Advances in Management & Applied Economics, vol. 5, no.1, 2015, 69-88
ISSN: 1792-7544 (print version), 1792-7552(online)
Scienpress Ltd, 2015

Dynamic Causal Relationships among CO2 Emissions, Energy Consumption, Economic Growth and FDI in the most Populous Asian Countries

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Abstract

This paper investigates the dynamic causal relationships among environmental degradation, economic growth, foreign direct investment (FDI) and energy consumption in the 12 most populous countries in Asia. 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 8.9341 (in logarithms). Applying Granger causality test, we find the existence of both short and long-run causality relationships among these variables, and economic growth, FDI, energy consumption and CO_2 emissions of 12 Asian most populous countries have relationships with Japanese income. On the other hand, our estimated results suggest that these countries have been exchanging the environmental degradation to implement economic activities. Furthermore, these results support the pollution haven hypothesis,which indicate the less stringent environmental regulations of the host countries have attracted FDI inflows. However, FDI inflows are found significantly that does not intensify the environment degradation within these 12 Asian countries as a panel sample.

JEL classification numbers: C33, O44, O53.
Keywords: MPCA12, EKC curve, Cointegration, Granger Causality, Japanese income, FDI inflows, CO_2 emissions.

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Article Info: *Received* : November 2, 2014. *Revised* : November 29, 2014.
Published online : January 15, 2015

1 Introduction

Asia is currently considered as one of the most dynamic economic areas in the world, showing the highest economic growth. While the average growth rate of globalreal Gross Domestic Product (GDP)was 1.1% in period 2006-2009, 4.02% in 2010 and 2.74% in 2011 (United Nations, 2013), Asia, comprised mainly of developing countries, had an averageGDP growth at 7.1%, 9.0% and 6.8% in same periods, respectively. [3]It also hasthe greatest potential for development, being the region withmore than 60.3% of total world population as of 2011, which provides both a huge potential market and a large working population. The 12most populouscountries in Asia (*MPCA12*) make up more than 88.1% of the region's population, and since the 1980s, this group accounts for almost 85.4% of Asian total GDP annually. In descending order, these are: China, India, Indonesia, Pakistan, Bangladesh, Japan, Philippines, Vietnam, Thailand, Iran, Myanmar and South Korea).[4]Most of these countries have strong economic ties with each other, facilitated by their geographical proximity and free trade agreements. Many a times the existing literatures have found that economic fluctuations in these economies can have a great impact on the economies of other countries and regions globally. Contributions include Angresano (2004), Lee (2006b), Eichengreen (2006), Holscher*et al*. (2010) and Mackenzie *et al*. (2012). Thus, these countries may be seen as the very important part of Asian economy as a whole, and the economic characteristics of the whole Asia region also appeared in *MPCA12*, such as Japan for developed countries; South Korea for new industrialized economies; Indonesia for crude oil exporters; China and India for developing, changing economies with high economic growth; Malaysia and Thailand for upper low income countries; and Iran for countries under economic embargo and other domestic crises (nuclear and political).[5]While getting the full data to investigate and estimate economic relationships of the Asia region as a whole is difficult, the *MPCA12* panel data sample can provide a good representation of patterns existing in Asia's economy.

FDI flows to *MPCA12* has increased rapidly in the last three decades, from 8.3% of total FDI inflows to the Asia region in 1980, to 19.1% in 1990, 36.9% in 2000 and 40.8% in 2010, according to data from UNCTAD database, 2013. FDI contributes to these countries' economic development (Bende-Nabende*et al*., 2000; Chakrabarti, 2002), which in turnaffecting their energy demand and environmental degradation (Minh Nguyen & Nurul Amin, 2002,Jian and Rencheng, 2007). Energy consumption increased rapidly in *MPCA12*, where from 1.38 million kilotonnes (kt) oil equivalence in 1980, it went up to more than 4.75 million kt in 2010. This makes up more than 80% of Asia's annual energy consumption. Likewise,CO_2 emissions increasedfrom 3.3 million kt carbon dioxide emissions to 13.79 million kt at the same period. The percentage of Asia's total CO_2

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[3]These numbers are calculated by the authors from United Nations Conference on Trade and Development (UNCTAD) Statistics, 2013. Growth rates are based on GDP in 2005 U.S. dollars.

[4]12 Asian most populous countries are ranked by total population of each country. We aggregate data from UNCTAD Statistics Database, 2013.We exclude Turkey out of the sample due to that Turkey is a member of Council of Europe (since 1949) and was an official candidate of European Union for full membership in 1999. See more on http://www.coe.int/en/web/portal/turkey

[5]Embargo against Iran has begun since 1979 by the bans on the import of Iranian crude oil into the United States. Recent United Nations sanctions against Iran include resolutions 1737, 1747, 1803, 1929 and 2049. See more on http://www.un.org/sc/committees/1737/

emissions that came from *MPCA12*gradually increased from 77% in 1980 to around 83% in 2010.[6]
There are some existing literatures studying the relationships between CO_2 emissions, energy consumption, economic growth and FDI. However, these studies focusonly on one country, or separate the sample of developed from developing countries, or use a sample with only a few types ofeconomies. We have not found any study examining the relationships of these variables using the panel sample of Asian countries, which usually have strong relationships and affect each other's social and economic development. In this study, we investigate the causal nexuses of environmental degradation –energy consumption – economic growth – FDI inflows. This paper also estimates the trend of environmental pollutants with respect to the abovementionedvariables based on a panel sample of *MPCA12* over 30 years, from 1980 until 2010. It is expected that working on a larger sample, which includes both developed and developing countries in Asia, will provide more accurate estimations. This will help us find causal relationships between said factors, which may provide valuable insights to these countries' policy makers.

