American Journal of Environmental Protection, 2020, Vol. 8, No. 1, 10-16
Available online at http://pubs.sciepub.com/env/8/1/2
Published by Science and Education Publishing
DOI:10.12691/env-8-1-2

Influence of Real GDP Growth Rate, Industrialization, Energy Consumption on Carbon Dioxide Emissions: An Evidence from Vietnam

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Received December 13, 2019; Revised January 28, 2020; Accepted February 16, 2020

Abstract The purpose of this paper is to investigate the effects of energy consumption, economic growth and industrialization on carbon dioxide emissions in Vietnam. Using an autoregressive distributed lag model (ARDL model) on the data during the period over 1985-2013, collected from World Development Indicators, Department of Statistics in Vietnam. Evidence from the study shows that carbon dioxide emissions, GDP growth, energy consumption and industrialization are co-integrated and have a long-run equilibrium relationship. Our results demonstrate that both industrialization and energy consumption have positively affected carbon dioxide emissions and significant while economic growth also has positively affected carbon dioxide emissions but insignificant. In addition to short run relationship, evidence from the long-run result has policy implications for Vietnam; a 1 percent increase in industry growth will increase carbon dioxide emissions by 276 kt, while a 1 kg of oil increase in energy consumption will increase carbon dioxide emissions by 168 kt in the long-run. Increasing industry growth in Vietnam will therefore increase environmental pollution in the long-run. Positive effect of energy consumption on carbon dioxide emissions raise a problem of using non-green energy in Vietnam. It is noteworthy that the Vietnamese Government promotes sustainable economics, which improves the use of clean and environmentally energy.

Keywords: *carbon dioxide emissions, economic growth, energy consumption, industrialization, autoregressive distributed lag model*

Cite This Article: Nghiem Van Bay, “Influence of Real GDP Growth Rate, Industrialization, Energy Consumption on Carbon Dioxide Emissions: An Evidence from Vietnam.” *American Journal of Environmental Protection*, vol. 8, no. 1 (2020): 10-16. doi: 10.12691/env-8-1-2.

1. Introduction

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Climate change is indeed a survival problem which has attracted attention from many policy makers and academic researchers recently (see [1]). This global issue has close relationship with the increasing the overuse of energy and increasing industrialization (see [2,3,4]). According to [5], “there has been a global rise of carbon dioxide emissions within the past 36 years (1979-2014) from 1.4 parts per million per year in earlier 1995 to 2.0 parts per million per year afterwards”.

Energy has been considered as a very important factor of production and economic development in each country. It has played a great role in the economic growth, production and trade expansion of any country. As a result, the use of energy that reflects the quality of lives, it is consistent with the level of economic growth, trade expansion. In previous literature, there are mixed results about the effects of energy use and balance trade. It is believed that energy consumption can significantly affect environmental consequences, such as in the long-run equilibrium, energy consumption has a positive and statistically significant impact on greenhouse gas emissions (see [6,7,8]). The negative effect of energy consumption on greenhouse gas emissions rarely found in literature review.

In the context of the global economic integration, a non-linear relationship is found between greenhouse gas emissions and economic growth, consistent with the environmental Kuznets curve. A various studies have been done on trade balance in both developed and developing countries. The literature on the nexus of greenhouse gas emissions and economic growth has been focused on a large number of empirical studies. As presented in some recent studies (see [9,10]), found evidence of long-run and short-run causality relationship while supporting the validity of the environmental Kuznets curve hypothesis. To be precise, more efficiency in economic performance that will enhance the use of clean and environmentally sound raw materials, industrial process and technologies.

Another finding in the literature is that industrialization can affect the carbon dioxide emissions, but lack of studies focus on this topic. The authors in [11] investigated the nexus among carbon dioxide emissions, industrialization, gross domestic product (GDP) per capita and population in Rwanda during the period from 1965 to 2011. The authors showed that a 1 percent increase in GDP per capita might cause a decrease of carbon dioxide emissions by 1.45 percent, but a 1 percent increase in industrialization would increase carbon dioxide emissions by 1.64 percent in the long-run. Industrialization can be considered as a novelty issue and potential impact on the course of future research in the subject area of climate change.

