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# Decoupling $Co_2$ Emissions From GDP in Asean-8: A Panel Data Analysis

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*Abstract: In this paper author attempted to analyze the decoupling hypothesis of $CO_2$ emission from GDP in ASEAN-8 countries during 1980-2016 in panel data which were collected from the World Bank with the assistance of the econometric models of panel fixed effect regression model, Johansen (1988)-Fisher (1932) panel co-integration and panel vector error correction model respectively for long run relationship and applied the Wald test (1943) for short run causality. The VEC residual normality test of Hansen-Doornik (1994) residual correlation was used to test normality. After verifying the Hausman test (1978) in the random effect model author used fixed effect panel regression model and found that there is no decoupling because the elasticity is positive and greater than or equal to +1. 0 with respect to GDP, there is absolute decoupling when the elasticity is zero or negative with respect to square of GDP, and there is relative decoupling with respect to the cube of GDP during the survey period. All are significant at 5% level. Thus, it proves the existence of inverted U shaped Environment Kuznets Curve. Residual cross section dependence test confirmed that there is cross section dependence in the statistic of Breusch-Pagan LM(1979) and Pesaran CD (2015) which were rejected at null hypothesis of no cross-section dependence (correlation) in residuals. The coefficient diagnostic test assured that the confidence ellipseis significant at 5% level. The co-integration test suggests that there is long run association among $CO_2$ emissions and the GDP of the ASEAN-8 having two co-integrating equations given by Trace and Max Eigen statistic. From the VECM-1of the system equation, co-integrating equation-2 has been approaching towards equilibrium which implies there is long run causality from GDP of previous period, square of GDP of previous period, and cube of GDP of previous period to the change of $CO_2$ emissionsalthough it is not significant at 5% level. The speed of adjustment is 0. 73% per year. The similar findings have been observed from other estimated VECM of the system equations. But, there is no short run causality from GDP to $CO_2$ emission in ASEAN-8. Besides, there are both short run and long run causality from GDP, square of GDP and cube of GDP of previous periods to GDP of the given period. In general, VECM is stable but non-stationary, non-normal and serially correlated.*

***Key Words:*** *$CO_2$ emission, GDP, decoupling, panel co-integration, panel VECM, short run causality, long run causality*

***JEL Classification codes:*** *C14, C23, C32, Q01, Q38, Q43, Q52, Q53, Q5*

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## I. INTRODUCTION

Kuznet (1955) hypothesized that economic inequality initially increases, reaches a critical threshold and then decreases as the country developed. Later on, this fundamental notion was developed by Gross and Krueger (1991, 1995)who stated that the Environment Kuznets Curve suggests that economic development initially leads to a deterioration in the environment, but after a certain level of economic growth a country begins to improve and reduces environmental degradation. Generally, a nation starts to improve its relationship with the environment and levels of environment degradation reduces generating the EKC inverted U curve. Again, while pollution per unit of output might go down and absolute pollution level will go up as economic growth increases where question arises about technological change on pollution. Simply, the EKC hypothesis postulates an inverted U-shaped relation between different pollutants and per capita income or in other words, environmental pressure increases up to a certain level as income goes up, after that, it decreases. Shafik (1994) reasserted that various indicators of environmental degradation tend to get worse as modern economic growth occurs until average income reaches a certain point over the course of development. In sum, EKC suggests that "the solution to pollution is economic growth". In EKC hypothesis, economists and policy makers take decoupling indicator to measure the correlation between the economic and environmental spheres to explain the mechanism of the relation. They preferred environment variable as $CO_2$ emissions and economic variable as GDP or GDP per capita. Generally, decoupling occurs when the rate of growth of $CO_2$ emissions becomes less than the growth of GDP over a period. Absolute decoupling occurs when emissions go down while economy grows. This is currently happening in many developed countries. Absolute decoupling is a subset of relative decoupling and it indicates emissions declining. Relative decoupling happens when emissions per unit economic activity go down and each dollar of economic activity requires less emissions. Relative decoupling is a consequence of the steady upward rising of economic growth . It is related with productivity growth and structural change. Most countries are experiencing relative decoupling. In China and in India, emissions grow with relative decoupling but in US and in EU, Sweden and UK, emissions reached at peak and declining with relative decoupling. The problem with relative decoupling is that emissions can still grow strongly depending on the level of economic activity. The USA has had relative decoupling for decades with emissions growing before 2005 and decoupling after. Chinahas also had relative decoupling for decades while maintaining strong emissions growth. If China maintains the same relative decoupling it may lead to a peak in emission i. e. absolute decoupling simply because of slower GDP growth. There may be weak and strong decoupling. In weak decoupling situation GDP increases while primary energy consumption or $CO_2$ intensity decreases. On the contrary, in strong decoupling GDP increases while primary energy consumption or $CO_2$ emission decreases. Another explaining area was shown by Kaya (1990) whose identity expressed that there is empirical trade-off between GDP growth and emission reduction. The higher the GDP growth the harder it is to reduce emission for a given relative decoupling. The higher is emission reduction the harder it is to grow the economy for a given relative decoupling.

The International Energy Agency and Nordic Energy Research present the Nordic countries' remarkable achievements in decarbonizing their energy systems and decoupling emissions from economic growth. A key message from Nordic Council ministers at COP21 is that low carbon growth is possible and 5 Nordic countries have actively used policy frameworks in decoupling $CO_2$ emissions from GDP.

Other researches on the opposite views on EKC remain crucial. Simon (1996) explained that rising income brings population growth rates down, therefore population growth is detrimental to the environment. Thus, economic value needs to be decoupled from resources depletion and environmental destruction. Stern (1998) stated that econometric technique used have improved, however, empirical decompositions of the EKC into proximate or underlying causes are either limited in scope or non-systematic and explicit testing of the various theoretical models have not been attempted. Arrow (2000) pointed out that the EKC provides very little information about the mechanisms by which economic growth affects the environments. For example, as income increases industry developments and innovations may have reduced negative externalities on the environment. Also with greater national income and wealth there is greater demand on the authorities for environmental regulations. Uchiyama(2018) stated that there seem to be little consensus about whether EKC is formed with regard to $CO_2$ emissions as $CO_2$ is a global pollutant that has yet to prove its validity within Kuznets curve.