2 Literature Review and Hypotheses

Energy is one of the most important components of economic development. Kraft and Kraft (1978) found unidirectional causality from income to energy use in the United States. Succeeding studies such asthose of Lee (2005) and Sari and Soytas (2007) found the causal nexus of energy consumption and economic growth, both in developed and developing countries. Lee's study (2006a) on energy intensityand economic development in G-11 countries found bidirectional causality between the two, which means that energy consumptionsupports economic growth and economic growth also increaseenergy consumption.The same conclusion was made in a recent study byPaoand Tsai (2011) on BRIC (Brazil, Russia, India and China) countries. However, economic growth and energy consumption are usually accompaniedby environmental degradation both in developed and developing countries,as proven by a large number of studies, such as that ofKeppler and Mansanet-Bataller (2010) for European countries, Narayan and Narayan (2010) for43 developing countries,andPao and Tsai (2010) for BRIC countries.
One of the popular approaches used in studying the relationship between environmental degradation and economic development is Environmental Kuznets Curve (EKC). 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 (which varies for different indicators) (Stern, 2004). This implies that the environmental impact indicator is an inverted U-shaped function of other economic variables. The development of EKC since its first application, when Grossman and Krueger (1991) used EKC to measure the potential environmental impacts of NAFTA, as well as critiquesto the theory, were summarized in the literature of Stern (2004). Chen *et al*. (2007) and Managiand Jena (2008) continued to employ EKC in the cases of China and India. Coondoo and Dinda (2008) and Akbostanci*et al*. (2009) tested EKC, focusing on time series dynamics of income and CO_2 emissions.Pao and Tsai (2011) also tested EKC hypothesis for BRIC countries.

[6]These numbers are calculated by the authors based on Word Bank Indicator database, 2013. This database is available online from ULR: http://data.worldbank.org/indicator

This study teststhe EKC hypothesis on the panel sample of *MPCA12*.In the same framework, we also conduct a similar test specifically for thethe case of Japan, which is included in *MPCA12*, to see whether EKC curve appears in Japan and whether there have differences of Japan's EKC curve (if appeared)from the sample. The parallel testing between Japan and our samples is due to Japan being one of the world's most developed countries. Ithas high income and is the leader of technological development, which can help its economy develop stably and quickly reduce CO_2 emissions. Thus, if EKC hypothesis is applicable in Japan's case, its EKC curve may reverse earlier than the sample EKC curve.

In order to test the EKC hypothesis for *MPCA12* as well as examine the difference of Japanese EKC curve (if existed) from the sample EKC curve, we assume that:

Hypothesis 1: Within the *MPCA12*, CO_2 emissions increase in the early stages of economic development and its trend reverses when the income per capital passes certain point. Concurrently, Japan's EKC reverses earlier than that of *MPCA12*.

Furthermore, many studies have discovered a strong link between capital investments and economic growth, and FDI emerged as an important contributor for economic development. Likewise, FDI may have relationships with energy intensity as well as environmental pollutants. Recent studies commonly applied time series dynamic with Granger causality test to assess the relationships among FDI, economic growth, energy consumption and environmental pollutants. Li and Liu (2005) expressed a strong complementary connection between FDI and economic growth in both developed and developing countries. Chakraborty and Nunnenkamp (2008) found the feedback effects between FDI and India's economic output both in the short-run and long-run. Other studies also suggest the causal relationships between these two indicators, such as those of Zang (2001), Kim and Seo (2003) or Pao and Tsai (2011). Investigating the relationships between FDI with energy consumption and CO_2 emissions, Mielnik and Goldemberg (2002) examined a sample of 20 developing countries and found that energy intensity declines as FDI increases. Sadorsky (2010) found that net FDI has a statistically significant impact on the energy demand after studying a sample of 22 emerging countries. Pao and Tsai (2011) validated the EKC hypothesis and suggested the short-run bidirectional causal relationships between energy consumption – FDI and CO_2 emissions – FDI, and bidirectional long-run causality between FDI and emissions in BRIC countries. Chandran and Tang (2013) suggested the long-run relationship between FDI and CO_2 emission in five ASEAN countries.

Aswith existing literature, this study examines the relationship among FDI, economic growth, energy consumption and CO_2 emissions in the *MPCA12*.In the same framework, we also examinewhether these factorsof Japan have causal nexuses with the sample's variables. We assume that:

Hypothesis 2:FDI, economic growth, CO_2 emissions and energy consumptionnot only have causal relationshipswith each other withinthe *MPCA12*panel sample but also have causal relationships with these of Japan.

3 Methodology and Empirical Results

3.1 Data and Variable Forms

3.1.1 Data

The data used in this report includes annual GDP per capita,annual FDI inflows and stocks per capita, measured byUS Dollars at current prices and current exchange rates.These datawas obtained from UNCTAD statistics database.[7] *IN* represents GDP per capital and*FDI* representsFDI inflows and stocks per capital. Data on energy consumption and CO_2 emissionswere obtained from theWorld Bank Indicator database.[8] The unit used for energy consumption and CO_2 emission is kt oil equivalence, and for CO_2 emissions is kt CO_2 emissions. All fourindicators are observed annually in *MPCA12*samplefrom 1980 until2010, which contributes to a balanced panel data (12x31) with 372 observations.