To discuss more causes of carbon dioxide emissions in the specific situation in Vietnam, this study has conducted on the relationship of energy consumption, economic growth, industrialization and carbon dioxide emissions. The study aims at fulfilling this gap by analyzing the impacts of energy consumption, economic growth and industrialization on carbon dioxide emissions.

The structure of the study is as follows. Section 2 discussed the literature review. Section 3 described the data, the research model, and methodology of this study. The empirical analysis is presented in section 4. Section 5 covers some discussion. Finally Section 6 is devoted to conclusion.

2. Literature Review

Numerous previous studies examining the causes of carbon dioxide emissions have been conducted in developing and developed countries all over the world, especially in a particular countries such as emerging market economies in Asia, including Vietnam. There exists numerous results in the previous empirical works consistent with the link between energy consumption, economic growth and carbon dioxide emissions in various situations. The findings indicate that energy policy and sustainable economic development are known as two of the most important factors to support environmental protection.

By analyzing in Latin America and the Caribbean, [12] conducted on the panel dataset from 1980 to 2008, the result of empirical research indicates that there is a long-run relationship among energy consumption, carbon dioxide emission and economic growth in 60 percent of countries, and the rest (40 percent) presents a mixed result.

Followed by [13], the impact of economic growth on carbon dioxide emission in 31 developing countries was estimated. The results showed that the economic growth negatively impact on carbon dioxide emission in the low growth regime, but it positively affected the carbon dioxide emission in the high growth regime.

In addition, [14] focused on the relationship among the urbanization, economic growth, energy consumption, and carbon dioxide emissions of 170 countries in the period of 1980 and 2011. Results demonstrated that there existed a co-integration relationship among variables in all the countries considered, and there was a statistically significant positive relationship among variables in the long run. Besides, the authors found that evidence of varied Granger causality relationships among the variables across the income-based subpanels.

Likewise, [15] assessed the relationship between energy consumption, carbon dioxide emissions and economic growth in Ethiopia during the period of 1970 and 2014. Empirical results showed that energy consumption, trade openness, economic growth and population all have positive effects on carbon dioxide in the long-run, while economic growth squared caused a negatively impact on carbon dioxide emissions. Similarly, considering six emerging countries in the panel data studies, [16] indicated that there is a Granger causality running from economic growth to energy consumption, and from urbanization to energy consumption and economic growth.

The author in [17] conducted on a study in a sample of energy production, economic growth and carbon dioxide emission in Pakistan for the period from 1970 to 2011. It was suggested that there is an existence of an environmental Kuznets curve hypothesis in the significance of energy production in this country. Besides, bidirectional causality is distinguished between energy production and carbon dioxide emission in the long-run.

Lastly, based on the empirical study in [18], it is believed that there existed the relationship among economic growth, energy consumption and carbon dioxide emissions of five Central Asian countries between 1998 and 2017. It was shown that per capita energy consumption had a positive relationship with per capita GDP, while per capita carbon dioxide emissions negatively affected per capita GDP in Central Asia. Further, per capita GDP had a negative impact on per capita energy consumption in the region. Results reflected that the economic growth of Central Asian countries still heavily depended upon energy consumption. In the short run, it was also found that there was a directional relationship running from per capita GDP to per capita energy consumption and per capita carbon dioxide emissions; and from per capita energy consumption to per capita GDP. Results showed that there was a co-integration among variables in the long run.

As we can see that, energy production or energy consumption, economic growth have been involved in various studies the influence on carbon dioxide emissions, but rarely industrialization has been considered, except for a minor research such as [11]. For a new situation of Vietnam, with a new combination of effect factors of energy consumption, economic growth and industrialization on carbon dioxide emission, we execute this study to fill the gap in empirical study.

