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EFFECTS OF ECONOMIC GROWTH, ELECTRICITY CONSUMPTION, ENERGY USE, AND URBANISATION ON CARBON DIOXIDE EMISSIONS IN VIETNAM

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ABSTRACT

The aim of this paper was to explore the causal relationship between CO_2 emissions, economic growth, electricity consumption, energy use, and urbanisation in Vietnam between 1982 and 2016 using the Vector Error Correction Model (VECM). In the short run, it has been empirically proven that GDP, electricity consumption, and energy use have significant and positive relationships with CO_2 emissions in Vietnam. Results also indicated that electricity consumption and energy use are the main contributors to increase GDP while CO_2 emissions and urban population negatively affect GDP. It was also found that GDP has a significant and negative impact on electricity consumption, but energy use positively affects electricity consumption in Vietnam. Further, urban population has a negative influence on energy use, while the latter has a positive relationship with urban population. In the long run, results showed that GDP per capita and energy use per capita have significant and positive influence on CO_2 emissions in Vietnam while urban population contributes to reducing CO_2 emissions. The results of the Johansen co-integration test showed that there is a long run relationship between CO_2 emissions, economic growth, electricity consumption, energy use, and urbanisation. Results implied that economic growth should be considered by the Vietnamese government along with the target in environmental protection, and urbanisation should be carefully managed to achieve sustainable development in Vietnam.

Keywords: carbon dioxide emission, economic growth, electricity consumption, energy use, urbanisation, Vietnam

INTRODUCTION

The relationship between carbon dioxide (CO_2) emissions, economic growth, electricity consumption, energy use, and urbanisation has been strongly debated by scholars all over the world. The CO_2 is a key source of global warming since it accounts for more than 50% of global greenhouse gas (Nguyen, 2012). Burnett et al. (2013) found that economic growth has a positive relationship with CO_2 emissions in the US in their study spanning 1981 to 2003. Nnaji et al. (2013) argued that economic growth and electricity supply are drivers leading to an increase of CO_2 emissions, but electricity supply does not have a significant impact on economic growth in Nigeria. Bilgili et al. (2016) found that biomass consumption reduces CO_2 emissions in the long run cycles after 2005 in the US while Bilgili et al. (2019) claimed that geothermal, wind, solar, biofuels, wood, and waste have significant impacts on industrial production in the short-term and long-term cycles of the US.

In Asia, studies have observed the relationship between CO_2 emissions, economic growth, and fossil energy consumption in China (Li et al., 2017; Li et al.,2011). Rehman et al. (2019) concluded that CO_2 emissions, electricity consumption, and renewable electricity output have a positive and significant relationship with the gross domestic product (GDP) per capita, but renewable energy consumption, energy use, and fossil fuel energy consumption negatively affected GDP per capita in Pakistan. Further, Alshehry and Belloumi (2015) claimed that there is a long run relationship between energy consumption, energy price, CO_2 emissions, economic growth, and energy price is the most important determinant of economic growth in Saudi Arabia. Phrakhruopatnoutakitti et al. (2020) concluded that development of energy supply investment and energy efficiency may reduce CO_2 emissions and not adversely affect economic growth in Malaysia, Myanmar, Vietnam, and Thailand. Bilgili et al. (2017) reported that urbanisation has a significant effect on energy intensity in Bangladesh, China, India, Indonesia, Malaysia, Nepal, Philippines, South Korea, Thailand, and Vietnam between 1990 and 2014.

Due to rapid economic growth, the demand for energy, especially fossil fuel, resulted in environmental degradation, namely pollution (Al-Mulali et al., 2015). According to the 2nd ASEAN Energy Demand Outlook (2009), energy consumption among ASEAN (Association of Southeast Asian Nations) nations is expected to rise 3.9% annually from 343 mega tonnes of oil equivalent (MTOE) in 2005 to 901 MTOE in 2030, primarily due to rapid growth of the transport sector which is growing at a rate of 5.1% annually, corresponding to an equivalent growth in CO_2 emissions (GFEI, 2010). By 2017, Southeast Asia has recorded

8% of global energy demand growth (International Energy Agency, 2018). By 2010, five countries, namely Indonesia, Malaysia, the Philippines, Thailand, and Vietnam accounted for about 90% of greenhouse gas emissions in Southeast Asia (ADB, 2015). Due to a rapid increase in energy consumption and heavy dependence on fossil fuel, greenhouse gas emissions of Vietnam reached 177 tonnes of CO_2 equivalent in 2005 and it is predicted to rise three times by 2030 (World Bank, 2011).