3.1.2 Variable forms

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. The 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. Moreover, an assumption of every econometric framework is that the variables should have normal distribution. However, all the variables in this sample's data have positively skewed distribution, with a long tail to the right (Fig. 1 shows the extremely skewed distribution of CO_2). Thus, normalization of the data is necessary, and natural logarithmic transformation will regularize data from extremely skewed distribution to become less asymmetric (Fig. 2expresses the histogram of $lnCO_2$). This also reduces the possible distortions of the dynamic properties of the variables. The four new variables in natural logarithmic form are *lnIN*for *IN*, *lnFDI* for *FDI*, $lnCO_2$ for CO_2 emissionsand *lnEN* for energy consumption.By taking logarithms, we also estimate the pollutants, energy consumption and income elasticities for dependent variables.

[7]This database is available online from ULR: http://unctadstat.unctad.org/ReportFolders/reportFolders.aspx

[8]This database is available online from ULR: http://data.worldbank.org/indicator

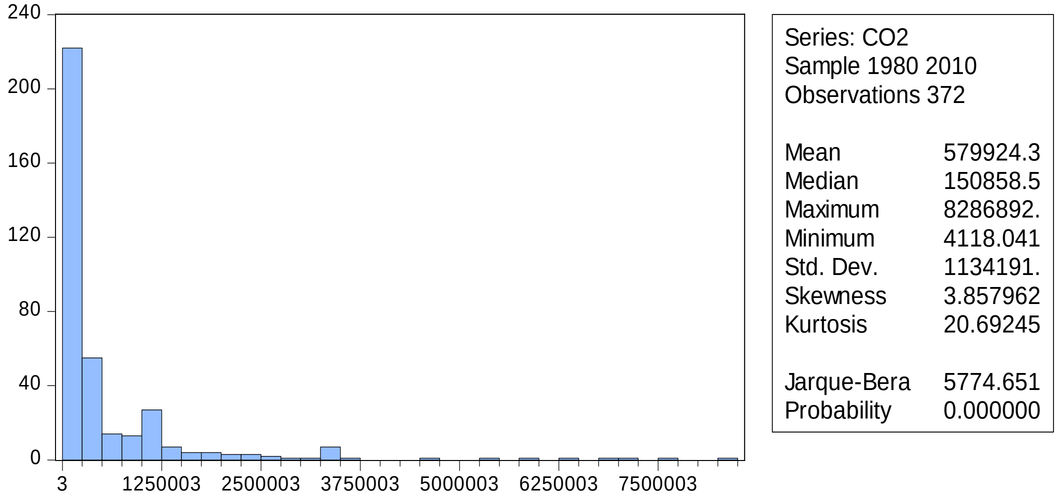

Figure 1: Histogram of CO_2 emission

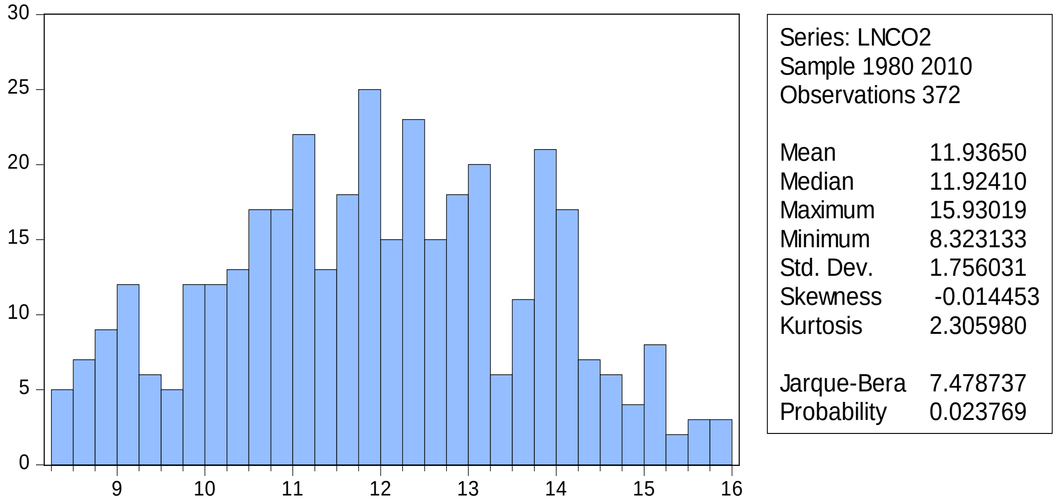

Figure 2: Histogram of $\ln CO_2$

Table 1 indicates the skewness of those four series before and after logarithmic transformation. The results indicate that all new variables are better than their previous forms. Thus, the possible distortion of dynamic properties is reduced.

Table 1: The skewness statistics of variables

	IN	lnIN	FDI	lnFDI	Energy	LnEN	CO_2	$\ln CO_2$
Skewness	2.9894	0.7257	2.6845	-0.9555	3.2537	0.3508	3.8580	-0.0145

Note: The skewness closer to zero indicates that the variable is closer to normal distribution.

3.2 Models

3.2.1 Model forms

EKC theory implies that the environmental impact is an inverted U-shaped function of income(*IN*) and logarithm of the indicator is modeled as a quadratic function of the logarithm of *IN*. Based on the EKC hypothesis, a linear logarithm quadratic model is formedto expressthe relationshipsbetween CO_2 emissions, energy consumption, economic growth and FDIas follows:

$$lnCO_{2i,t} = \beta_0 + \beta_1 lnEN_{i,t} + \beta_2 lnIN_{i,t} + \beta_3 lnINC_{i,t}^2 + \beta_4 lnFDI_{i,t} + v_{i,t} \quad (1)$$

or

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

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.