3. Data and Methodology

3.1. Data

The study attempts to examine the causal nexus of GDP growth, industrialization and energy consumption on carbon dioxide emissions with an evidence from Vietnam by employing a time series data spanning from 1985 to 2013 using the Autoregressive Distributed Lag (ARDL) Model. Four studied variables were employed from the World Bank which include; carbon dioxide emissions (kt), GDP growth rate (annual %), Industry (including construction), value added (current LCU) growth rate and Energy use (kg of oil equivalent per capita). It is noteworthy that industry value added is used as a proxy for industrialization.

Table 1. Measurement of Variables Used in the Study

Dependent Variables	Abbreviation	Source
Carbon dioxide emissions (kt)	CO2	WDI
Independent Variables		
Energy use (kg of oil equivalent per capita)	ENERGY	WDI
GDP growth rate (annual %)	GDP_GROWTH	WDI
Industry, value added (current LCU) growth rate	IND_GROWTH	WDI and calculated by the author

3.2. Research Model

Impact of energy consumption, economic growth, industrialization and carbon dioxide emissions have been investigated in a large amount of empirical studies in the world. Based on theoretical consideration, it is evident that the study is used a model for time series with Granger causality, cointegration test, variance decomposition analysis, VECM Granger causality approach and robustness of causality analysis is tested by innovative accounting approach (IAA), Zivot-Andrews unit root test and the ARDL bounds testing approach, etc. In this study, we will investigate time series thanks to ARDL model. This model was proposed by the authors in [19].

The mathematical form of the ARDL model used in the article is as follows:

$$\begin{aligned} D(CO2)_t &= \alpha_0 + \sum_{i=1}^{m} \alpha_i D(CO2)_{t-i} \\ &+ \sum_{i=1}^{n} \beta_i D(GDP\_GROWTH)_{t-i} \\ &+ \sum_{i=1}^{p} \gamma_i D(IND\_GROWTH)_{t-i} \\ &+ \sum_{i=1}^{q} \delta_i D(\mathrm{ENERGY})_{t-i} + u_i, \end{aligned} \tag{3.1}$$

where D is the difference operator; $\alpha_i, \beta_i, \gamma_i, \delta_i$ are the regression coefficients, and u_t is the residual which has a simultaneous correlation but no correlation with its lags and all independent variables. So the right side of the regression equation consists of the lags of independent and dependent variables.

The ARDL model estimation process can be summarized through the following steps:

Step 1, the stationarity of the time series are verified.

Step 2, the optimal lag for the ARDL model is selected: This is an important step before estimating the ARDL model.

Step 3, the best ARDL model selected in the above step is estimated.

Step 4, the result of ARDL model estimation is back tested:

+ the test in which show that the model is well specified or not: Using Ramsey RESET test;

+ the test of the stability of ARDL model thanks to the cumulative sum of residuals (CUSUM: Cumulative Sum of Recursive Residuals).

+ the test the residual of ARDL model without autocorrelation thanks to Lagrange Multiplier test (abbreviated as LM test).

If the estimated ARDL model is appropriate, then the ARDL model can be used to describe the impact of the energy consumption, economic growth and industrialization on carbon dioxide emissions in the short term.

Step 5, to see whether there exists a cointegration among energy consumption, economic growth, industrialization and carbon dioxide emissions or not, we implement the Bound Test.

Details of the ARDL model can be found in Chapter 17 of [20].

4. Results of Economic Modeling

4.1. Descriptive Statistics

Table 2. Descriptive Statistics

	CO2	GDP_GROWTH	IND_GROWTH	ENERGY
Mean	66214.26	6.436274	64.14697	403.6001
Median	47693.00	6.320821	21.50206	345.5891
Maximum	152169.5	9.540480	440.6250	669.6999
Minimum	17509.93	2.789292	2.504849	260.7910
Std. Dev.	46170.41	1.671950	114.4688	146.1844
Skewness	0.605220	-0.087254	2.526915	0.705580
Kurtosis	1.903411	2.606346	7.768579	2.039672
Jarque-Bera	3.223440	0.224045	58.33899	3.520604
Probability	0.199544	0.894024	0.000000	0.171993
Sum	1920214.	186.6520	1860.262	11704.40
Sum Sq. Dev.	5.97E+10	78.27164	366886.9	598356.6
Observations	29	29	29	29

Table 2 presents data description including 29 observations of each variable of Vietnam over a 29-year period from 1985 to 2013.

