high economic growth is affected by a high volume of exports, plentiful natural resources, longer life expectancy and higher investment rates (Upreti, 2015). The income growth may support the development of agricultural production in these countries in return, by the increase in investment and the application of new technology to agricultural sector.

For example, in a particular case of Vietnam, on the one hand, Vietnamese government has increasingly interested in agricultural development, agricultural production productivity tends to increase, combining with the infrastructure improvement in rural area (Vietnam National Productivity Institute, 2014). On the other hand, Vietnam's firms begin putting their focus on agricultural sectors.[1] Gaining much benefit after many years operating in high growth sectors such as industrial production, real estates or banking, and receiving their government's encouraging policies, these firms have opened their investments to agricultural sectors. They invest not only in domestic agricultural production but also invest abroad in Cambodia, Laos, and Myanmar *among others* (Vietnamese MARD, 2016). These firms' capital surplus and agriculture sector's development potential, which partially come from government's investment and attractive policies, should be the motivation of their investment transition. Investment shifting phenomenon to domestic and oversea agricultural production is also appeared in other ASEAN's members such as Indonesia, Malaysia, Singapore or Thailand (ASEAN National Communications Desks, 2016). For examples, ASEAN's members have abroadly invested 81 agricultural projects in Vietnam, equaling 1.08 billion US dollars, occupying 2% in ASEAN's total invested capital in Vietnam by May 2016. The largest investors (from ASEAN) to Vietnam's agriculture is Thailand (29 projects, 477 million US dollars),

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[1]Agricultural sectors correspond to ISIC divisions 1-5 and consist of activities in agriculture, forestry, hunting, and fishing. For the good explanation, the reader is referred to http://data.worldbank.org/topic/agriculture-and-rural-development?view=chart).

followed by Singapore (28 projects, 335 million US dollars) and Malaysia (18 projects, 146 million US dollars) *among others*.

While literature suggests contribution of agricultural production to economic growth, there is rare evidence shows the effect of the vice versa. In addition, rising energy prices as well as changing energy and environmental policies have transformed the relationship between energy and agriculture sectors. Since the past decade, the mutual importance of energy and agriculture has been expressed, and the energy sector's use of agricultural products as renewable-fuel feedstocks has increased substantially (Beckman et al., 2013). There are numerous literatures have verified the relationships among energy use, economic growth and environmental degradation, which might be called economic – environmental linkages (by our paper). This is a guarantee to extend the scope of recent interest, and we add agricultural development to one model showing economic – environmental linkages.[2] This study then examines the causality nexuses between agricultural development, economic growth, energy consumption and CO_2 emissions in a panel sample of developing countries within Association of South East Asian Nations. The linkages between ASEAN's members have been high, which might accompany with the investment expansion among these countries, especially after the establishment of ASEAN Economic Community in 2015. Within ASEAN's members, due to the lack of data of Brunei Darussalam, Cambodia, Laos and Myanmar, this paper thus uses the rest developing countries data to do the analysis. They include Indonesia, Malaysia, Philippines, Thailand and Vietnam.

This paper not only investigates the causality relationships among above-mentioned indicators of ASEAN's five developing members, but also estimates the effect of economic and agricultural development on environmental degradation within these countries, by applying Environmental Kuznetz Curve (EKC) method. This is one of the most popular approaches used in analyzing the relationships between economic factors and environment. EKC theory suggests that environmental pollutant increases in the early stages of economic growth, but the trend reverses beyond some level of income per capita (Stern, 2004). The theory implies that the environmental impact indicator is an inverted U-shaped function of other economic variables. Current literature often includes financial and trade development as economic indicators to test ECK hypothesis in the both developed and developing countries (Pao and Tsai's, 2011 and Chandran and Tang, 2013; Javid and Sharif, 2016). Meanwhile, agricultural production is also an important factor of economic development. Its outputs further are important inputs of renewable energy production. It also consumes energy and emits CO_2 to the natural environment. Based on

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[2]This paper uses agricultural value-added as proxy of agricultural development, which is a measure of agricultural productivity (World Bank, 2016).

these arguments, we collect agricultural value-added variable to the ECK model of ASEAN's five developing members and examine whether these countries trade the environment degradation for agricultural development.