Based on the EKC theory, we expect the signs of $lnEn_{it}$, $lnIN_{it}$to bepositive, since CO_2 emissions increase when energy consumption increases and income increases. Wealso expect that $lnIN_{it}^2$ hasa negative sign. For the purpose of testing our hypotheses, we estimate the relationship between the aforementioned variables using the panel data, and then we also examine the differences of Japan's economy from the sample. There maybe differencesbetween the EKC of developed and developing countries, for example, Japan's CO_2 emissions maystart its decline at a lower income level than of other countries.Toexamine these possible differences between Japan and the sample, and whether causality relationships exist between the characteristics of Japan's economy and our sample series, interaction terms of Japan (hereinafter *JPN*) with all the original explanatory variables are taken into account. The model becomes:

$$lnCO_{2it} = \beta_0 + \beta_k X_{i,t} + \gamma j JPNt{*}X_{i,t} + v_{i,t} \quad (3)$$

The interaction terms between *JPN* and vector $X_{i,t}$ include $JPN{*}lnCO_2$,$JPN{*}lnEN$,$JPN{*}lnIN$, $JPN{*}lnIN^2$ and $JPN{*}lnFDI$, which are denoted as JCO_2, *JEN*, *JIN*, $JIN^2$and *JFDI*, respectively.

3.2.2 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 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 roottestsare 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 test. These are: Levin *et al*. (2002) (LLC), Breitung, Im, Pesaran and Shin (IPS),and two Fisher-types tests.In these tests, LLC is a generalization of the ADF individual country unit root tests to a common panel unit root test. The null hypothesis is that each individual time series containsunit root against the alternative that each time series is stationary. IPS test has the same null hypothesis with LLC but the alternativeallows 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 → 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 test suffer from a dramatic loss of power if individual specific trends are included. The Breitung unit root test equation 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 $N \to \infty$, Fisher-type is an exact test which depends on $T \to \infty$ (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. The null and alternative hypotheses of these tests are summarized in Table 2.

Table 2: 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

The unit root test equations 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. A series is considered as stationary after all unit root tests reject the null hypothesis expressed in Table 2. Table 3 shows the result of unit root tests at level, first difference and second difference. The row “level” in each series expresses that *lnEN*, *lnIN* and $lnIN^2$ are nonstationary after all kinds of tests. Only LLC test suggests $lnCO_2$ is stationary (at 5% levels of significance) while the others suggest $lnCO_2$ is nonstationary. Besides, we cannot reject the null hypothesis that *lnFDI*contains unit root after IPS and Fisher ADF tests. Inside the interactions between country dummy Japan with sample variables, all five tests indicate JCO_2 and *JEN* are non-stationary. Only LLC test suggests *JIN* and JIN^2 are stationary, while Beitung tests suggest *JFDI* is nonstationary. The unit root tests results express data is not informative enough to conclude each series is stationary at level.

Table 3: Panel unit root tests results at level, 1st and 2nd differences

		Common		Individual		
		LLC	**Breitung**	**IPS**	**Fisher ADF**	**Fisher PP**
$lnCO_2$	Level	-2.1745**	-0.2314	2.6924	12.8877	13.1187
	1st dif.	-11.4852***	-5.8959***	-12.4429***	176.402***	202.378***
	2nd dif	-3.5074***	-6.7471***	-15.1656***	223.551***	266.195***
lnEN	Level	-0.9356	0.1222	4.9124	18.4654	21.7314
	1st	-11.0144***	-6.5849***	-10.5759***	151.721***	199.460***
	2nd dif	-6.2403***	-2.2596**	-15.1707***	222.487***	298.397***
lnIN	Level	3.0377	3.2195	7.2426	5.1816	4.2730
	1st	-8.5608***	-6.0812***	-8.1952***	114.879***	136.085***
	2nd dif	-9.5141***	-4.4510***	-14.6304***	214.718***	325.692***
$lnIN^2$	Level	5.9438	3.7108	8.7713	3.6851	3.5661
	1st	-7.8972***	-5.3719***	-7.6108***	106.478***	125.514***
	2nd dif	-8.4338***	-4.7571***	-13.7882***	202.509***	345.479***
lnFDI	Level	-2.8122***	-1.4207*	-1.1934	32.2322	49.6468***
	1st	-13.9336***	-4.3039***	-14.7278***	206.156***	338.014***
	2nd dif	14.6380	-3.7009***	-11.4337***	169.579***	249.101***
$JC0_2$	Level	-0.3918	0.2166	0.3767	0.8163	0.8006
	1st	-4.4788***	-0.6164	-4.2274***	17.4006***	17.3842***
	2nd dif	-0.3025	-1.3176*	-4.9086***	20.8224***	18.5117***
JEN	Level	-1.2783	1.3036	-0.1644	1.6662	1.5576
	1st	-3.3037***	-0.8303	-3.0815***	12.1184***	12.1184***
	2nd dif	7.9189	2.6207	-2.5726***	10.2191***	28.7408***
JIN	Level	-1.5535*	0.4394	-0.5846	2.6407	2.3756
	1st	-3.3224***	-2.8637***	-2.4549**	9.3621***	9.2758***
	2nd dif	-3.0207***	-1.9427**	-3.2378***	13.0420***	30.6850***
JIN^2	Level	-1.5510*	0.3721	-0.4835	2.3837	2.2541
	1st	-3.1498***	-2.8090***	-2.4473***	9.3295***	8.9865**
	2nd dif	-2.8942***	-3.1401***	-3.4103***	13.8432***	34.7275***
JFDI	Level	-2.4621***	0.2956	-1.9217**	7.1667**	6.8945**
	1st	-1.5339*	1.5283	-3.3411***	13.5878***	36.0693***
	2nd dif	2.7494	-1.5736	-3.8304***	16.1113***	18.4207***

Notes: *, **, *** denote test statistic significance at the 10%, 5% and 1% level; 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).