4.2. Multi-Collinear Test

Table 3. Correlation Coefficents between Variables

	CO2	GDP_Growth	IND_Growth	Energy
CO2	1			
GDP_Growth	- 0.0774 (0.6899)	1		
IND_Growth	- 0.4048 (0.0294)	- 0.6290 (0.0003)	1	
Energy	0.9973 (0.0000)	- 0.0835 (0.6666)	- 0.3990 (0.0320)	1

In the theory of correlation analysis conduct on [20], it is evident that multi-collinearity existence between independent variables could be certainly found if correlation coefficient is 0.8 and more, severe multicollinearity could be exactly present when absolute value of pairwise correlations between variables may be somewhat high. Table 3 highlights the correlation matrix among variables used in the study. In fact, there is less multi-collinearity problem in all cases in the analysis, correlation coefficients do not have an excess of 0.8 so that the multi-collinearity is not present.

Another test we used in the study is that the analysis needs to check the station of time series. We transform time series which are non-stationary to station ones. It means that after being transformed, times series have expectation, variance and covariance is constant over time. The time series in ARDL model must be stationary. Stationarity is an important concept when studying time series. However, in fact, most financial data series are non-stationary. To test the stationarity, we use unit root tests, thanks to a common test Augmented Dicky-Fuller test (ADF test). We use the unit root test with the order of lag is automatically selected according to Schwarz criterion, with intercept is included in test equation. ADF tests for the initial time series, and their first difference will be performed. Usually, after taking the first difference, we get the stationary time series. The use of the first difference of time series is not only to obtain stationary time series, but also the first difference series provide information about increasing or decreasing trend (depending on the sign of the difference) rather than focusing on providing information about the real value of the time series. The results in Table 4 shows that only IND_growth is station at level while all the others are non-station at level, but at first different level. So that, we can put all first different level series in to ARDL model for investigation.

4.3. Discussion of Estimation Models

First of all, Hannan-Quin information criterion value is used to choose the most appropriate model. The traditional way to select the optimal lag is to estimate the ARDL model multiple times with descending lags to 0. Among the estimated ARDL models, we choose the one with smallest Hannan-Quin information criterion value. In this article, the authors try out up to the top 4 lags and selects the recommended model according to Hannan-Quin criterion. The image depicting Hannan-Quin's criterion value for the best 20 models, including the best model. Thanks to this Hannan-Quin information criterion, the best ARDL selected is that ARDL(1,0,3,4).

Table 4. ADF Stationarity test results of the time series

Variable	Statistical value	Corresponding probability	Conclusion
CO2	1.5492	0.9990	Non-stationary
D(CO2)	- 3.5475	0.0143	Stationary
GDP_Growth	-2.3605	0.1615	Non-stationary
D(GDP_Growth)	-5.1073	0.0003	Stationary
IND_Growth	-4.9117	0.0006	Stationary
Energy	1.6145	0.9992	Non-stationary
D(Energy)	-3.0988	0.0386	Stationary

4.4. Results of Econometric Modeling

ARDL(1,0,3,4) is estimated as in Table 5.

Table 5. Results of ARDL(1,0,3,4) model estimation

Variable	Coefficient	Std. Error	t-Statistic	Prob.*
D(CO2(-1))	0.041085	0.254260	0.161587	0.8743
D(GDP_GROWTH)	1264.773	575.8693	2.196285	0.0485
D(IND_GROWTH)	81.10335	82.73917	0.980229	0.3463
D(IND_GROWTH(-1))	153.9586	65.43752	2.352758	0.0365
D(IND_GROWTH(-2))	-19.22795	20.80746	-0.924089	0.3736
D(IND_GROWTH(-3))	48.82030	19.74406	2.472658	0.0294
D(ENERGY)	152.0330	40.03578	3.797429	0.0025
D(ENERGY(-1))	107.7733	55.40692	1.945123	0.0756
D(ENERGY(-2))	-130.2478	58.06601	-2.243099	0.0445
D(ENERGY(-3))	-142.9504	46.20346	-3.093933	0.0093
D(ENERGY(-4))	174.8036	63.47782	2.753774	0.0175
C	3940.585	1502.452	2.622769	0.0223