Table 1
GDP per capita, electricity consumption per capita, energy use per capita, urban population, and CO_2 emissions in Vietnam

Year	GDP per capita (current USD)	Electricity consumption per capita (kWh)	Energy use per capita (kg of oil)	Urban population (%)	CO_2 emissions per capita (metric tonne)
1985	231.5	68	262.2	19.6	0.3
2013	1,886.7	1,276.8	660.3	43.4	1.6
2016	2,192.2	–	–	34.5	2.1

Source: World Bank, 2021

Table 1 shows GDP per capita of Vietnam increased more than 9 times from about USD231 in 1985 to about USD2,192 in 2016, while electricity consumption per capita rose by more than 18 times between 1985 and 2013. Energy use of Vietnam increased by more than 2.5 times from 262.2 kWh in 1985 to 660.3 kWh in 2013. In 2016, the urban population of Vietnam accounted for 34.5%, an increase of nearly 15% compared with 1985. The CO_2 emissions per capita increased 7 times from 0.3 metric tonnes in 1985 to 2.1 metric tonnes in 2016.

In Vietnam, due to post-war housing pressures and land speculation, the process of urbanisation occurred many years before the industrialisation process, causing the urban model to experience crises. Urbanisation increasingly revealed weaknesses associated with issues, such as incomplete architecture, traffic congestion, domestic wastewater, and unregulated migration among others. By 2020 the urban population accounted for 40% of the country's total population of more than 45 million people (Chu & Nguyen, 2017).

Vietnam implemented the United Nations Framework Convention for Climate Change (UNFCCC) in 1994 and the Kyoto Protocol in 2002 (Zimmer et al., 2015). On 24 July 2020, the prime minister approved Vietnam's updated Nationally Determined Contribution (NDC) which sets the mitigation target of reducing the greenhouse gas (GHG) emissions by 9% compared with Business-As-Usual scenario (BAU) by domestic resources; the mitigation target can increase up to 27% if Vietnam receives international support. In terms of NDC, Vietnam focuses on reducing GHG emissions in five sectors, namely energy, agriculture, industrial processes, land use, land use and forestry change, and waste between 2021 and 2030 (MONRE, 2020). Vietnam may obtain benefits from NDC, including reduction of negative effects from climate change, enhancement of economic growth, re-structure the economy, achievement of energy security, reduction of local air pollution, and encouragement of international support (Zimmer et al., 2015).

In Vietnam, the relationship between energy consumption and economic growth was examined by Ha and Ngoc (2020) and Morelli and Mele (2020) while Long et al. (2018) focused on investigating the relationship between foreign direct investment, electricity consumption, and economic growth. Nguyen et al. (2018) on the other hand, estimated factors affecting CO_2 emissions while Phong et al. (2018) assessed the relationship between CO_2 emissions, industrialisation, urbanisation, and energy use. Thanh and Khuong (2017) examined the relationship between CO_2 emissions, economic growth, energy consumption, financial development, and trade openness. However, none of these studies explored the impact of economic growth, electricity consumption, energy use, and urbanisation on CO_2 emissions in Vietnam. Therefore, the current study aimed to examine the relationship between economic growth, electricity consumption, energy use, urbanisation, and CO_2 emissions in Vietnam between 1982 and 2016 employing the Vector Error Correction Model (VECM). The study recommends useful appropriate policies to foster economic growth and achieve sustainable development in Vietnam.

The remainder of this paper is structured as follows. Section 2 presents the literature review. Section 3 contains methodology. In section 4, the study findings are discussed. Section 5 summarises the study and policy implications.

EMPIRICAL REVIEW

The relationship between economic growth, electricity consumption, energy use, urbanisation, and CO_2 emissions has been debated by scholars all over the world. Burnett et al. (2013) found that economic growth generates CO_2 emissions in the US between 1981 and 2003 while Khobai and Roux (2017) concluded that reducing energy consumption and controlling CO_2 emissions may decrease economic growth in South Africa. Likewise, Nnaji et al. (2013) claimed that economic growth and electricity supply are drivers leading to increasing CO_2 emissions in Nigeria for the period 1971−2009.