The same unit root tests are applied to the first difference of all series. The tests results in Table 3, rows "1st dif." indicate that all variables (excluding the interactions of dummy) can be made stationary by taking the first difference, and are integrated of order one, denoted as I(1). Within the dummy interactions, $JCO_2$is I(1) with LLC, IPS, Fisher ADF and Fisher FF (at 1% level of significance), but is not I(1) with Breitungtess. Breitung test continues to suggest that *JEN* is not I(1). On the other hand, the results from rows "1st dif." of this table expresses *JIN* and $JIN^2$are I(1), but one more time, Breitung test indicates *JFDI* is not I(1).[9]

The panel unit root test results in rows "1stdif."of Table 4 show that $lnCO_2$, *lnEN*, *lnIN*, $lnIN^2$, *lnFDI*, *JIN* and JIN^2 are I(1) after all tests but JCO_2, *JEN* and *JFDI* are not I(1). Thus, panel unit root tests at second difference of all variables should be applied to investigate whether these variables are integrated of order two, I(2) or not. Rows "2nd dif." in the same table express the unit root test results at the second difference of the series, all tests indicate that $lnCO_2$, *lnEN*, *lnIN*, $lnIN^2$, *lnFDI*, *JIN* and JIN^2 are I(2). However, LLC and/or Breitung tests continue suggesting that JCO_2, *JEN* and *JFDI* are not I(2).

To summarize, based on all unit root tests' results, $lnCO_2$, *lnEN*, *lnIN*, $lnIN^2$, *lnFDI*, *JIN* and JIN^2 are I(1). Finally, JCO_2, *JEN* and *JFDI* are not I(1) after some tests, LLC or/and Breitung tests even express they are not I(2). Because a model can only be estimated if its variables are integrated of the same order, model consisting of Equation 3 should have only two interaction terms, *JIN* andJIN^2 in testing hypothesis. BecauseJCO_2, *JEN* and$JFDI^2$are not integrated with the same order with other variables, we cannot include them to the model. Thus, we cannot test one part of hypothesis 2, which implies that Japan's CO_2 emissions, energy consumption, economic growth and FDI inflows have causal relationships with these characteristics of *MPCA12*. The new hypotheses that replace to hypothesis 2 should be:

Hypothesis 2a: FDI, economic growth, CO_2 emissions and energy consumption not only have causal relationships with each other within the *MPCA12* panel sample but also have causal relationships with Japanese income.

Model consisting of Equation 3 becomes:

$$lnCO_{2it} = \beta_0 + \beta_k X_{i,t} + \gamma_1 JIN_t + \gamma_2 JIN^2_t + v_{i,t} \quad (4)$$

Now, assume a vector Z_{it} which includes $lnCO_{2it}$ and all other variables in model consisting of Equation 4. 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.

3.2.3 Panel cointegration test

The panel cointegration estimation allows the appearance of heterogeneity problems among individuals within the panel both in long-run and in the dynamics (Kao and Chiang (2000). Granger (1981) and Granger and Weiss (1983) introduced a definition for co-integrating vector as follows:

[9]If we use the time period from 1980 until 2009 for *MPCA12* panel sample, all unit root tests (including Breitung test) suggest *JFDI* is I(1).

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 $I(d)$; (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$z_t = \alpha' y_t \sim I(d\text{-}b)$. The vector α is called the *co-integrating vector*.

Despite the fact that all the variablesin model consisting of Equation 4 are non-stationary, the first difference of each (i.e. $\Delta Z_{i,t} = (1-L)Z_{i,t}$) is stationary.Thus, the spurious regressions may be avoided if 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 one) (Engle and Granger, 1987).For clearing interpretation, if *y* and *x*are nonstationaryI(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)). In this case, *y* and *x* are said to be cointegrated.The cointegrating relationships imply long-run equilibrium relationships among these variables.

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, including dummy variables (one of the Kao's test applications for the model with dummy variable is Kao *et al.*, 1999). 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 converge to a standard normal distribution. Table 4 shows the Kao's test results with the max lag of seven.

Kao's test is residual-based, it cannot be used to test for more than one cointegrating equation (Carlsson*et al.*, 2007). On the other hand, we purpose to examine the difference between the EKC of Japan versus that of the*MPCA12*, and whether the Japan dummy variables affect the remaining variables.We treat Japan dummy variables as exogenous and propose Johansen's (1991) cointegration test to examine whether $lnCO_2$,*lnEN*, *lnIN*, $lnIN^2$, and *lnFDI are*cointegrated in the context of vector autoregressive model. Although Johansen's test critical values are not appropriate when the model includes dummy variables, even if all variables are integrated of the same order, but this test methodology 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 4 reports the results of Johansen cointegration test with null and alternative hypotheses.