The rest of this study is structured as follows: the second section explains literature review, the third section presents methodology, the fourth section shows empirical results, and the last section expresses the conclusion.

2. Literature Review

2.1. Literature on Energy Consumption, CO_2 Emissions and Economic Growth

Current literature has focused on the relationships among energy consumption, economic growth and CO_2 emissions (we call this is economic – environmental linkages). Narayan and Narayan (2010) test EKC hypothesis for 43 developing countries by examining the short- and long-run income elasticities. Using the panel cointegration and panel long-run estimation techniques, these authors find that only for South Asian and Middle Eastern regions, the long-run income elasticity is smaller than that of the short run. This implies that CO_2 emissions have fallen with a rise in income. Pao and Tsai (2010) also test EKC hypothesis and investigate the relationships between three said variables, but in BRIC countries. Their panel causality estimation shows that energy consumption has bidirectional strong nexuses with pollution and output in the long-run, along with unidirectional causalities from emissions and energy consumption to output in the short-run, respectively. They then suggest that the energy-dependent BRIC countries should build up energy conservation policies, increase energy supply investment and energy efficiency in order to improve environment. Alam et al. (2011) employ a dynamic modeling approach to investigate the causal relationships between energy use, CO_2 emissions and income in India. These authors suggest the presence of bidirectional causal relationship between energy consumption and CO_2 emissions in the long-run. Furthermore, their results show no causality nexus between income and energy consumption in the long-run. These findings imply that India may concentrate on energy conservation and efficiency improvement polices without impeding economic growth.

Alkhathlan and Javid (2013) apply aggregate and disaggregate analyses in the linkages between energy consumption, environmental degradation and economic growth in Saudi Arabia. They find that electricity produces less CO_2 than other energy sources. Their study also concludes the existence of a positive relationship between pollution and economic development. Saboori et al. (2014) focus on the road transport sector of OECD countries and find causality relationships among road sector energy consumption, economic growth and CO_2 emissions. These authors also suggest that OECD countries need to interest in energy diversification to enhance energy efficiency. This goal can be reached by investing in biofuel, renewable and nuclear energy. Using the panel of Gulf Cooperation Council

(GCC) countries, Hamdi and Sbia (2014) test the Granger causality between pollution, energy consumption and growth at aggregate level. Their results support the EKC hypothesis in the long-run and provide evidence of two-way relationship between energy consumption and CO_2 emissions in the short-run.

2.2. Literature on Energy Consumption, CO_2 Emissions and Economic Growth in Linkages with other Economic Indicators and Agricultural Development

Recent literature interests not only in the energy-growth-environment relationship, but also in the associations between these indicators with financial development, trade openness and even urbanization. Pao and Tsai (2011) investigate these associations in BRIC countries, and find that the pollution is inelastic with the changes in foreign direct investment (FDI). Their results present the existence of strongly bidirectional nexus between CO_2 emissions and FDI as well as unidirectional causal relationship running from Gross Domestic Products (GDP) to FDI. These authors then suggest that BRIC countries should strictly examine the qualifications for attracting FDI to reduce environmental degradation. Shahbaz et al. (2013) examine the linkages among above- mentioned variables in Indonesia, and find the existence of structural breaks in long-run relationship between variables. Their results suggest that Indonesia should use energy efficient technologies to protect the environment. Meanwhile, financial development and trade openness may take higher role in reducing pollution. Dugan and Turkekul (2016) take trade, financial development and urbanization into the environmental linkages and test the EKC hypothesis for the USA. They find that energy consumption and urbanization increase emissions while financial development has no effect on it in the long-run, Furthermore, trade leads to environmental improvements. However their results do not support the validity of the EKC hypothesis for the USA because real output leads to environmental improvements while the square of GDP increases the levels of gas emissions. The results from the Granger causality test show that there are bidirectional causality linkages between CO_2 and GDP, CO_2 and energy consumption, CO_2 and urbanization, GDP and urbanization, and GDP and trade openness while no causality is determined between CO_2 and trade openness, and gas emissions and financial development. The unidirectional causalities running from GDP to energy consumption, from financial development to output, and from urbanization to financial development are found. These authors present that the U.S. government should take into account the importance of trade openness, urbanization, and financial development in controlling for the levels of GDP and pollution. There are also other literature investigate the relationship between said indicators, including Ozturk and Acaravci (2013), Islam et al. (2013) and Shahbaz et al. (2013a, 2013b) *among others*.