## II. LITERATURE REVIEW

Sugiawanand Managi (2016) studied the relationship between economic growth and $CO_2$ emission in Indonesia from 1971 to 2010 using ARDL approach to cointegration and found long run relation and an U shaped environment Kuznets curve. Marques, Fuinhasand Leal (2018) verified the nexus between economic growth and $CO_2$ emission using EKC and decoupling index in Australia during 1965-2016 and showed the validity of environment Kuznets curve which stated that economic growth causes $CO_2$ emissions and consequently environment degradation. Joshua *et al* (2017) examined empirically the relation between $CO_2$ emission, economic growth and energy consumption in China during 1970-2015 by ARDL model and found U shaped curve. Lu *et al* (2007) analyzed the decoupling of transport energy demand and $CO_2$ emissions from economic growth in Taiwan, Germany, Japanand South Korea. Tapio (2005) also analyzed the decoupling of GDP and traffic volume and $CO_2$ emissions from transport in EU15 countries during 1970-2001. Both of them found significant EKC hypothesis. Finel and Tapio (2012) studied 137 countries during 1975-2005 to link GDP and transport $CO_2$ emissions. They found weak negative decoupling in a two largest group and a strong decoupling where GDP growth and emissions decreased in 21 countries. Armeanu *et al* (2018) studied empirically the relation between economic growth and GHG emissions in 28 EU countries during 1990-2014 using OLS with Driscoll-Kraay standard error and panel vector error correction and confirmed that there is a short run unidirectional causality from primary energy consumption and GHG emissions and there is no causal link between economic growth and primary energy consumption. Lise *et al* (2007) supported a unidirectional causality from economic growth to energy consumption and motivated that energy consumption policies will not impairs economic growth. Wang (2017) examined the relationship between economic growth and environmental quality in Sweden and Albania during 1984-2012 and found that there was no decoupling between economic growth and environmental quality. Asante (2016) verified the relationship between $CO_2$ emissions, economic growth, energy consumption and trade openness in Ghana during 1980-2011 by ECM and Granger causality and found significant existence of EKC and unidirectional causality from economic growth to $CO_2$ emissions, energy consumption and trade openness, energy consumption to $CO_2$ emissions and $CO_2$ emissions to trade openness and there is long run equilibrium among them with the speed of adjustment of 122% per year. Zhou *et al* (2018) studied five developing countries i. e. China, India, Brazil, Mexico and South Africa and four developed countries i. e. EU, USA , Canada and Japan during 1983-2013 on the relationship between economic growth and emissions. It observed that carbon emission is heterogenous across quantiles where energy consumption increases the $CO_2$ emission. Energy consumption in $CO_2$ emission for developed countries are higher than developing countries and found inverted U shaped EKC. Zhou *et al* (2016) and Honma (2014) found a little evidence in support of an inverted U shaped curve in ASEAN-5 and Asia-Pacific countries respectively. Bhowmik (2018) verified decoupling per capita $CO_2$ emission from per capita GDP in Euro Area and South Asia during 1991-2017. The paper showed that there is absolute decoupling in income elasticity , no decoupling in square of income elasticity , absolute decoupling cubic income elasticity, and relative decoupling in income elasticity to the power four respectively. There is a long run association between per capita $CO_2$ emission and cubic function of per capita GDP of South Asia and Euro Area during 1991-2017. The speeds of adjustment of error corrections are 8. 86% and 161. 6% per annum respectively. There is no short run association between per capita $CO_2$ emission and per capita GDP in different order. It satisfied EKC hypothesis.

## III. OBJECTIVE OF THE PAPER

In this paper author tried to show the relationship between $CO_2$ emission and GDP in ASEAN-8 regions through fixed effect panel regression, panel cointegration and vector error correction models during 1980-2016 with the hypothesis of decoupling to justify the Environment Kuznets Curve in the form of inverted U or N shaped. The short and long run association between $CO_2$ emission and GDPwith higher order were also the aim of analysis of the paper.

## IV. METHODOGY AND SOURCE OF DATA

To find the relationship between per capita $CO_2$ in kilo ton and GDP in US$ in current prices during 1980-2016, author used fixed effect panel regression model after verifying the Hausman Test (1978) taking decoupling model. Fisher (1932)-Johansen cointegration test (1988) was used to show cointegration. Johansen (1991) Panel Vector Error Correction Model was also used to show long and short run association between $CO_2$ emission and GDP where Wald test (1943) was used to verifyshort run causality in the system equations.

Data of $CO_2$ emissions in metric ton and GDP in US$ in current prices for ASEAN-8 from 1980 to 2016 were taken from the World Bank. The ASEAN-8 consists of Brunei, Indonesia, Lao PDR, Malaysia, Philippines, Singapore, Thailand and Vietnam respectively.

## V. OBSERVATIONS FROM ECONOMETRIC MODELS.

Random Effect Model of OLS between $CO_2$ emissions and GDP of ASEAN-8 during 1980-2016 in panel data is given below where cross sections=8, periods=37, observations=296, y = $CO_2$ emissions in Kilo ton, x = GDP in current US $.

$$\text{Log}(y)=5.43960+1.868129\log(x)-0.14150\log(x)^2+0.004029\log(x)^3+u_i$$
$$(38.33)^* \quad (11.06)^* \quad (-2.47)^* \quad (0.71)$$

$R^2$=0. 89, F=814. 29*, DW=0. 187, $\pi^2$ (3)=107. 004(p=0. 00), *=significant at 5% level.

Therefore, Random effect model is rejected. And the fixed effect model is shown below.

$$Log(y)=5.033073+2.350266log(x)-0.340356log(x)^2+0.028098log(x)^3+u_i$$

(33.95)* (13.26)* (-5.57)* (4.58)*

$R^2$=0.926, F=82.597*, DW=0.248, *=significant at 5% level.