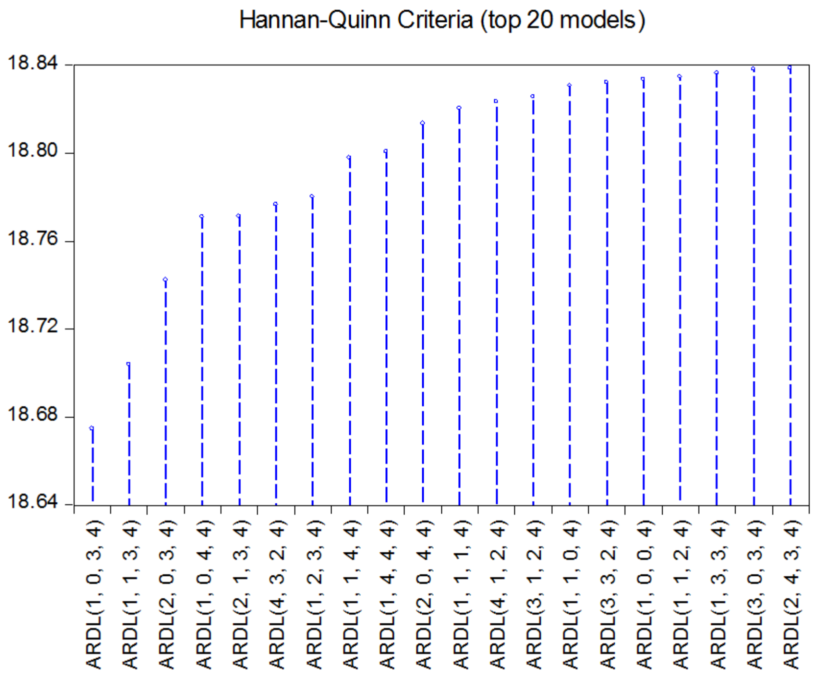

Figure 1. Hann-Quin's Criteria for the 20 Best Models

4.4.1. Autocorrelation Test

Based on the Breusch-Godfrey Serial Correlation LM Test, we have:

The Null hypothesis H0: no first order autocorrelation

The Alternative hypothesis Ha: existence of an autocorrelation

At this stage, autocorrelation test used for null hypothesis: "no first order autocorrelation", the Breusch-Godfrey Serial Correlation LM Test is used. According to the results in Table 6, the p-value of the ARDL is far from zero. They are all larger than 0.05 so that null hypothesis is not rejected, which indicated that there is no autocorrelation between variables in the model.

Table 6. LM test for the residual of the ARDL model

F-statistic	0.769905	Prob. F(2,10)	0.4887
Obs*R-squared	3.202429	Prob. Chi-Square(2)	0.2017

4.4.2. Model Specification Test

To test for model specification of ARDL(1,0,3,4), the Ramsey Reset test is performed. In the theory, if the test result with p-value over 0.05, so the model is well specified at the significant level at 5 percent. In a result, Table 7 indicates that the test results with p-values are all over 0.05, which proved that the model is well specified.

Table 7. Model specification Test

	Value	df	Probability
t-statistic	0.604195	11	0.5580
F-statistic	0.365051	(1, 11)	0.5580

4.4.3. Stability Test

The next back testing is that the stability of ARDL model thanks to the cumulative sum of residuals. If the cumulative sum of the residuals is within the standard range at the 5% significance level, then it can be concluded that the residual of the model is stable and thus the model is stable.