While study on the nexus of energy-emissions-growth and financial development, trade openness and urbanization has been abundant, there is rare literature includes agricultural development into the environmental linkages. Furthermore, existing literature often separately looks into the relationship of energy consumption, economic development or environmental degradation with agricultural development. Mushtaq et al. (2007) test the linkages between real agricultural GDP, energy prices and agricultural energy consumption (oil, gas and electricity) in Pakistan. Their results express a unidirectional causality running from agricultural GDP to oil consumption, and another one from electricity consumption to agricultural GDP. These authors then suggest that Pakistan should develop the infrastructure and subsidize rural and agricultural electricity in order to increase agricultural output. Chebbi and Boujelbene (2008) investigate the causality nexus between energy consumption and agricultural outputs. They find a unidirectional causality running from agricultural outputs to energy consumption. Their results indicate that Tunisian agricultural sector growth does not depend on energy, and high energy consumption does not imply more productivity for this sector in the short-run. Also looking into Tunisia's agriculture, Sebri and Abid (2012) examine the causality linkages between agricultural value-added, energy use and trade openness. They find the unidirectional Granger causality running from energy consumption to agricultural value-added, and from this factor to oil energy consumption. Agricultural policy makers should forecast and manage any shocks in energy supply, which strongly effect on agricultural production.

3. Methodology

3.1. Data

The data used in this article includes real GDP per capita and agricultural value-added per worker. These two variables are measured by 2005 constant US dollars. The unit used for energy consumption and CO_2 emission is kilotones (kt) oil equivalence, and for CO_2 emissions is kt CO_2 emissions. All datasets were obtained from the World Bank Indicator database. We denote *IN*, *AVA*, *ENER* and CO_2 to represents GDP per capita, agricultural value-added per worker, energy consumption and CO_2 emissions, respectively. All four indicators are observed annually in the panel of five ASEAN's developing members from 1985 until 2011, which contributes to a balanced panel data (5x27) with 175 observations.

3.2. Panel Unit Root Test

The economic variables used in this study are cross-sectional units which are observed over time. Thus, these variables may have stochastic trends and therefore be non-stationary, resulting to estimates that are likely to be spurious in nature (Engle and Granger, 1987). To avoid this spurious regression problem, the unit root tests are employed in order to examine whether variables are stationary or non-stationary (have unit root).

This study uses five recent types of panel unit root tests. These are: Levin *et al.* (LLC), Breitung, and Im, Pesaran and Shin (IPS), and two Fisher-types tests. In these tests, LLC is a generalization of the ADF individual unit root test to a common panel unit root test. The null hypothesis is that each individual time series contains unit root against the alternative that each time series is stationary. IPS test has the same null hypothesis with LLC but the alternative allows for some of the individual series to have unit roots. Both LLC and IPS tests require N (number of cross-sectional units) $\rightarrow \infty$ such that N/T $\rightarrow 0$ (T is number of time periods), i.e., N should be small enough relative to T, which indicates LLC and IPS have size distortions if N gets large relative to T. Breitung (2000) found that the LLC and IPS tests suffer from a dramatic loss of power if individual-specific trends are included. The Breitung unit root test includes individual fixed effects and individual trends as regressors, with the same null and alternative hypotheses with LLC test. Fisher-type tests proposed by Maddala and Wu (1999) and Choi (2001) combine the p-values from unit root tests for each cross-section unit to test for unit roots in the panel data, where the alternative hypothesis would allow some groups to have unit root while others may not. While IPS is an asymptotic test, which depends on $N \rightarrow \infty$, Fisher-type is an exact test which depends on $T \rightarrow \infty$ (Maddala and Wu, 1999). In Fisher-type tests, Fisher augmented Dickey-Fuller (Fisher ADF) test can use different lag lengths in the individual ADF regressions and can be applied to any other unit root tests, and Fisher Phillips-Perron (Fisher PP) test removes the autocorrelation using an adjustment to the standard errors.