Thus, it is proved that dlog(y)/dlog(x)=2. 350266>1 which implies that there is no decoupling because the elasticity is positive and greater than or equal to +1. 0, then $CO_2$ emissions is directly coupled with GDP. Moreover, dlog(y)/dlog$(x)^2$=-0. 340356<0, i. e. there is absolute decoupling when the elasticity is zero or negative. Even, dlog(y)/dlog$(x)^3$=0. 028098>0<1, here the elasticity is positive and less than +1. 0, so that there is relative decoupling. All values are significant at 5% level and the estimation is a good fit except for low DW which implies autocorrelation problems. Therefore, it can be noted that there is existence of environment Kuznets curve in ASEAN-8 during 1980-2016. In the Figure -1, the inverted U shaped environment Kuznets curve is seen clearly in the actual and fitted lines of the fixed effect panel regression model.

Residual cross section dependence test confirmed that there is cross section dependence in the statistic of Breusch-Pagan LM(1979), Pesaran

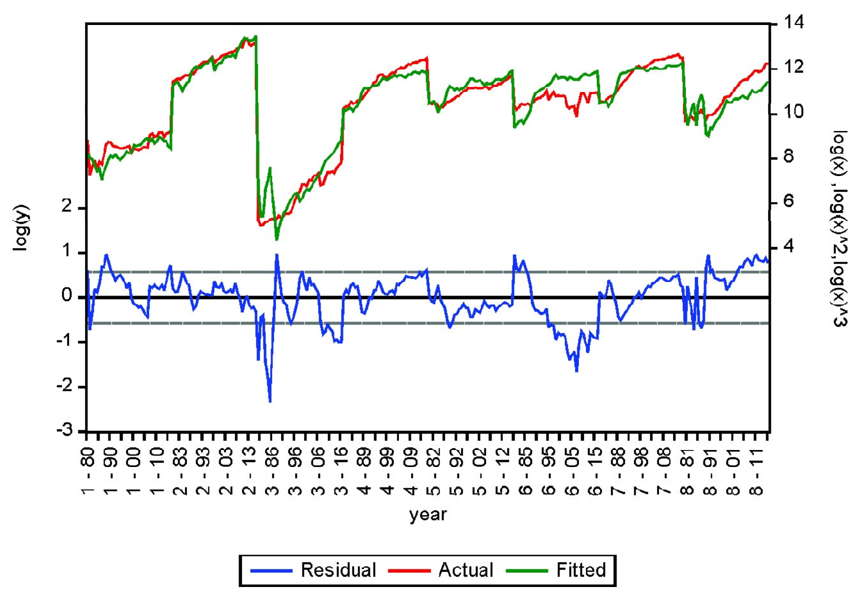


**Figure 1: Inverted U shaped EKC**

*Source:* Plotted by author

scaled LM(2004) and Pesaran CD (2015)which were rejected at null hypothesis of no cross-section dependence (correlation) in residuals given in the Table 1.

**Table 1**
**Residual cross section dependence test**

| *Test* | *Statistic* | *Degree of freedom* | *Probability* |
|---|---|---|---|
| Breusch-Pagan LM | 195.7657 | 28 | 0.0000 |
| Pesaran scaled LM | 21.34959 | | 0.0000 |
| Pesaran CD | -2.651163 | | 0.0080 |

Null hypothesis: No cross-section dependence (correlation) in residuals
*Source:* Calculated by author.

The coefficient diagnostic test of the above estimated equation assured that the confidence ellipse of the coefficients namely c(1)=5.033, c(2)=2.350, c(3)=-0.34 and c(4)=0.028 at the confidence level 0. 95% are highly significant which are plotted in the Figure 2.

Johansen (1988)-Fisher (1943) panel cointegration test among log(y), log(x), $\log(x)^2$, $\log(x)^3$ during 1980-2016 under the assumption of linear

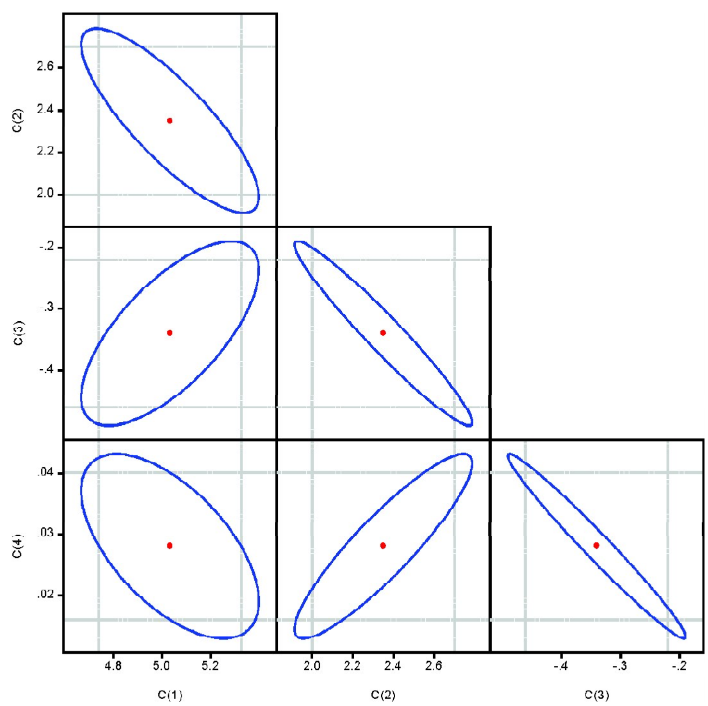


**Figure 2: Confidence ellipse of the coefficients**

*Source:* Plotted by author

deterministic trend with lag one confirmed two cointegrating equations as verified by Trace statistic and Max Eigen statistic which are arranged in the Table 2.

**Table 2**
**Panel cointegration test**

| *Hypothesized No. of CE(s)* | *Fisher Stat. ** (from Trace Test)* | *Probability* | *Fisher Stat.** (from Max-Eigen test)* | *Probability* |
|---|---|---|---|---|
| None | 78.90 | 0.0000 | 63.07 | 0.0000 |
| At most 1 | 30.73 | 0.0146 | 30.08 | 0.0176 |
| At most 2 | 12.77 | 0.6891 | 13.51 | 0.6353 |
| At most 3 | 14.80 | 0.5390 | 14.80 | 0.5390 |

*Source:* Calculated by author, **MacKinnon-Haug-Michelis (1999) p values.