Bilgili et al. (2016) estimated the effects of biomass energy consumption on CO_2 emissions in the US between 1984 and 2015. Results indicated that the biomass consumption reduces CO_2 emissions in the long run cycles post 2005. Bilgili et al. (2019) also examined the influence of renewable on industrial production in the US for the period 1989−2016. They found that geothermal, wind, solar, biofuels, wood, and waste have significant impacts on industrial production in the short-term and long-term cycles. Bilgili et al. (2020) also evaluated the relationship between waste energy usage and CO_2 emissions in the US between 1980 and 2018. Results showed there are either positive or negative lead-lag relations between waste and CO_2 emissions. Kuskaya and Bilgili (2020) explored the influence of wind energy usage on GHG emissions between 1989 and 2017. They argued that wind energy consumption should be considered since it may mitigate CO_2 emissions. Bilgili et al. (2021a) also examined the relationship between hydroelectric energy consumption and CO_2 emissions in the US between 1980 and 2019. Results suggested that hydro energy uses enhance CO_2 emissions in the short run while it reduced CO_2 emissions in the long run. Bilgili et al. (2021b) examined the effects of geothermal on CO_2 emissions in the US from 1980 to 2019. They concluded that geothermal increases CO_2 emissions in both short and long run. Bilgili et al. (2017) estimated the relationship between urbanisation and energy intensity in 10 Asian countries between 1990 and 2014. Results showed that the urbanisation variable has a significant impact on energy intensity in the short-run and long-run.

In Asia, economic growth is associated with increased energy consumption and CO_2 emissions in China (Li et al., 2011; Li et al., 2017), while Khan et al. (2019) argued that economic growth, coal consumption, oil consumption, and natural gas consumption have positive effects on the environmental degradations in Pakistan both in short run and long run. Sasana and Aminata (2019) found that economic growth, primary energy consumption, and population growth have positive relationships with CO_2 emissions, but renewable energy consumption negatively influenced CO_2 emissions in Indonesia between 1990 and 2014.

Alom et al. (2017) examined the relationship between financial development, CO_2 emissions, urbanisation, industrial value addition, agricultural value addition, and energy consumption in Bangladesh between 1985 and 2015. They found that except financial development, all the explanatory variables are statistically insignificant in the short run. However, the error correction term is statistically significant and negative. Nugraha and Osman (2019) examined the causal relationship between CO_2 emissions, energy consumption, value added of three development sectors, and household final consumption expenditure in Indonesia for the period 1975–2014. They concluded that energy conservation, mitigation policies, and the application of energy-saving technologies should be an important priority on sustainable development planning in Indonesia to reduce CO_2 emissions and enhance economic growth in this country. Jian et al. (2019) estimated the effects of economic growth, financial development, and energy consumption on CO_2 emission in China between 1982 and 2017. Results indicated that financial innovation should be encouraged in the country to meet the demand of sustainable development and optimising energy structure and increasing the efficiency of energy utilisation should be considered in the process of development.

Studies also have shown a relationship between energy consumption and economic growth (Ha & Ngoc, 2020; Morelli & Mele, 2020). Likewise, Long et al. (2018) concluded that electricity consumption and foreign direct investment (FDI) have positive influences on economic growth in Vietnam for the period 1990−2015. Nguyen et al. (2018) found that household, export, and investments are major drivers of rapid increase of CO_2 emissions while population has a small effect on total CO_2 emissions in Vietnam. Phong et al. (2018) argued that energy consumption, industrialisation, and GDP per capita positively affect CO_2 emissions, while globalisation contributes to decrease in CO_2 emissions in Vietnam between 1985 and 2015. Thanh and Khuong (2017) found that economic growth, energy consumption, financial development, and trade openness have positive impacts on CO_2 emissions, but FDI has a negative influence in the study period 1990−2011.