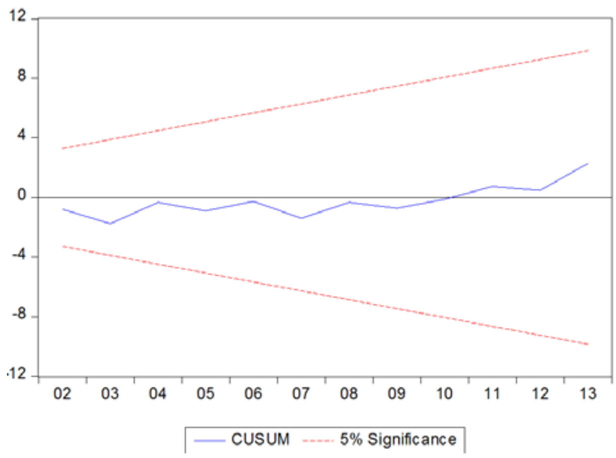

Figure 2. The cumulative sum of recursive residuals of the ARDL model at a 5% significance level

To go further to investigate the long-run relationship among the above considered variables, we use cointegration test thanks to Bound test.

Table 8. Test of long-run relationship between the variables

Null Hypothesis: No long-run relationships exist		
Test Statistic	Value	k
F-statistic	9.861479	3
Critical Value Bounds		
Significance	I0 Bound	I1 Bound
10%	2.72	3.77
5%	3.23	4.35
2.5%	3.69	4.89
1%	4.29	5.61

According to Table 8, the test statistic value is larger than every critical Value Bounds at every significance levels. Therefore, there exists a long run relationship among energy consumption, economic growth, industrialization and carbon dioxide emissions. That long-run from is presented in Table 9.

Table 9. Long-run relationship among the variables

Variable	Coefficient	Std. Error	t-Statistic	Prob.
D(GDP_GROWTH, 2)	1264.773092	575.869270	2.196285	0.0485
D(IND_GROWTH, 2)	81.103352	82.739175	0.980229	0.3463
D(IND_GROWTH(-1), 2)	19.227948	20.807463	0.924089	0.3736
D(IND_GROWTH(-2), 2)	-48.820304	19.744057	-2.472658	0.0294
D(ENERGY, 2)	152.033026	40.035783	3.797429	0.0025
D(ENERGY(-1), 2)	130.247827	58.066013	2.243099	0.0445
D(ENERGY(-2), 2)	142.950413	46.203456	3.093933	0.0093
D(ENERGY(-3), 2)	-174.803600	63.477823	-2.753774	0.0175
CointEq(-1)	-0.958915	0.254260	-3.771397	0.0027
Cointeq = D(CO2) - (1318.9629*D(GDP_GROWTH) + 275.9936 *D(IND_GROWTH) + 168.3274*D(ENERGY) + 4109.4215)				
Long Run Coefficients				
Variable	Coefficient	Std. Error	t-Statistic	Prob.
D(GDP_GROWTH)	1318.962875	852.308244	1.547519	0.1477
D(IND_GROWTH)	275.993561	139.365202	1.980362	0.0711
D(ENERGY)	168.327429	73.906389	2.277576	0.0419
C	4109.421502	1910.566593	2.150892	0.0526

In the cointegration test, the cointegration regression coefficient is negative (-0.958915) and is statistically significant at 5% (with very small probability value of 0.0027) indicating that cointegration relationship exists between variables. That is, in the long term when the system is in equilibrium, when a shock occurs, the variables in the model tend to move, "pull" the whole system "back" to the equilibrium, which means a reverse movement tendency (the negative sign of the cointegration regression coefficients) compared to those fluctuations. The cointegration equation, or equation that represents the long-run equilibrium relationship among the variables is as follows:

$$\begin{aligned} DCO2_t &= 1318.97 * DGDP\_GROWTH_t \\ &+ 275.99 * DIN\_GROWTH_t \\ &+ 168.32 * DENERGY_t + u_t \end{aligned} \tag{4.1}$$

5. Discussion the Results

5.1. Short-Run Relationship

According to Figure 1, the estimation of the ARDL (1,0,3,4) is finally selected as the best model to discuss. Regarding the estimation results, our analysis shows the relationship of energy consumption, economic growth, industrialization on carbon dioxide emissions - in the case of Vietnam, we have the result in short run in the following Table 10.