The cointegration test suggests that there is long run association among $CO_2$ emissions and the GDP of the ASEAN-8 during the survey period 1980-2016 under the decoupling hypothesis.

Since there are two cointegrating equations, then the estimated vector error correction model is shown below.

[1] $\Delta logy_t = 0.001753EC_1 - 0.007319EC_2 - 0.046005\Delta logy_{t-1} - 0.1451\Delta logy_{t-2}$
(0.293) (-0.157) (-0.742) (-2.88)*
$-0.1149\Delta logx_{t-1} + 0.0586\Delta logx_{t-2} + 0.0405\Delta logx_{t-1}^2 - 0.0258\Delta log\, x_{t-2}^2$
(0-97) (0.504) (0.96) (-0.66)
$-0.00205logxt-1^3 + 0.00339\Delta logx_{t-2}^3 + 0.0505$
(-0.43) (0.73) (5.20)
$R^2=0.051$, F=1.42, SC=-0.98, AIC=-1.12, *=significant at 5% level.

In Figure 3 the estimated VECM-1 is plotted below.

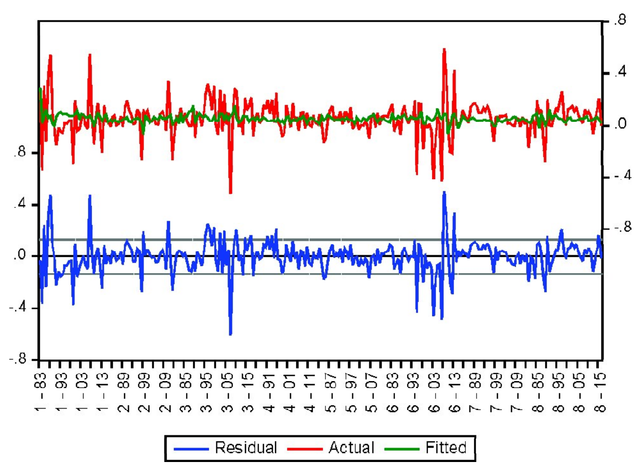


**Figure 3: VECM-1**

VECM-1 is a bad fit with low $R^2$, F, and insignificant SC and AIC. All coefficients are insignificant except the coefficient of Älogy$_{t-2.}$ Yet the coefficient of $EC_2$ is negative but not significant which implies the cointegrating equation tends to equilibrium with speed of adjustment 0. 73% per year during 1980-2016.

[2] $\Delta logx_t = 0.00561EC_1 - 0.0446EC_2 + 0.02518\Delta logy_{t-1} + 0.03508\Delta logy_{t-2}$

(0.64) (-0.65) (0.27) (0.47)

$+0.5608\Delta logx_{t-1} - 0.2056\Delta logx_{t-2} - 0.1269\Delta logx_{t-1}^{2} - 0.00253\Delta logx_{t-2}^{2}$

(3.24)* (-1.21) (-2.06) (-0.04)

$+0.00949logx_{t-1}^{3} + 0.00172\Delta logx_{t-2}^{3} + 0.06836$

(1.36) (0.25) (4.59)*

$R^2$=0.066, F=1.86, SC=-0.227, AIC=-0.372, *=significant at 5% level.

VECM-2 is also a bad fit with low $R^2$, F, and insignificant SC and AIC. All coefficients are insignificant except the coefficient of $\Delta logx_{t-1.}$ Yet the coefficient of $EC_2$ is negative but not significant which implies the cointegrating equation tends to equilibrium with speed of adjustment 4. 46% per year during 1980-2016.

In Figure 4 the estimated VECM-2 is plotted below.

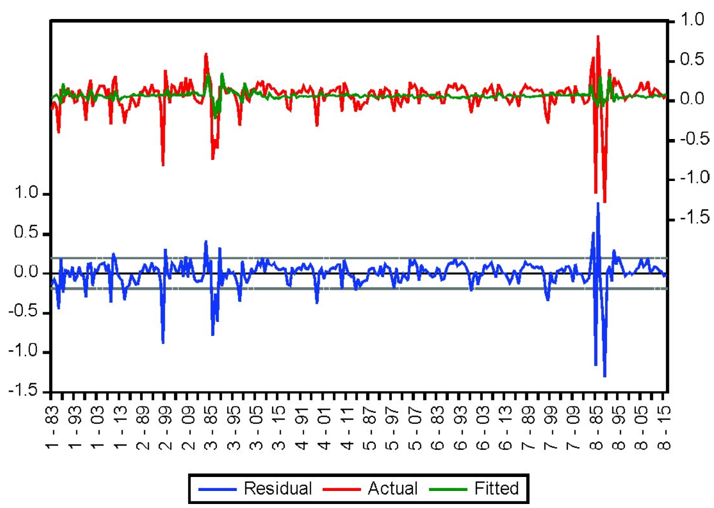


**Figure 4: VECM-2**

The estimated VECM-3 is given below.

[3] $\Delta logx_t^{2} = -0.040009EC_1 + 0.\ 251159EC_2 + 0.\ 4177\Delta logy_{t-1} + 0.\ 2463\Delta logy_{t-2}$

(-0.68) (0.55) (0.691) (0.50)

$+0.6701\Delta logx_{t-1} - 0.0923\Delta logx_{t-2} - 0.27234\Delta logx_{t-1}^{2} - 0.3935\Delta logx_{t-2}^{2}$

(0.58) (-1.08) (-0.66) (-1.006)

$+0.003398\log x_{t-1}^{3}+0.0457\Delta\log x_{t-2}^{3}+0.533$
(0.73) (1.01) (5.36)*
$R^2$=0.044, F=1.217, SC=3. 57, AIC=3.42, *=significant at 5% level.

VECM-3 is not a good fit with low $R^2$, F, and insignificant SC and AIC. All coefficients are insignificant. Yet, the coefficient of $EC_1$ is negative but not significant which implies the cointegrating equation tends to equilibrium with speed of adjustment 4.0% per year during 1980-2016.

In Figure 5 the estimated VECM-3 is plotted below.