METHODOLOGY

Data and Sources

A panel dataset for the relationship between economic growth, electricity consumption, energy use, urbanisation, and CO_2 emissions in Vietnam for the period 1982–2016. Data was gathered from World Development Indicators released by World Bank. Thus, 35 observations was entered for data analysis. The panel data had the following advantages: (1) a large sample size that provides a greater degree of freedom, more information, and less multi-collinearity among variables; and (2) overcome constraints related to control individual or time heterogeneity faced by cross-sectional data (Hsiao, 2014).

The Vector Error Correction Model

The model used to examine the relationship between CO_2 emissions, economic growth, electricity consumption, energy use, and urbanization can be formulated as follows (Phong et al., 2018; Sasana & Aminata, 2019; Phrakhruopatnoutakitti et al., 2020):

$$CO_{2t} = f\,(GDP_t,\ EL_t,\ EN_t,\ URB_t) \qquad (1)$$

Where: CO_2 denotes CO_2 per capita (metric tonne); GDP_t means GDP per capita (current USD); EL_t denotes electricity consumption per capita (kWh); EN_t presents energy consumption per capita (kg of oil); and URB_t denotes the rate of urban population in the total population (%).

Table 2
Covariates of the VECM

Variable definition	Unit	Source
CO_2 emissions per capita	metric tonne	World Development Indicators
GDP per capita	current USD	World Development Indicators
Electricity consumption per capita	kWh	World Development Indicators
Energy use per capita	kg of oil	World Development Indicators
The rate of urban population	%	World Development Indicators

After transforming the functional form of Equation 1, the following formula was used:

$$LnCO_{2t} = \beta_0 + \beta_1\, InGDP_t + \beta_2 InEL_t + \beta_3 InEN_t + \beta_4 InURB_t + \mathcal{E}_t \qquad (2)$$

Where: $lnCO_{2t}$, $lnGDP_t$, $lnEL_t$, $lnEN_t$, and $lnURB_t$ denote the natural logarithms of CO_2 per capita, GDP per capita, electricity consumption per capita, energy use per capita, and the rate of urban population in the total population; β_0 is the intercept; ($\beta_1,\ldots,\beta_4$) are parameters to be estimated; and $\mathcal{E}_t$ presents the error term.

The VECM consists of three steps. The first step involved checking the stationarity of the series or their order of integration in all variables. In this research, the Augmented Dickey Fuller (ADF) test and Phillips-Perron (PP) test were employed to examine the stationary state of the series. The second step entailed checking the presence of a long run relationship among all variables in the equation. In this stage, the co-integration tests will be carried out to explore the existence of long run relationships between the variables. In the third step, the residuals from the equilibrium regression can be used to estimate the VECM (Azlina & Mustapha, 2012).

RESULTS AND DISCUSSION

CO_2 Emissions, Economic Growth, Electricity Consumption, Energy Use, and Urbanisation in Vietnam: An Overview

Table 3
Characteristics of CO_2 emissions, economic growth, electricity consumption, energy use, and urbanisation in Vietnam

Variable	Mean	SD	Min	Max
CO_2 emissions per capita	0.86	0.57	0.3	2.1
GDP per capita	683.45	657.83	0	2,192.2
Electricity consumption per capita	392.06	413.00	0	1,423.7
Energy use per capita	357.24	177.26	0	669.7
The rate of urban population	24.98	4.86	19.4	34.5

Source: Author's calculation, 2021
Note: SD denotes standard deviation

The average CO_2 emissions and GDP per capita of Vietnam account for 0.86 metric tonnes and USD683.4, respectively. Electricity consumption and energy use per capita of this country accounted for 392 kWh and 357.2 kg of oil, respectively on average. The average urban population rate of Vietnam reaches nearly 25% (Table 3).