3.3. Panel Cointegration Test

Granger (1981) and Granger and Weiss (1983) introduced a definition for cointegrating vector as follows:

The components of the vector $y_t = (y_{1t}, y_{2t}, \ldots, y_{nt})'$ are said to be co-integrated of order d, b where $b > 0$, denoted $y_t \sim CI(d,b)$, if (i) all components of y_t are $I(d)$; and (ii) there exists a vector $\alpha = (\alpha_1, \alpha_2, \ldots, \alpha_n)$ (α # 0) that the linear combination $z_t = \alpha_1 y_{1t} + \alpha_2 y_{2t} + \ldots + \alpha_n y_{nt}$ is integrated of order $(d-b)$ or $z_t = \alpha' y_t \sim I(d-b)$. The vector α is called the *co-integrating vector*.

In the case that all the variables in the model are non-stationary but the first difference of each is stationary, the spurious regressions may still be avoided. The condition is that any existing linear combination of the series is integrated of order zero or one (which means that these variables are cointergrated of order smaller than 1) (Engle and Granger, 1987). For clearing interpretation, if y and x are nonstationary $I(1)$ variables, and the linear combination of them, such as, $e = y - \beta_1 - \beta_2 x$, is stationary (or integrated of order zero, I(0)), y and x are said to be cointegrated (Hill *et al.*, 2009). The cointegrating relationships imply long-run equilibrium relationships among these variables.

3.4. Granger Causality Test

Granger causality test investigates the direction of causality between variables, which is the lack of the autoregressive distributed lag (ARDL) method. If the null hypothesis of cointegrating equation cannot be rejected, Granger causality test will be applied in the context of vector autoregression (VAR). In the case that the cointegration tests suggest the existence of at least one cointegrating relation and of long-run equilibrium relationships between related indicators, Granger causality test in the context of vector error-correction model (VECM) will help us know whether past value of one variable affects another variable in the current period. These test results also indicate the directions of causal relationships between variables. The Granger causality test in the context of VECM framework is as follows:

$$\Delta Y_{i,t} = \alpha_{10} + \alpha_{11}(Y_{i,t-1} - X_{i,t-1}) + \delta_{11}\Delta Y_{i,t-p} + \delta_{12}\Delta X_{i,t-p} + \beta_1 \Delta z_{i,t-p} + e_{i,t} \quad (1)$$

$$\Delta X_{i,t} = \alpha_{20} + \alpha_{21}(Y_{i,t-1} - X_{i,t-1}) + \delta_{21}\Delta Y_{i,t-p} + \delta_{22}\Delta X_{i,t-p} + \beta_2 \Delta z_{i,t-p} + v_{i,t}$$

where $i = 1,..., N$ denotes the countries, $t = 1, ..., T$ denotes the time period, Δ denotes change operator, $Y_{i,t}$ and $X_{i,t}$ is a pair of endogenous variables, z is the vector of other variables, β_1 and β_2 are vectors of its parameters in each equation; $e_{i,t}$ *and* $v_{i,t}$ are two error terms; and $(Y_{i,t-1} - X_{i,t-1})$ is the error correction term (ECT). α_{11} and α_{21} are the parameters that show the speed of adjustment to the long-run equilibrium, which might confirm the long-run relationship between variables.

Granger causality test will examine whether $X_{i,t-p}$ (or $Y_{i,t-p}$) affect $Y_{i,t}$ (or $X_{i,t}$) through the significance of δ_{12} and δ_{21}, which might express the short-run causality relationship. If both δ_{12} and δ_{21} are significant, we conclude the bi-directional causality between $X_{i,t}$ and $Y_{i,t}$. If only one between δ_{12} and δ_{21} is significant, we conclude the uni-directional relationship from $X_{i,t}$ to $Y_{i,t}$ or from $Y_{i,t}$ to $X_{i,t}$. If both δ_{12} and δ_{21} are insignificant, then there is no short-run causality relationship between these two variables. If any component of β_1 and β_2 is significant, unidirectional relationships also exist from the corresponding component in vector $z_{i,t-p}$ to $Y_{i,t}$ or $X_{i,t}$. Long-run causality is determined by the error correction term, whereby if it is significant and negative, then it indicates evidence of long-run causality from the explanatory variable to the dependent variable. If both α_{11} and α_{21} are significant, we conclude the long-run bidirectional relationship between $X_{i,t}$ and $Y_{i,t}$. Finally, if only one between α_{11} and α_{21} is significant, we conclude long-run unidirectional relationship from $X_{i,t}$ to $Y_{i,t}$, or from $Y_{i,t}$ to $X_{i,t}$.