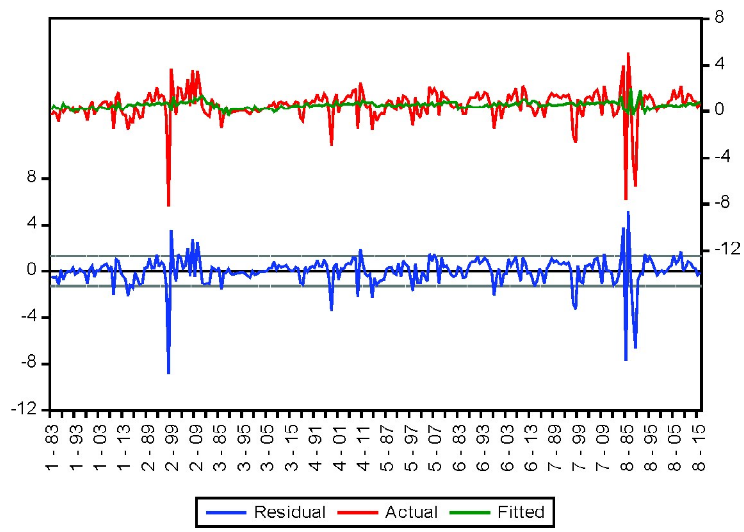


**Figure 5: VECM-3**

The estimated VECM-4 is shown below.

$[4]\Delta\log x_t^{3} = -0.0839EC_1+0.0474EC_2+1.58109\Delta\log y_{t-1}+1.166\Delta\log y_{t-2}$
(-0.22) (0.016) (0.40) (0.36)
$+3.0098\Delta\log x_{t-1}+1.5038\Delta\log x_{t-2}-2.1569\Delta\log x_{t-1}^{2}-2.539\Delta\log x_{t-2}^{2}$
(0.40) (0.204) (-0.80) (-1.00)
$+0.3277\log x_{t-1}^{3}+0.2904\Delta\log x_{t-2}^{3}+3.5351$
(1.08) (0.99) (5.47)*
$R^2$=0.075, F=2.11, SC=7.31, AIC=7.16, *=significant at 5% level.

VECM-4 is not a good fit with low $R^2$, F, and insignificant SC and AIC. All coefficients are insignificant. Yet, the coefficient of $EC_1$ is negative but not significant which implies the cointegrating equation tends to equilibrium with speed of adjustment 8.39% per year during 1980-2016.

In Figure 6 the estimated VECM-4 is plotted below.

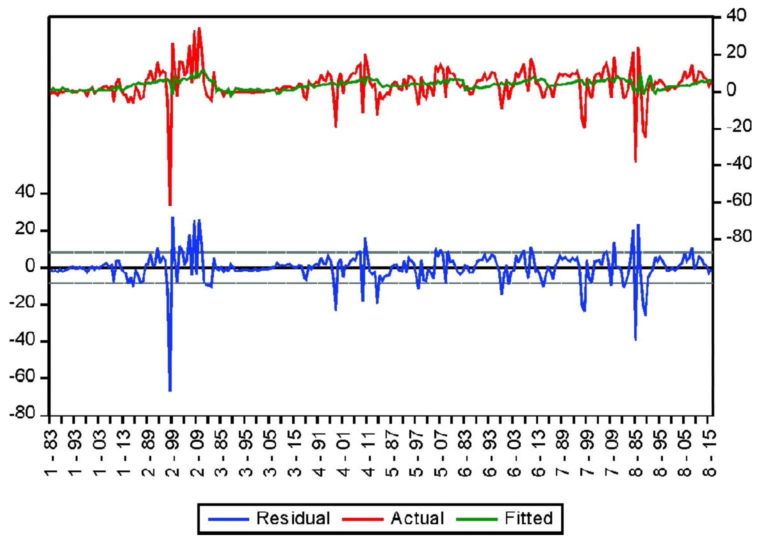


**Figure 6: VECM-4**

*Source:* Plotted by author

Four pairs of cointegrating equations of estimated VECM can be found from the system equations .

In the system equation of VECM-1, the corresponding cointegrating equations are as follows:

[i] $\Delta logy_t$=0.001753$logy_{t-1}$-4.543$logx_{t-1}^2$+0.39715$logx_{t-1}^3$+33.82
(0.293) (-2.38)* (1.276)

[ii] $\Delta logy_t$=-0.007319$logx_{t-1}$-0.8101$logx_{t-1}^2$+0.06732$logx_{t-1}^3$+4.4217
(-0.157) (-3.33)* (1.69)

Cointegrating equation-ii has been approaching towards equilibrium which implies there is long run causality from $logx_{t-1,}$ $logx_{t-1}^2$and log $x_{t-1}^3$ to $\Delta$ $logy_t$ although it is insignificant. The speed of adjustment is 0. 73% per year and *=significant at 5% level.

In the system equation of VECM-2, the corresponding cointegrating equations are as follows:

[iii] $\Delta logx_t$=0.0056$logy_{t-1}$-4.543$logx_{t-1}^2$+0.39715$logx_{t-1}^3$+33.82
(0.64) (-2.38)* (1.276)

[iv] $\Delta logx_t$=-0.0446$logx_{t-1}$-0.8101$logx_{t-1}^2$+0.06732$logx_{t-1}^3$+4.4217
(-0.656) (-3.33)* (1.69)

Cointegrating equation-iv has been approaching towards equilibrium which implies there is long run causality from log $x_{t-1,}$ log $x_{t-1}^2$ and log $x_{t-1}^3$ to $\Delta$ log$x_t$ although it is insignificant. The speed of adjustment is 4. 46% per year and *=significant at 5% level.

In the system equation of VECM-3 , the corresponding cointegrating equations are as follows:

[v] $\Delta \log x_t^2 = -0.0400 \log y_{t-1} - 4.543 \log x_{t-1}^2 + 0.39715 \log x_{t-1}^3 + 33.82$
(-0.686) (-2.38)* (1.276)

[vi] $\Delta \log x_t^2 = 0.2511 \log x_{t-1} - 0.8101 \log x_{t-1}^2 + 0.06732 \log x_{t-1}^3 + 4.4217$
(0.552) (-3.33)* (1.69)

Cointegrating equation-v has been tending towards equilibrium which implies there is long run causality from log $y_{t-1,}$ log $x_{t-1}^2$ and log $x_{t-1}^3$ to $\Delta$ log $x_t^2$ although it is insignificant. The speed of adjustment is 4.0% per year and *=significant at 5% level.