Table 4: Results of the Johansen cointegration test

Kao's test					
	t-statistic				
ADF	-5.6101***				
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	67.9603***	r = 0	r = 1	88.0007***
r ≤ 1	r ≥ 2	79.9596***	r = 1	r = 2	39.8435***
r ≤2	r ≥ 3	40.1161***	r = 2	r =3	32.7887 ***
r ≤ 3	r ≥ 4	7.3274	r = 3	r = 4	4.5734
r ≤ 4	r ≥ 5	2.7540	r = 4	r = 5	2.7540

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

ADF test statistics reported in Table 4 indicate all variables (including Japan's interaction terms) are cointegrated within our panel sample. The max-eigen statistics reported in the same table suggest that there are three cointegrating vectors at 1% and 5% levels of significance. The significance of both ADF and Max-eigen statistics imply the existence of long-run relationship between variables, and the spurious regression is avoided. The existence of cointegration among model consisting of Equation 4 variables suggests that the ordinary least square (OLS) estimation is super consistent in estimating the model parameters (Alves and Brueno, 2003).
The estimated equation of model consisting of Equation 4 by OLS is:

$\widehat{lnCO_2}=$	-4.9954	$+1.1823lnEN$	$+0.8809lnIN$	$-0.0493lnIN^2$	(5)
S. E	(0.3131)	(0.0106)	(0.0915)	(0.0064)	
t-statistic	-15.9547	111.2211	9.6302	-7.7079	
p-value	0.0000	0.0000	0.0000	0.0000	
	$-0.0301lnFDI$	$+0.0534JIN$	$-0.0027JIN^2$		
S. E	(0.0068)	(0.0961)	(0.0096)		
t-statistic	-4.4085	-0.5557	0.2831		
p-value	0.0000	0.5788	0.7772		

The results from Equation 5 show that the estimated coefficients of $lnEn_{it}$, $lnIN_{it}$, and $lnIN_{it}^2$ have the expected signs at 1% level of significance, which support our EKC hypothesis 1, stating that when income is at 0.8809/(2*0.0493) = 8.9341 (in logarithms), the EKC begins to reverse. Furthermore, the results indicate that CO_2 emissions becomes income elastic when its absolute partial derivative on income is greater than unity, equals that income is smaller than -1.3292 (in logarithms, exclude Japan) or greater than 19.0761 (in logarithms), and significantly. Conversely, the variable CO_2 emissions is inelastic if *lnIN* is smaller than 19.0761 (excluding Japan dummy interaction terms). As for energy use elasticity, the results express that CO_2 emissions is elastic with energy consumption, where CO_2 emissions will increase by 1.1823% when energy consumption increases by 1%. In Japan, the estimated results in Equation 5 show that *JIN* and JIN^2 are insignificant, although its coefficients' magnitude is quite small. Thus, in testing EKC hypothesis, we cannot conclude the difference of Japan from *MPAC12*. We also cannot confirm the difference between Japan and the *MPAC12* with regard to CO_2 emissions of income. The estimated coefficients magnitude of *lnFDI*is quite small and negative (only –0.0260), but significant at 1% level. This result indicates that FDI is to be inelastic in reducing CO_2 emissions in our *MPAC12* sample.

3.2.4 Granger causality test

The cointegration tests suggest the existence of at least one cointegrating relation (from Kao's test results in Table 4), and of long-run equilibrium relationships between CO_2 emissions, energy consumption, economic growth and FDI on the *MPCA12* sample. 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 in the model consisting of Equation 4. The Granger causality test in the context of VECM framework is as follows:

$$\Delta Y_{i,t} = \alpha_{10} + \alpha_{11}(Y_{i,t-1} - X_{i,t-1}) + \delta_{11}\Delta Y_{i,t-p} + \delta_{12}\Delta X_{i,t-p} + \beta_1 \Delta z_{i,t-p} + e_{i,t} \tag{6}$$
$$\Delta X_{i,t} = \alpha_{20} + \alpha_{21}(Y_{i,t-1} - X_{i,t-1}) + \delta_{21}\Delta Y_{i,t-p} + \delta_{22}\Delta X_{i,t-p} + \beta_2 \Delta z_{i,t-p} + v_{i,t}$$

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 variableswhereβ_1 and β_2 are vectors of its parameters in each equation;$e_{i,t}$, $v_{i,t}$ 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}andδ_{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, thenthere 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 betweenα_{11}andα_{21} is significant, we conclude long-run unidirectional relationship from$X_{i,t}$ to $Y_{i,t}$, or from $Y_{i,t}$ to $X_{i,t}$.In this report, the pairs of (X_{it}, $Y_{i,t}$) include ($lnCO_2$, *lnEN*), ($lnCO_2$, *lnIN*and $lnIN^2$), ($lnCO_2$, *lnFDI*), ($lnCO_2$, *JIN* and JIN^2) and other pairs that are combinations of each variable with one or two other variables such as *lnEN* with*lnIN* and $lnIN^2$ or with*lnFDI*and so forth.

Table 5 presents Granger causality results with the null hypothesis of no causal relationship in each pair of variables. The results support hypothesis 2a, indicating the existence of short-run relationships between variables, where two bidirectional causality relationships exist between *MPCA12*'s CO_2 and energy consumption, and between its income and FDI inflows. The unidirectional relationship is found from *MPCA12*'s income to CO_2 emissions, and from its income to energy consumption. However, we do not find the short-run causality relationships between CO_2 emissions and FDI, and between FDI and energy consumption within *MPCA12* sample. In testing the causality between Japanese income and *MPCA12*'s variables,we find only one bidirectional relationship between Japanese income and *MPCA12*'s FDI inflows, while we do not find any causal relationship between Japan income and *MPCA12*'s CO_2 emissions, energy consumption and income.