3.5. EKC Model Form

The standard EKC regression model has natural logarithmic form in all variables (dependent and independent), and also has logarithmic quadratic form in some independent variables. This natural logarithmic form permits us to estimate the constant elasticity from each estimated coefficient, which expresses constant relative change between a regressor and dependent variable.

EKC theory implies that the environmental impact is an inverted U-shaped function of income. Based on the EKC hypothesis, a linear logarithm quadratic model is formed to express the relationships between CO_2 emissions, energy consumption, income and agricultural value-added as follows:

$$lnCO_{2i,t} = \beta_0 + \beta_1 lnENER_{i,t} + \beta_2 lnIN_{i,t} + \beta_3 lnIN^2_{i,t} + \beta_4 lnAVA_{i,t} + v_{i,t} \quad (2)$$

or

$$lnCO_{2i,t} = \beta_0 + \beta_k X_{i,t} + v_{i,t} \quad (3)$$

where $i = 1, \ldots, N$ denotes the country, $t = 1, \ldots, T$ denotes the time period, $X_{i,t}$ is the vector of explanatory variables and $v_{i,t}$ is the error term, which is assumed to be serial uncorrelated.

4. Empirical Results

4.1. Panel Unit Roots Tests

The unit root test equation of LLC, IPS and Fisher-types tests only contain an intercept, while the equation of Breitung test includes the individual fixed-effect intercepts and time trends by augmenting a time specific constant. The null and alternative hypotheses of Levin *et al*. (LLC), Breitung, and Im, Pesaran and Shin (IPS), and two Fisher-types tests are summarized in Table 1. A series is considered as stationary of all unit root tests reject the null hypothesis.

Table 1:. The Null and Alternative Hypotheses of Unit Root Tests

Test	Null hypothesis	Alternative hypothesis
LLC (no trends)	Panel contains a unit root	Panel is stationary
Breitung (include trends)	Panel contains a unit root	Panel is stationary
IPS (no trends)	Panel contains a unit root	Some of the individual series have unit roots
Fisher-type (no trends)	Each sample contains unit root	Some groups to have unit root

Table 2 shows unit root tests' results, which are performed at level and fist difference. The row "level" in each series indicates that *lnAVA* is nonstationary after all kinds of tests while Breitung and IPS tests suggest that $lnCO_2$ and *lnENER* are nonstationary. Breitung test further states that there are unit root for the series *lnIN* and $lnIN^2$. The same unit root tests are applied to the first difference of all series. The tests' results in rows "1st dif." Table 2 indicate that all variables can be made stationary by taking the first difference, and are integrated of order one, denoted as I(1), and this is unnecessary to test unit root at second difference. We thus assume a vector Z_{it} including $lnCO_{2it}$ and all other variables in model consisting of Equation 3. From the panel unit root test results, all components of the vector Z_{it} are I(1), or the first difference $\Delta Z_{i,t} = (1-L)Z_{it}$ is integrated of order zero, where L is the lag operator of $Z_{i,t}$ and $(1 - L)$ is the first difference. This is the insurance for further cointegration tests among variables while the spurious regressions can be overcome.

4.2. Panel Cointegration and Granger Causality Tests

The first test that we used to examine the panel cointegration is Kao's (Engle-Granger based) test. Kao's (1999) test conveys residual-based tests for cointegration regression in panel data, which is suitable in testing the cointegration of all series that are integrated of order one. Kao (1999) applied Dickey-Fuller (DF) and Augmented Dickey-Fuller (ADF) tests, which are based on a simple ordinary least squares (OLS) regression of the residual, to test the null of no cointegration in panel data. The statistics were constructed to confirm that the limiting distribution of all tests converges to a standard normal distribution.