In the system equation of VECM-4 , the corresponding cointegrating equations are as follows:

[vii] $\Delta \log x_t^3 = -0.0839 \log y_{t-1} - 4.543 \log x_{t-1}^2 + 0.39715 \log x_{t-1}^3 + 33.82$
(-0.221) (-2.38)* (1.276)

[viii] $\Delta \log x_t^3 = 0.0474 \log x_{t-1} - 0.8101 \log x_{t-1}^2 + 0.06732 \log x_{t-1}^3 + 4.4217$
(0.016) (-3.33)* (1.69)

Cointegrating equation-vii has been moving towards equilibrium which implies there is long run causality from log $y_{t-1,}$ log $x_{t-1}^2$ and log $x_{t-1}^3$ to $\Delta$log $x_t^3$ although it is insignificant. The speed of adjustment is 8. 39% per year and *=significant at 5% level.

The short run causalitieswere found from the Walt test and the observations are as follows.

[i] There are short run causalities from $\Delta$log $y_{t-1}$ and $\Delta$ log $y_{t-2}$ to $\Delta$log$y_t$ because $\pi^2(2)$=0. 0141 is rejected from the Wald Test where $H_0$=no causality where c(3)=c(4)=0.

[ii] There are short run causalities from $\Delta$log $x_{t-1}$ and $\Delta$ log $x_{t-2}$ to $\Delta$ log $x_t$ because $\pi^2(2)$=0. 0051 is rejected from the Wald Test where $H_0$=no causality where c(16)=c(17)=0.

[iii] There are short run causalities from $\Delta$ log$x_{t-1}^2$ and $\Delta$ log$x_{t-2}^2$ to $\Delta$ log$x_t$ because $\pi^2(2)$ = 0. 098 is rejected from the Wald Test where $H_0$=no causality where c(18)=c(19)=0.

Their two cointegrating equations in terms of graph of cointegration test are shown in the Figure 7.

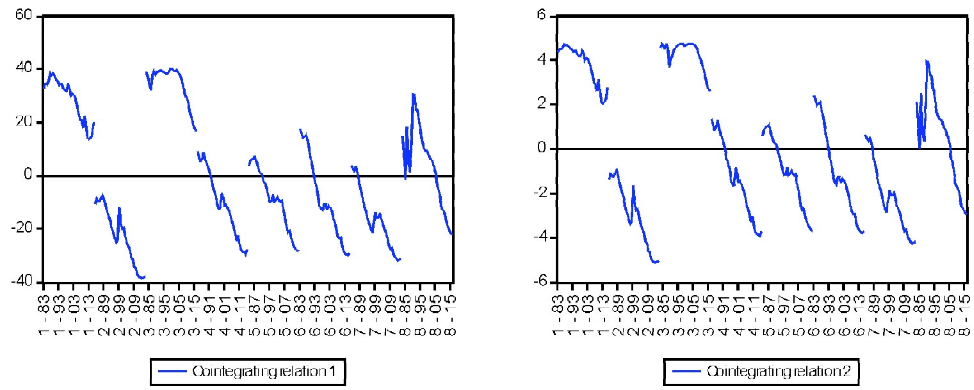


**Figure 7: Cointegration graph**

*Source:* Plotted by author

In general, the VECM is stable because there are 3 unit roots, two roots are less than one, one root is negative and six roots are imaginary under AR roots of characteristic polynomial. These are shown in Table 3.

**Table 3**
**Values of roots**

| *Root* | *Modulus* |
|---|---|
| 1.001425 | 1.001425 |
| 1.000000 | 1.000000 |
| 1.000000 | 1.000000 |
| 0.862635 | 0.862635 |
| 0.277945 - 0.353104i | 0.449372 |
| 0.277945 + 0.353104i | 0.449372 |
| -0.056787 - 0.413282i | 0.417165 |
| -0.056787 + 0.413282i | 0.417165 |
| 0.029794 - 0.390006i | 0.391142 |
| 0.029794 + 0.390006i | 0.391142 |
| 0.218469 | 0.218469 |
| -0.108898 | 0.108898 |

*Source:* Calculated by author

In the unit circle all roots lie inside or on the circle which proved that VECM is stable and non-stationary.

All the variables in the VECM suffer from autocorrelation problem that's why the correlogram showed vertical bars are either sides which are shown in Figure 9.