Table 5: Results of short-run Granger causality test

	$D(lnCO_2) \rightarrow$	$D(lnEN) \rightarrow$	$D(lnIN)\&D(lnIN^2) \rightarrow$	$D(lnFDI) \rightarrow$	$D(JIN)\&D(JIN^2) \rightarrow$
$D(JIN^2)$	0.0182	0.2309	0.2462	5.3473**	-
$D(JIN)$	0.3480	0.2934	0.2539	7.0358***	-
$D(lnFDI)$	1.3606	0.1934	12.3663***	-	11.7717***
$D(lnIN^2)$	1.1713	2.4523	-	2.3049	0.4786
$D(lnIN)$	0.6420	1.5361	-	12.2321***	0.5619
$D(lnEN)$	4.2810**	-	8.2438***	0.8533	1.0936
$D(lnCO_2)$	-	8.6356***	5.8396*	0.0130	0.0003

Notes: *, ** and *** denote test statistical significance at the 10%, 5% and 1% level; → denotes causality direction from X → Y

The significance of the estimated coefficients of ECTs from model consisting of Equation 6indicateslong-run causal relationship between variables. This result continues to support hypothesis 2a.Table 6 shows two bidirectional causality relationships in the *MPCA12* sample, which includeenergy consumption – income and income – FDI.CO_2 emissions haveunidirectional long-run relationships to energy use, income and FDI.*MPCA12*'s FDI has unidirectional relationship to energy consumption. Furthermore, we found that*MPCA12* has long-run causality relationships with Japan'sincome. Unidirectional relationships are found as follows: from *MPCA12*'s CO_2 emissions to Japan's income, and from*MPCA12*'s FDI to Japan's income. Bidirectional causality relationships are found in the following: Japan's income with *MPCA12*'senergy consumption, and Japan's income with *MPCA12*'s income.

Table 6: Long-run panel causality test

Causal direction	**ECT t-stat**	**Causal direction**	**ECT t-stat**	**Conclusion Direction**
$\Delta lnCO_2 \rightarrow \Delta lnEN$	-4.0042***	$\Delta lnEN \rightarrow \Delta lnCO_2$	0.4717	$CO_2 \rightarrow$ energy use
$\Delta lnCO_2 \rightarrow \Delta lnIN$ $\Delta lnCO_2 \rightarrow \Delta lnIN^2$	-20.7445*** -19.1462***	$\Delta lnIN$ &$\Delta lnIN^2 \rightarrow \Delta lnCO_2$	-1.2257	$CO_2 \rightarrow$ Income
$\Delta lnCO_2 \rightarrow \Delta lnFDI$	-4.7120***	$\Delta lnFDI \rightarrow \Delta lnCO_2$	-0.4266	$CO_2 \rightarrow$FDI
$\Delta lnCO_2 \rightarrow \Delta JIN$ $\Delta lnCO_2 \rightarrow \Delta JIN^2$	-2.2402** -11.5598***	ΔJIN &$\Delta JIN^2 \rightarrow \Delta lnCO_2$	0.8013	$CO_2 \rightarrow$Japanese income
$\Delta lnEN \rightarrow \Delta lnINC$ $\Delta lnEN \rightarrow \Delta lnINC^2$	-21.4862*** -18.3458***	$\Delta lnINC$ &$\Delta lnINC^2 \rightarrow \Delta lnEN$	-4.5032***	Energy use$\leftrightarrow$ Income
$\Delta lnEN \rightarrow \Delta lnFDI$	-0.6457	$\Delta lnFDI \rightarrow \Delta lnEN$	-7.4977***	FDI$\rightarrow$Energy use
$\Delta lnEN \rightarrow \Delta JIN$ $\Delta lnEN \rightarrow \Delta JIN^2$	-0.2389 -11.5844***	ΔJIN &$\Delta JIN^2 \rightarrow \Delta lnEN$	-2.7503***	Energy use $\leftrightarrow$ Japanese income
$\Delta lnIN$ &$\Delta lnIN^2 \rightarrow \Delta lnFDI$	-2.7343***	$\Delta lnFDI \rightarrow \Delta lnIN$ $\Delta lnFDI \rightarrow \Delta lnIN^2$	-21.7924*** -19.1462***	Income $\leftrightarrow$ FDI
$\Delta lnIN$&$\Delta lnIN^2 \rightarrow \Delta JIN$	-1.5453	ΔJIN &$\Delta JIN^2 \rightarrow \Delta lnINC$	-21.7901***	Income$\leftrightarrow$ Japanese income
$\Delta lnIN$&$\Delta lnIN^2 \rightarrow \Delta JIN^2$	11.0917***	ΔJIN &$\Delta JIN^2 \rightarrow \Delta lnINC^2$	-18.3821***	
$\Delta lnFDI \rightarrow \Delta JIN$ $\Delta lnFDI \rightarrow \Delta JIN^2$	-0.0162 -11.5500***	ΔJIN &$\Delta JIN^2 \rightarrow \Delta lnFDI$	-0.2833	FDI$\rightarrow$ Japanese income

Notes: *, ** and *** denote test statistical significance at the 10%, 5% and 1% level; $\rightarrow$ denotes causality direction from X $\rightarrow$ Y; $\leftrightarrow$ denotes bidirectional relationship between X and Y.