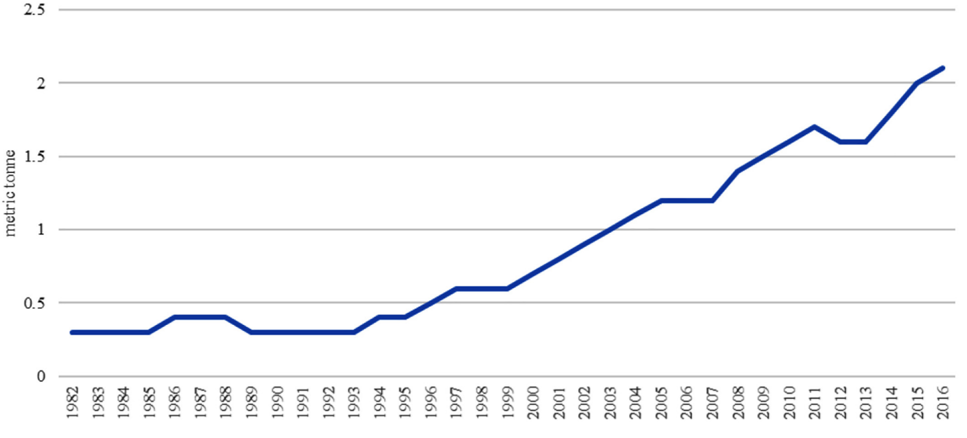

Figure 1. CO_2 emissions per capita in Vietnam
Source: World Bank, 2021a

As seen in Figure 1, between 1982 and 2016, the average amount of CO_2 emissions per capita of Vietnam presented an upward trend. By 2016, CO_2 emissions per capita of this country accounted for 2.1 metric tonnes, and which increased 7 times compared with 1982. This could be seen as a result of rapid industrialisation and modernisation in the socio-economic development of this country (Figure 1).

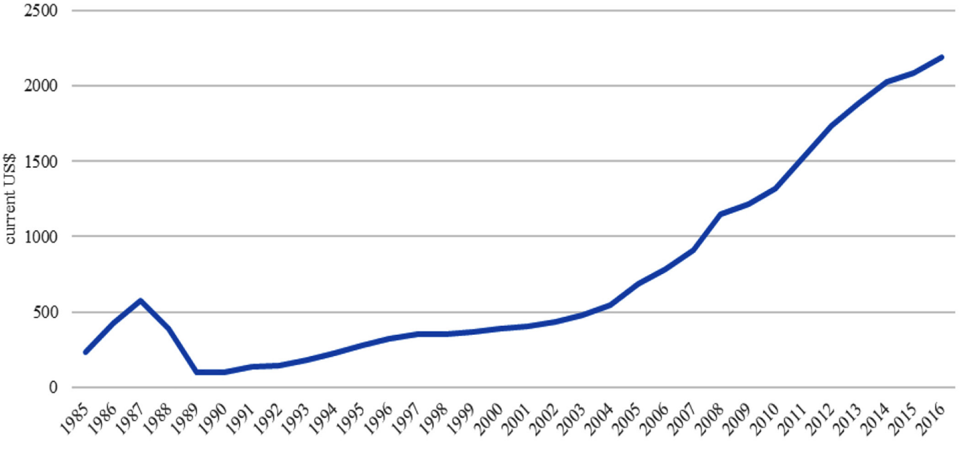

Figure 2. GDP per capita in Vietnam
Source: World Bank, 2021d

As seen in Figure 2, GDP per capita of Vietnam grew between 1985 and 2016. In 2016, the average GDP per capita of this country accounted for about USD2,192, which was 9 times higher than that of 1985. This suggests the economic transformation of the country via management mechanism and integration of international economics, especially from 1986 onward (Figure 2).