Table 2: Panel Unit Root Tests Results at Level and 1st Difference

		Common		Individual		
		LLC	**Breitung**	**IPS**	**Fisher ADF**	**Fisher PP**
$lnCO_2$	Level	-2.9262***	1.3335	0.4085	17.8546*	13.7533
	1st dif.	-2.8103***	-4.3142***	-3.7502***	32.5453***	63.6695***
lnENER	Level	-1.8515**	1.7075	0.7352	10.4416	32.6604***
	1st dif.	-3.4359***	-3.3430***	-3.6097***	31.5683***	65.7848***
lnIN	Level	-2.5822***	-0.1176	-1.4075*	21.5858**	10.7288
	1st dif.	-4.2421***	-5.7814***	-4.0138***	34.3581***	52.4904***
$lnIN^2$	Level	-4.2237***	-0.0522	-2.0591**	28.6473***	13.3488
	1st dif.	-4.2709***	-5.8831***	-4.1786***	35.6937***	50.2371***
lnAVA	Level	3.0749	0.3831	5.3491	0.1558	0.0643
	1st dif.	-6.8406***	-3.4186***	-7.8891***	70.8765***	89.2130***

Note: *, ** and *** denote significant at 10%, 5% and 1% levels of significance. Fisher ADF and Fisher PP tests use asymptotic Chi-squares distribution. All other tests assume asymptotic normality. The lag lengths are selected by Akaike Info Criterion (AIC).

Kao's test is residual-based, it cannot be used to test for more than one cointegrating equation (Carlsson *et al.*, 2007). We thus propose Johansen's (1991) cointegration test to examine whether $lnCO_2$, *lnENER*, *lnIN*, $lnIN^2$, and *lnAVA* are cointegrated in the context of VAR model. Johansen's test performs well when error terms are not normally distributed

(Gonzalo, 1994), and allows for some relationships to be cointegrated (Maddala and Wu, 1999). Johansen cointegration test employed trace and maximum eigenvalue tests to determine the number of cointegration relationships. Because the maximum eigenvalue test carries out separate tests on each eigenvalue, and has the sharper alternative hypothesis, its results should be used in choosing the number of cointegrated relationships. Table 3 reports the results of Kao's test with the max lag of six, as well as of Johansen cointegration test with null and alternative hypotheses.

ADF test statistics reported in Table 3 indicate all variables are cointegrated within our panel sample. The max-eigenvalue statistics reported in the Table suggest that there is one cointegrating vector at 1% levels of significance. The existence of cointegration and long-run equilibrium relationships between CO_2 emissions, energy consumption, economic growth and agricultural value-added assures the application of Granger causality test in the context of vector error-correction model (VECM). This report sets up the pairs of (X_{it}, $Y_{i,t}$) and includes ($lnCO_2$, *lnENER*), ($lnCO_2$, *lnIN and* $lnIN^2$), ($lnCO_2$, *lnAVA*) and other pairs that are combinations of each variable with one or two other variables, such as, *lnENER* with *lnIN* and $lnIN^2$ or with *lnAVA* and so forth.

Table 3: Cointegration Tests' Results

Kao's test					
	t-statistic				
ADF	-2.7184***				
Johansen cointegration test					
Trace test			*Maximum eigenvalue test*		
Null Hypothesis	Alternative Hypothesis	Trace statistic	Null Hypothesis	Alternative Hypothesis	Max-Eigen Statistic
r = 0	r ≥ 1	202.734***	r = 0	r = 1	167.327***
r ≤ 1	r ≥ 2	35.4067	r = 1	r = 2	16.3824
r ≤2	r ≥ 3	0.1070	r = 2	r =3	14.1528
r ≤ 3	r ≥ 4	0.0313	r = 3	r = 4	3.9802

Note: Trace and max-eigen statistics calculated at 5% level; *** denotes 1% level of significance. Probabilities are computed using asymptotic Chi-square distribution, and r is the number of cointegration equations. The lag lengths are selected using AIC.