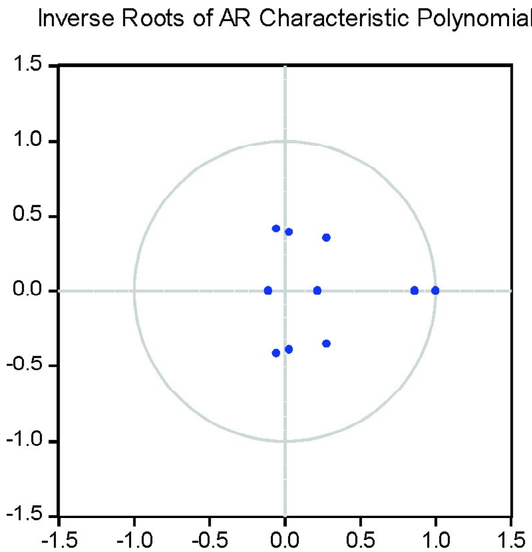


**Figure 8: Unit circle**

*Source:* Plotted by author

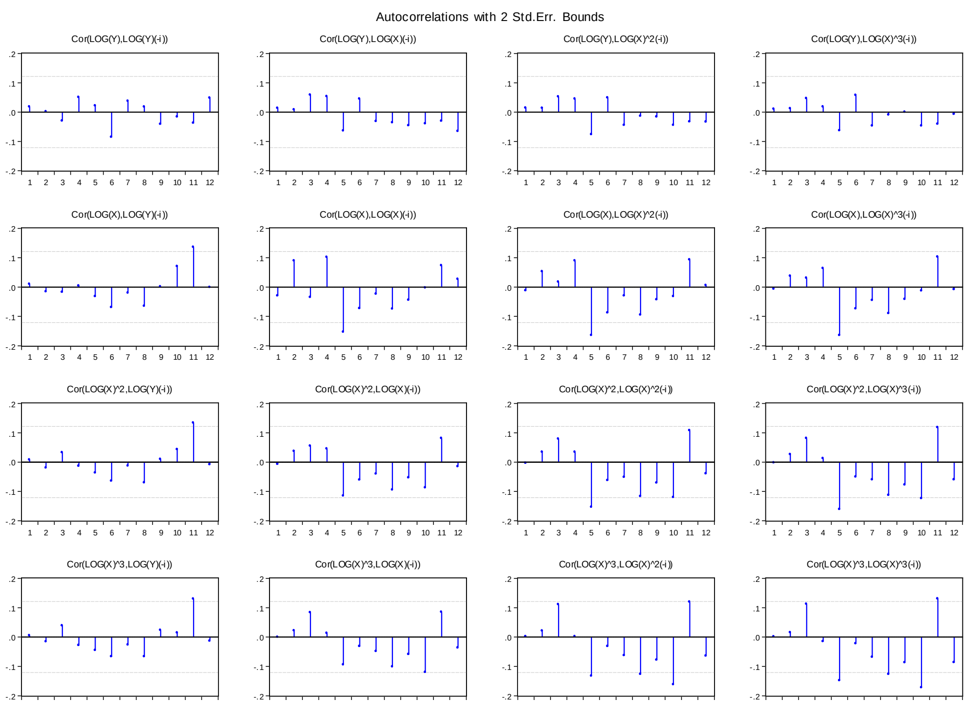


**Figure 9: Autocorrelation**

*Source:* Plotted by author

The VEC residual normality test of Hansen-Doornik(1994 ) residual correlation showed that the Chi-squares values of skewness and kurtosis and the values of Jarque-Bera were not accepted for normality during 1980-2016 which is shown in the Table 4.

**Table 4**
**Normality test**

| *Component* | *Skewness* | *Chi-square* | *Degree of freedom* | *Probability.* |
|---|---|---|---|---|
| 1 | -0.311402 | 4.433455 | 1 | 0.0352 |
| 2 | -2.748108 | 123.0982 | 1 | 0.0000 |
| 3 | -0.759953 | 22.30854 | 1 | 0.0000 |
| 4 | -1.093667 | 39.48967 | 1 | 0.0000 |
| Joint | 189.3298 | 4 | 0.0000 | |
| Component | Kurtosis | Chi-square | Degree of freedom | Probability. |
| 1 | 7.747851 | 108.2612 | 1 | 0.0000 |
| 2 | 22.92494 | 0.592656 | 1 | 0.4414 |
| 3 | 20.90326 | 521.8076 | 1 | 0.0000 |
| 4 | 22.66816 | 486.2992 | 1 | 0.0000 |
| Joint | 1116.961 | 4 | 0.0000 | |
| Component | Jarque-Bera | Degree of freedom | Probability. | |
| 1 | 112.6946 | 2 | 0.0000 | |
| 2 | 123.6908 | 2 | 0.0000 | |
| 3 | 544.1162 | 2 | 0.0000 | |
| 4 | 525.7889 | 2 | 0.0000 | |
| Joint | 1306.290 | 8 | 0.0000 | |

*Source:* Calculated by author

The Impulse Response Functions assure that any external shocks from the independent variables on the emission do not move the system into the equilibrium i. e. the functions diverge from the equilibrium which is shown in the Figure 10.

## VI. LIMITATION AND THE FUTURE PROSPECT OF RESEARCH

Pollution is not simply a function of income but depends on many factors;such as the effectiveness of government regulations, the development of the economy, population level, energy price shock, literacy, income inequality, structural shifts in manufacturing, trade openness on environmental quality and other socio-economic variables. Even, environmental impacts also fall with technological development. Sometimes, EKC may be N shaped. In this model, the inverted U shaped would be more perfect if the observations are to be very large. The link between Kaya identity to the EKC hypothesis and the decomposition analysis in ASEAN-8 are absent here although there is positive association among $CO_2$emission, GDP and carbon intensity which is highly significant

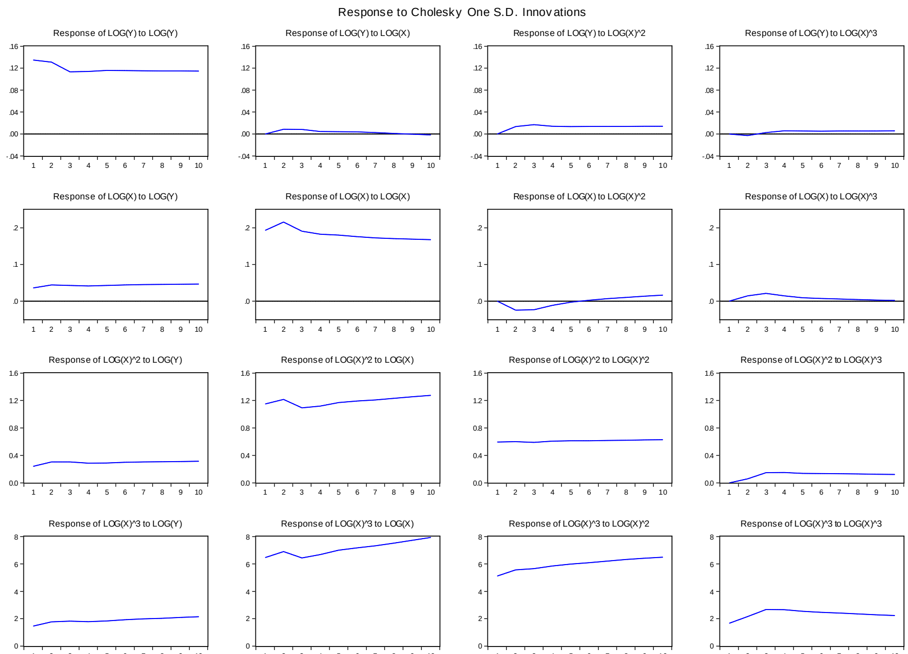


**Figure 10: Impulse Response Functions**

*Source:* Plotted by author

at 5% level in ASEAN-8 during 1980-2016 under fixed effect panel regression model.

$$\Delta y = 1077.443 + 433.9351\Delta x + 15.81398\Delta(y/x)$$
$$(1.103) \qquad (8.508)^{*} \qquad (3.448)^{*}$$
$$R^2 = 0.313,\ F = 3.089^{*},\ DW = 2.36$$

Actual and estimated lines of Kaya equation in ASEAN-8 have been approaching towards equilibrium point which is shown in Figure 11.