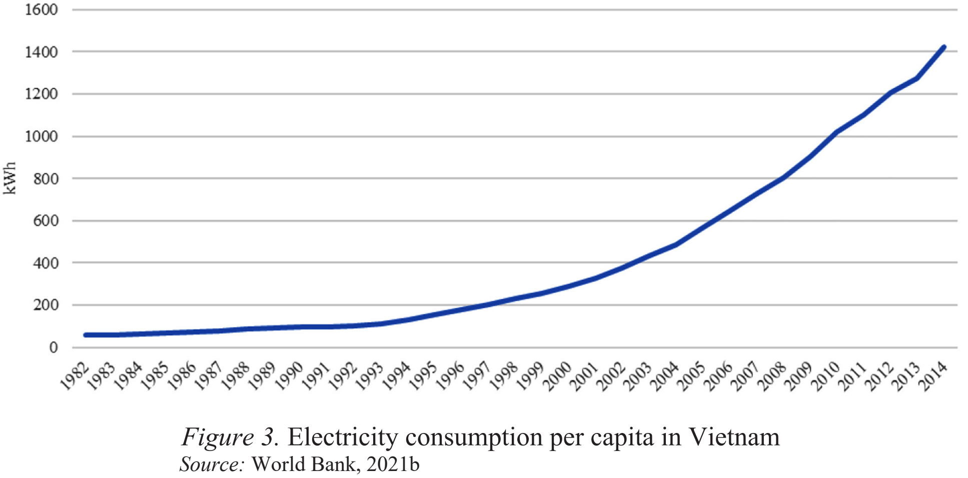

Figure 3. Electricity consumption per capita in Vietnam
Source: World Bank, 2021b

Electricity consumption per capita of Vietnam increased for the period 1982−2014. For instance, by 2014, the average electricity consumption per capita of this country accounted for about 1,423 kWh, which was more than 25 times higher than that of 1982. This reflects the growth of demand for electricity consumption in the socio-economic development (Figure 3).

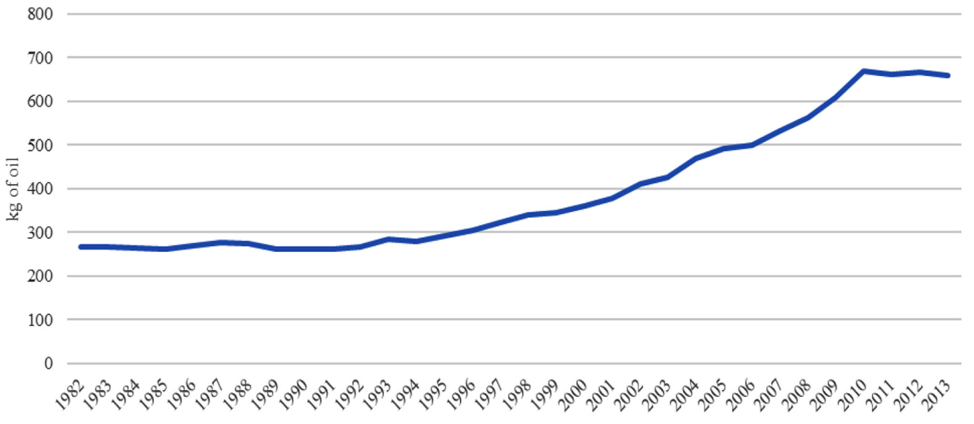

Figure 4. Energy use per capita in Vietnam
Source: World Bank, 2021c

Figure 4 shows the average amount of energy consumption per capita of Vietnam between 1982 and 2013. By 2013, the average amount of energy consumption per capita reached 660 kg of oil, nearly 2.5 times higher than that of 1982. This reveals an increasing demand for energy because of the socio-economic development in recent decades (Figure 4).

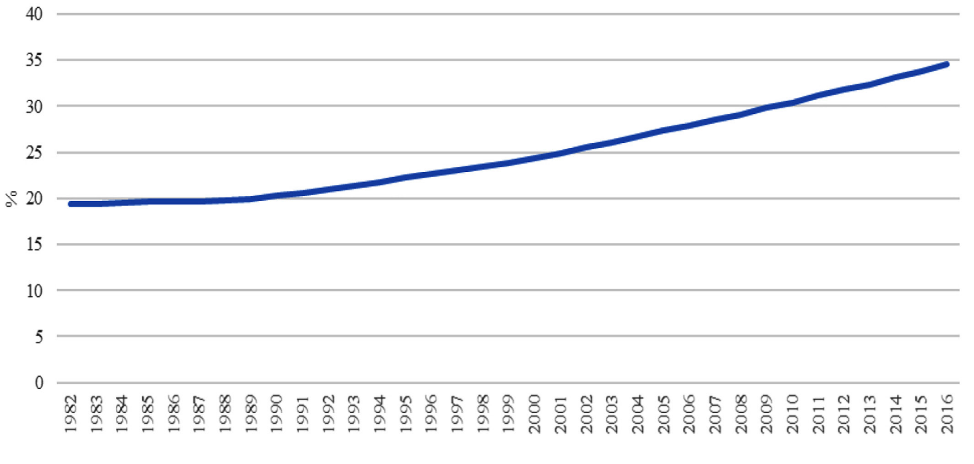

Figure 5. Rate of urban population in Vietnam
Source: World Bank, 2021e

Urbanisation followed industrialisation and modernisation in Vietnam. After 35 years (1982–2016) of modernisation, in 2016, urban population accounted for 34.5%, an increase of more than 15% compared with 1982 (Figure 5).