Table 4 presents short-run Granger causality results with the null hypothesis of no causal relationship in each pair of variables. The results show the significantly unidirectional causality nexus from income to CO_2 emissions in the short-run. At the same time, we do not find any causal linkages between income, energy consumption and agricultural value-added. However, the estimated significance of the speed of adjustment parameters from VECM framework (model consisting of Equation 1), which are shown in Table 5, ensures the long-run causal relationships among data series. Table 5 expresses three long-run bidirectional causality relationships between income with energy consumption, environmental pollutant and agricultural development in the sample of ASEAN's five developing members. The results from this Table also suggest two long-run unidirectional linkages from agricultural development to CO_2 emissions and energy consumption. However, we do not find significant causality nexus between CO_2 emissions and energy consumption in the long-run.

Table 4: Short-run Granger Causality Test

	D(lnCO2)	*D(lnENER)*	*D(lnIN)*	*D(lnIN2)*	*D(lnAVA)*
	Chi-sq				
D(lnCO2)→	-	1.0363	2.0500	1.5215	0.5020
D(lnENER) →	1.6863	-	0.4351	0.6798	0.2567
D(lnIN)&D(lnIN2) →	21.6711***	2.4490	-	-	3.3896
D(lnAVA) →	0.9130	0.3138	0.1278	0.0283	-

Note: *** denotes 1% level of significance and → denotes causality direction from X→Y.

4.3. EKC Estimation

The significant cointegration among variables from Kao's and Johansen tests results (Table 3) implies the existence of long-run relationship between variables, and the spurious regression is avoided. This existence suggests that the ordinary least square (OLS) estimation is super consistent in estimating the model parameters (Alves and Brueno, 2003).

Table 5: Long-run panel causality test

Causal direction	ECT t-stat	Causal direction	ECT t-stat	Conclusion Direction
ΔlnCO2→ ΔlnENR	1.0325	ΔlnENR → ΔlnCO2	-1.2800	CO2×energy use
ΔlnCO2→ ΔlnIN	67.9667***	ΔlnIN &ΔlnIN2→ ΔlnCO2	-3.7257***	CO2 → Income
ΔlnCO2→ ΔlnIN2	-64.4337***			
ΔlnCO2→ ΔlnAVA	-0.2892	ΔlnAVA→ ΔlnCO2	-3.7808***	CO2→FDI
ΔlnENR → ΔlnIN	-65.7049***	ΔlnIN&ΔlnIN2→ ΔlnENR	-3.0343***	Energy use↔ Income
ΔlnENR → ΔlnIN2	62.0682***			
ΔlnENR → ΔlnAVA	-0.2631	ΔlnAVA→ ΔlnENR	-5.5501***	FDI→Energy use
ΔlnIN & ΔlnIN2→ ΔlnAVA	2.2847**	ΔlnAVA → ΔlnIN	-65.3616***	Income ↔ FDI
		ΔlnAVA→ ΔlnIN2	63.2609***	

Notes: ** and *** denote 5% and 1% level of significance, × denotes no causality nexus between *X* and *Y*, → and ↔ denotes unidirectional relationship from *X* → *Y* and bidirectional relationship between *X* and *Y* respectively.

The estimated equation of model consisting of Equation 3 by OLS is:

$$\widehat{lnCO_2} = -9.147 + 1.377lnENR + 0.227lnIN + 0.013lnIN^2 - 0.07lnAVA \quad (4)$$

S. E	(0.322)	(0.036)	(0.093)	(0.005)	(0.023)
t-stat	-28.37***	38.25***	2.44**	-2.49**	-3.10***

The results from Equation 4 show that the estimated coefficients of $lnENER_{it}$, $lnIN_{it}$, and $lnIN_{it}^2$ have the expected signs at 1% and 5% level of significance, which support our EKC hypothesis, stating that when income is at 8.602 (in logarithms), the EKC begins to reverse. The results further indicate that CO_2 emissions becomes income elastic when its absolute partial derivative on income is greater than unity, equals that income is greater than 46.4811 (in logarithms), and significantly. In addition, the results express that CO_2 emissions is elastic with energy consumption, where CO_2 emissions will increase by 1.38% when energy consumption increases by 1. The estimated coefficients magnitude of *lnAVA* is quite small and significantly negative (only –0.07) at 1% level. This indicates that AVA is to be inelastic in reducing CO_2 emissions in our panel sample of ASEAN's five developing members.