Moreover, the diagnostic test for coefficients of the estimated equation in confidence ellipse at 5% significant level is proved to be accepted which is shown in Figure 12.

## VII. POLICY RECOMMENDATIONS

The imposition of emission tax, carbon tax, a system of tradable emission quota, a ceiling on total annual emissions level and increase in production of renewable energy are recommended to reduce emissions level of ASEAN. More convergence of GDP are necessary among ASEAN regions which can accelerate emission reduction in the countries of the bloc in EKC hypothesis.

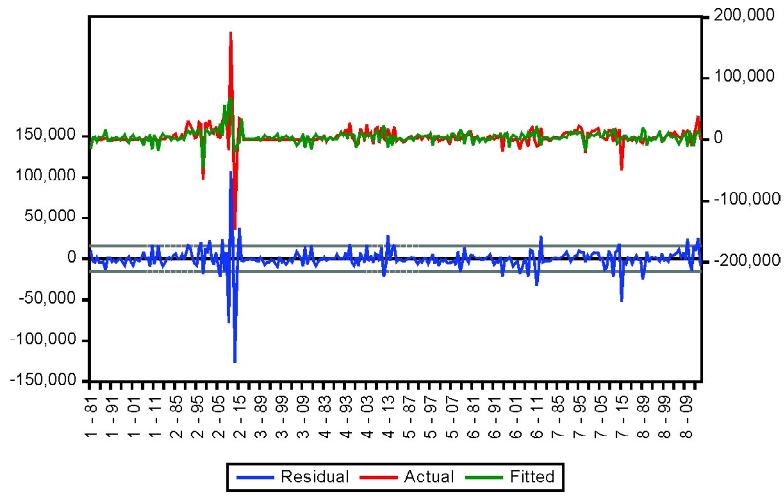


**Figure 11: Estimated Kaya equation**

Source: Plotted by author

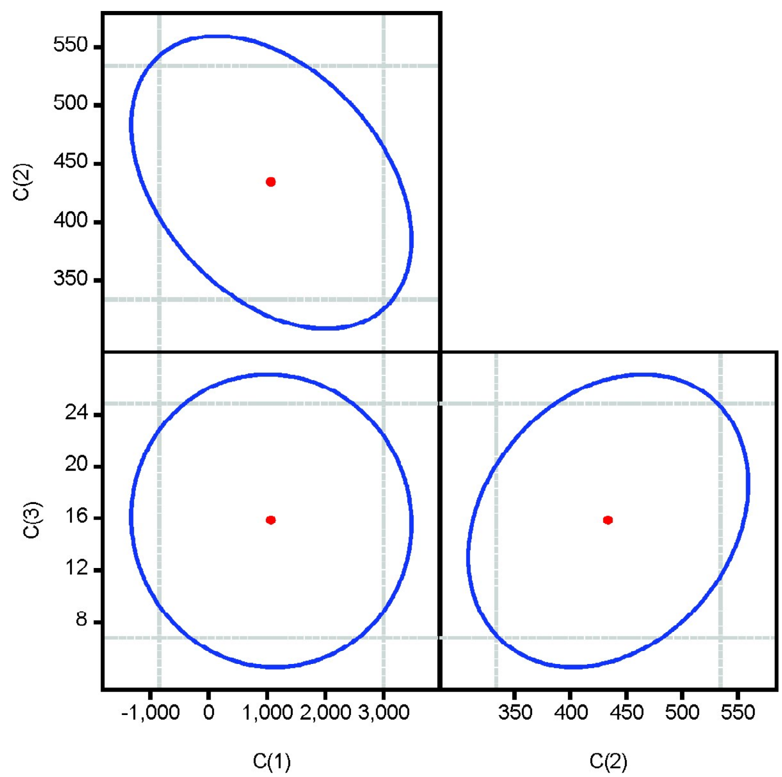


**Figure 12: Diagnostic test for coefficients**

*Source:* Plotted by author

## VIII. CONCLUSIONS

The paper concludes thatthere is no decoupling because the elasticity is positive and greater than or equal to +1. 0 with respect to GDP, there is absolute decoupling when the elasticity is zero or negative with respect to square of GDP, and there is relative decoupling with respect to the cube of GDP during the survey period. All are significant at 5% level. Thus, it proves the existence of inverted U-shaped Environment Kuznets Curve. Residual cross section dependence test confirmed that there is cross section dependence in the statistic of Breusch-Pagan LM (1979) and Pesaran CD (2015) which were rejected at null hypothesis of no cross-section dependence (correlation) in residuals. The coefficient diagnostic test assured that the confidence ellipseis significant at 5% level. The co-integration test suggests that there is long run association among $CO_2$ emissions and the GDP of the ASEAN-8 having two co-integrating equations given by Trace and Max Eigen statistic. From the VECM-1of the system equation, co-integrating equation-2has been approaching towards equilibrium which implies there is long run causality from GDP of previous period, square of GDP of previous period, and cube of GDP of previous period to the change of $CO_2$ emission although it is not significant at 5% level. The speed of adjustment is 0. 73% per year. The similar findings have been observed from other estimated VECM of the system equations. But, there is no short run causality from GDP to $CO_2$ emission in ASEAN-8. Besides, there are both short run and long run causalities from GDP, square of GDP and cube of GDP of previous periods to GDP of the given period. In general, VECM is stable but non-stationary, non-normal and serially correlated.

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