Effects of Economic Growth, Electricity Consumption, Energy Use, and Urbanisation on CO_2 Emissions in Vietnam

Implementation of the Unit Root Test

The unit root test is carried out to check the stationarity of the time series variables (Adeola & Ikpesu, 2016). In this study, the Augmented Dickey-Fuller (ADF) test and the Phillips-Peron (PP) test are used to examine the stationarity of CO_2 emissions, economic growth, electricity consumption, energy use, and urbanisation in Vietnam. Therefore, the following hypotheses is formulated:

Null hypothesis (H_0): The variables contain a unit root
Alternative hypothesis (H_a): The variables do not contain a unit root

If a variable contains a unit root, then this implies that the time series of this variable is not stationarity.

Table 4
Results of the unit root test

Variables		ADF Test		PP Test		Conclusion
		Level	1st difference	Level	1st difference	
$LnCO_2$ emissions per capita	Constant	0.03	-3.55^{***}	0.19	-5.13^{***}	I(1)
	Constant & trend	−2.14	-3.53^{**}	−2.16	-5.11^{***}	I(1)
LnGDP per capita	Constant	-3.92^{***}	-3.79^{***}	-3.19^{**}	-5.12^{***}	I(0)
	Constant & trend	-4.83^{***}	-4.08^{***}	-3.28^{*}	-5.30^{***}	I(0)
LnElectricity consumption per capita	Constant	−1.67	1.02	−1.53	-5.66^{***}	I(1)
	Constant & trend	−0.05	1.87	−0.57	-6.06^{***}	I(1)
LnEnergy use per capita	Constant	−0.69	-3.93^{***}	−0.80	-5.68^{***}	I(1)
	Constant & trend	−0.75	-4.35^{***}	−0.94	-6.03^{***}	I(1)
LnUrban population	Constant	1.86	-2.60^{*}	2.99	-3.17^{**}	I(1)
	Constant & trend	-4.33^{***}	−2.81	-5.27^{***}	-4.38^{***}	I(1)

Source: Author's calculation, 2021
Note: ***, ** and * denote statistical significance at 1%, 5%, and 10%, respectively

The results in Table 4 show that the time series of GDP per capita are stationary at the level [I(0)] because the absolute value of test statistic is greater than critical values at the 1% and 5% respectively. However, the time series of CO_2 emissions per capita, electricity consumption per capita, energy use per capita, and urban population are not stationary at that level. Thus, the first difference is carried out to examine the stationary of these variables. The results indicate that the absolute values of test statistics are greater than critical values at the 1% and 5%, respectively. Therefore, it can be concluded that the time series of these variables do not contain unit roots and this suggests that the time series are stationary at the first difference [I(1)].

Examination of the Long Run Relationship among Variables

Before examining the long run relationship among variables, the optimal lag length should be determined. The purpose of this step is to specify the optimal lag for the VECM.

Table 5
Selection of the lag length

Lag	LL	LR	df	P	FPE	AIC	HQIC	SBIC
0	−88.15				0.000	6.010	6.085	6.241
1	152.14	480.6	25	0.000	2.7e-10	−7.880	−7.427	−6.492
2	210.76	117.25	25	0.000	3.5e-11	−10.049	−9.220	−7.505
3	235.61	49.69	25	0.002	5.2e-11	−10.039	−8.833	−6.338
4	328.98	186.74*	25	0.000	1.6e-12*	−14.450*	−12.867*	−9.593*

Endogenous: $LnCO_2$ LnGDP LnElectricity consumption LnEnergy use LnUrban population
Exogenous: Constant
Number of observations = 31

Source: Author's calculation, 2021
Notes: *denotes lag order selected by the criterion; LL means log likelihood values; LR represents sequential modified LR test statistics; FPE denotes final prediction error; AIC means Akaike information criterion; HQIC represents Hannan-Quinn information criterion, and SBIC means Schwarz's Bayesian information criterion

Table 5 shows that the optimal lag length is four lags because this value is recommended by AIC, HQIC, and SBIC indicators. Therefore, four lags (the number of lag is equal to 4) is chosen to run the VECM in the third step.