4 Conclusions

This study examines whether EKC hypothesis is confirmedin the case of the 12 most populousAsian countries (*MPCA12*), as well as whether the EKC of Japan,the most developed country within*MPCA12*, is different from the sample'sreference EKC.After applying unit root tests, we find that all series are integrated of order one and their linear combinations are stationary. This result permitsus to use OLS as a super consistent estimator. From the consistent OLS estimated results, we find that when income per capita is at8.9341 (in logarithms) or 7586.306US dollars, CO_2 emissions begin to decline significantly. These results supportthe EKC concept, which suggest an inverted U-shape curve of environmental degradation with respect to income. However, we cannot find the difference between Japan's EKC from the sample's EKC due to the insignificance of interaction terms between dummy variable Japan and income series.On the other hand, the CO_2 emissions variable is only elastic with income when income level is greater than 19.0761 (in logarithms), or when income per capita is greater than 192 million US dollars, which is not likely to happen in next many decades. Thus, we suggest that CO_2 emissions are income-inelastic within our sample. In the case of energy consumption elasticity, we find that *MPCA12*'sCO_2 emissions are elastic with energy consumption, where CO_2 emissions increase 1.1823% if energy consumption increases by 1%. We also find that within *MPCA12*,pollutants decrease by 0.0301% when FDI inflows increase by 1%.We did not find a significant difference betweenJapan's incomeand that of*MPCA12* that affects CO_2 emissions, because the estimated coefficients of Japan dummy interaction terms are all insignificant.

Besides testing the EKC theory, this paper studies the dynamic relationship between CO_2 emissions, energy consumption, FDI and economic growth in*MPCA12* panel sample from 1980 to2010. We test not only the differences of Japan's income from that of the samplethat affects CO_2 emissions but also whether thisfactor hasa relationship with*MPCA12*'sCO_2 emissions, energy consumption, incomeand FDI. By using the Granger causality test in the context of VCEM, we find that there are twoshort-run bidirectional relationships between CO_2 emissions and energy consumption as well as between its income and FDI inflowswithin the*MPCA12* sample. Furthermore, we also find two long-run bidirectional relationships of the sample's series, which are between income and energy consumption, and between income and FDI inflows. The long-rununidirectional causality relationships exist from CO_2 emissions to energy use, income, FDI and from FDI to energy consumption.Both the short and long-runbidirectional relationshipsbetween income and FDI suggest that an increase income within *MPCA12*will attract more FDI, and FDI inflows in turn also helps increase income.Upon testing the causal relationship of Japan'sinteraction terms with the sample variables,we find only one short-run bidirectional relationship between the sample's FDI inflows and Japanese income. We also find two long-run bidirectional causality relationships between *MPCA12* and Japan, where Japan's income has the relationship with *MPCA12*'s income and energy consumption. Meanwhile, twolong-run unidirectional causality associations are found from *MPCA12*CO_2 emissions to Japan's income and from*MPCA12* FDI to Japan's income.

For the *MPCA12* sample, our estimated results indicate the existence of causality relationships between environmental pollutants, energy consumption, economic growth, and FDI inflows.With regard to environmental protection and economic development, the existence of long-run causality among CO_2 emissions – energy consumption – economic growth – FDI pose important challenges to the sample countries' policy makers. The bidirectional causality between economic growth and energy use indicates that these variables are jointly determined andaffect each other simultaneously. Thisbidirectional causality implies that the *MPCA12*in our panel sample have been developingits economythrough increasing its energy consumption. Meanwhile, the unidirectional relationships from CO_2 emissions to energy use and income within *MPCA12* seems to express that its environmental protection regulations are weak, allowing the entry of inefficient energy technologies causing energy wastage. This is a rational result because most countries in *MPCA12* are developing countries with very high population and low income such as China, India, Indonesia, Bangladesh, Philippines, and Vietnam among others. There have been many studied express the problem that these countries usually focus on increasing economic growth but do not take the necessary measures to protect the environment, such as Zang*et al.*(2013),Jafari*et al.*, (2012),Alam*et al.*, (2011) andTisdell, (2002). 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 in this study should implement more stringent laws that require the use of energy-efficient technologies, which can reduce CO_2 emissions while driving economic growth.

Still from our estimated results, the long-run unidirectional causalities from FDI inflows to energy consumption and from CO_2 emissions to FDI inflowswithin the panel sample imply the closed relationships of FDI – energy consumption – environmental reduction. Usually, energy consumption increases as FDI increase to cater to increased production in host countries. However, the one direction effect of CO_2 emissions on FDI inflows supports the pollution haven hypothesis, which states that when the host countriesare less able to afford the costs of implementing and monitoring environmental regulations, the country becomes a pollution haven.[10] However, from OLS consistent estimated results, we find the significant role of FDI inflows in reducing CO_2 emissions. Although the magnitude of the estimated coefficient FDI in Equation 5 is very small, expresses that pollutants only decrease by 0.0301% when FDI inflows increase by 1%,it implies that FDI stillhas positive effect onenvironmental improvement of *MPCA12* panel sample. This implication also appeared in some researches, such asHübler (2009) for China orLetchumananand Kodama (2000) for Thailand.Our evidencesuggests that besides improving itsenergy efficiency and strengthening their economic growth,the, which includes almost developing countries,should try to attract more FDI, which can helptheir economies develop stably, increase the country's income andcurb environmental pollutants.

With the use of dummy variables, we find that Japan'sincome hascausal relationships with the*MPCA12*'s income, FDI, energy consumption and CO_2 emissions. The long-run unidirectional relationship of CO_2 emissions to Japan's income and long-run bidirectional relationships between energy use and this series may imply that there are many Japanese firms operating in the*MPCA12* countries which sends money back to Japan, thereby increasing Japan's income by, while contributing to these countries energy consumption as well as CO_2emissons.Similarly, the unidirectional relationship from the*MPCA12*'s FDI inflows to Japan's income may be referred to the reason that Japan's companies have been investing heavily to the most populous countries in Asia.

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