Table 10. Short-run impacts of the variables on carbon dioxide emissions at first differential

Variables	Regression coefficients
D(CO2(-1))	0.0411 (0.8743)
D(GDP_Growth)	1264.773 (0.0485)**
D(IND_Growth)	81.1033 (0.3463)
D(IND_Growth(-1))	153.9586 (0.0365)**
D(IND_Growth(-2))	-19.2280 (0.3736)
D(IND_Growth(-3))	48.8203 (0.0294)**
D(ENERGY)	152.033 (0.0025)***
D(ENERGY(-1))	107.7733 (0.0756)*
D(ENERGY(-2))	-130.2478 (0.0445)**
D(ENERGY(-3))	-142.9504 (0.0093)***
D(ENERGY(-4))	174.8036 (0.0175)**
C	3940.585 (0.0223)**

Note: the number in ( ) is the probability value of test of estimated coefficients' significance.
*, **, and *** indicate significance level of 10%, 5% and 1%

For energy consumption, the energy consumption of this year and last year had positive and statistically significant impact on this year carbon dioxide emissions. To be precise, a 1 kg of oil increase in energy consumption this year will increase carbon dioxide emissions in the same year by 152 kt, while a 1 kg of oil increase in energy consumption this year will increase carbon dioxide emissions in the next year by around 108 kt. This result is consistent with many other empirical findings and also with our theoretical expectation because theoretically. In fact, energy consumption including non-green energy will cause more carbon dioxide emissions.

Regarding economic growth, it is evident that the effect of economic growth on carbon dioxide emissions is also positive and significant in the right year. More specifically, an increase in economic performance will impact on carbon dioxide emissions in the case of Vietnam. This finding is in relation to theoretical expectations and in significantly correlated with others empirical studies. In concrete, a 1 percent increase in economic growth this year will increase carbon dioxide emissions by 81 kt in the right same year.

As far as Industrialization concerned, regression coefficient of both D(IND_Growth(-1)) and D(IND_Growth(-3)) are all positive and statistically significant at significance levels of 0.05. This means that the industrialization can not effect immediately on carbon dioxide emissions but with a lag of 1 to 3 years.

5.2. Long-Run Relationship

The long-run equilibrium relationship among the variables is as in equation (4.1), in which, a 1 percent increase in industry growth will increase carbon dioxide emissions by 276 kt, while a 1 kg of oil increase in energy consumption will increase carbon dioxide emissions by 168 kt in the long-run. At the same time, economic growth may increase the carbon dioxide emissions, but insignificant. This empirical results is consistent with results of [6] and [7].

6. Conclusion

This paper investigates the impact of economic growth, energy consumption, and industrialization on carbon dioxide emissions of Vietnam between 1985 and 2013. The empirical reveals that in the short run, there is a directional relationship running from economic growth and industrialization to carbon dioxide emissions, especially the strong impact of energy consumption on carbon dioxide emissions. Results even show that there is a co-integration among variables in the long run, with positive impact of energy consumption and industrialization on carbon dioxide emissions. In long run, economic growth has no impact on carbon dioxide emissions. It is recommended that economic growth with sustainable development achievement in Vietnam is in help to create a green economy so that it does not cause carbon dioxide emissions. Some policy implications for Vietnamese government may be raised, such as reduction of the dependence on fossil fuel energy by exploiting renewable energy sources such as wind, solar or hydropower. As a consequence, it leads to corruption and helps to consolidate authoritarian regimes (see [21]). Furthermore, energy system in the region should be reformed to reduce government spending and improve the efficiency of the energy system. For instance, in Vietnam, energy subsidies may facilitate wasteful consumption because it increases government spending and pushes prices below true costs. In addition, retail electricity prices are lower than the global average (see [22]). Lastly, regional cooperation and integration should be encouraged to ensure energy security and economic development (see [23]).

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