5. Conclusion

This study aims to investigate the effects of economic growth, energy consumption and agricultural development on environmental pollutant within the panel sample of ASEAN's five developing members, including Indonesia, Malaysia, Philippines, Thailand and Vietnam. Using data for the period of 1985-2011, it further investigates the causality relationships among said variables by employing VECM Granger causality. The unit root tests' results imply that all series are integrated of order one and their linear combinations are stationary. These permits us to use OLS as super consistent estimator to accept EKC hypothesis in our panel sample, indicating that when income per capita is at 8.602 (in logarithms) or 5,422.53 US dollars, CO_2 emissions begin to decline significantly. Furthermore, pollutant is inelastic with the increase in their income. Based on the fact that income per capita of three over these five countries is lower than 5.422.53 US dollars, including Indonesia, Philippines and Vietnam, the findings suggest an important implication that although these countries still trade their economic development by environmental degradation, it is compensated by the faster increase in their income. Coordinating with economic forecast for ASEAN (Asian Development Bank, 2014), the Association of South East Asian Nations may consider this result to state that their economy has been greenlized, and the factors contributing to economic growth may help reduce CO_2 emissions from the next decade. However, the estimated energy use elasticity implies that the ASEAN panel sample countries have used energy-inefficient technologies to boost their economic growth, where CO_2 emissions increase 1.377% if energy consumption increases by one. We also find that within the sample, agricultural production has significantly contributed to environmental protection.

One of the main purposes of this study is to investigate the relationships between agricultural development, economic growth, energy consumption and CO_2 emissions within ASEAN's developing members. We further examine whether the economic development induces the development of agriculture in these countries. The causality investigation implies the feedback effect between series. With regard to environmental protection and economic development, the existence of long-run causality among CO_2 emissions – energy consumption – economic growth – agricultural development poses important challenges to the sample countries' policy makers. The bidirectional causality between economic growth and energy consumption indicates that these variables are jointly determined and affect each other simultaneously. This implies that five countries as a whole have been developing its economy through increasing its use of energy. However, a high level of growth also leads to a high level of energy consumption. Meanwhile, the bidirectional relationship between CO_2 emissions and income indicates that these countries seem to loosen their environmental protection regulations to reach their economic goals, and a cut in CO_2 emissions will hurt their growth. These results should serve as a precaution to policy makers that focusing on economic development while being indifferent about the environment will accelerate their country's environmental degradation. The countries involved should implement stringent laws that require the use of energy-efficient technologies and support environmental protection while driving economic growth.

An important question, which we had mentioned, is that whether the economic development induces the growth of agricultural production in the case of ASEAN's developing members. We add agricultural value-added to EKC model and examine the causality relationships between variables in the context VECM. Estimated results express the existence of feedback hypothesis between agricultural value-added and income, showing that agricultural production not only contributes to economic growth but the growth also leads agricultural development in return. This suggests the implication that economic development promotes the innovation and contributes to ASEAN developing members' agricultural productivity growth. This also partially states evidence of these countries firms' investment transition to agricultural sector, after gaining benefits of industrialization and modernization within these countries. On the other hand, any negative shocks to their economies will adversely affect their agricultural development. The policy makers thus should implement the solutions to ensure the sustainable agriculture from any fluctuation of other sectors. Further results show the evidence of unidirectional nexus from agricultural value-added to energy consumption. This may be explained by the expanded consumption of people living in ASEAN developing countries' rural areas following their social economic development. The unidirectional directional from agricultural value-added to CO_2 emissions implies the significant effect of agricultural development on environment. Coordinating with the estimated results from EKC model, which shows the significantly negative impact of agricultural value-added on CO_2 emissions, our results indicate that these countries seem to increasingly use green technology in agricultural production. Agricultural products further may be used to produce renewable energy, and agricultural development has been significantly contributing to ASEAN developing members' environment improvement.

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