The Johansen co-integration test is performed to examine the long-run relationship among variables. If variables are co-integrated, it suggests that there is a long-term relationship among variables (Musunuru, 2017).

The following hypotheses are hence proposed:

Null hypothesis (H0): There is no co-integration among variables
The alternative hypothesis (Ha): There is co-integration among variables

In this study, the Johansen co-integration test is carried out by the trace statistic test. Trace test is a likelihood-ratio-type test which operates under different assumptions in the deterministic part of the data generation process (Lutkepohl et al., 2001).

As seen in Table 6, the null hypothesis cannot be rejected in the rank three (three co-integrations) and rank four (four co-integrations) because trace statistics are less than the 1% critical value (19.74 < 20.04) and the 5% critical value (1.70 < 3.76) and these reflect that there are three co-integrations at the 1% and four co-integrations at the 5% critical values among variables.

Table 6
Results of trace statistic in the Johansen co-integration test

Maximum rank	LL	Eigenvalue	Trace statistic	5% critical value	1% critical value
0	225.03		207.89	68.52	76.07
1	283.84	0.977	90.28	47.21	54.46
2	307.65	0.784	42.66	29.68	35.65
3	319.11	0.522	19.74*1	15.41	20.04
4	328.13	0.441	1.70*5	3.76	6.65
5	328.98	0.053	–	–	–

Source: Author's calculation, 2021
Note: *1 and *5 denote the number of co-integration (ranks) chosen to accept the null hypothesis at 1% and 5% critical values

Estimation of the VECM

Table 7 shows GDP, electricity consumption, and energy use have significant and positive relationships with CO_2 emissions in the short run. It has been empirically found that electricity consumption and energy use are drivers contributing to increased GDP while CO_2 emissions and urban population negatively affect GDP. The study also found that GDP has a significant and negative effect on electricity consumption, but energy use positively influences electricity consumption in Vietnam. Additionally, it is shown that urban population has a negative impact on energy use, while energy use has a positive relationship with urban population.

Table 7
Estimation of the VECM in the short run

Variables	Coefficient	Std. Error	z	P-value
DLnCO_2 per capita				
LnCO_2 per capita				
LD	–0.022	0.21	–0.10	0.918
L2D	0.070	0.21	0.33	0.742
L3D	0.029	0.20	0.14	0.886
LnGDP per capita				
LD	0.070***	0.02	3.50	0.000
L2D	0.064**	0.03	2.08	0.038
L3D	0.061*	0.03	1.83	0.067
LnElectricity consumption per capita				
LD	0.875**	0.42	2.07	0.039
L2D	0.527	0.68	0.77	0.441
L3D	0.232	0.51	0.45	0.651
LnEnergy use per capita				
LD	0.133***	0.04	2.89	0.004
L2D	–0.800	0.49	–1.61	0.107
L3D	–0.542	0.61	–0.88	0.380
LnUrban population				
LD	1.349	3.65	0.37	0.712
L2D	–3.697	3.42	–1.08	0.280
L3D	1.974	3.23	0.61	0.542
Constant	–0.236**	0.09	–2.51	0.012
DLnGDP per capita				
LnCO_2 per capita				
LD	0.463	0.29	1.59	0.112
L2D	–0.509*	0.28	–1.78	0.075
L3D	–0.446	0.27	–1.62	0.106
LnGDP per capita				
LD	0.234***	0.02	8.68	0.000
L2D	0.266***	0.04	6.37	0.000
L3D	0.273***	0.04	6.08	0.000
LnElectricity consumption per capita				
LD	–0.171	0.56	–0.30	0.763
L2D	1.749*	0.91	1.90	0.057
L3D	2.501***	0.68	3.63	0.000
LnEnergy use per capita				
LD	0.607***	0.06	9.79	0.000
L2D	0.999	0.66	1.50	0.133
L3D	1.450*	0.82	1.75	0.080

(*continued on next page*)

Table 7: (*continued*)

Variables	Coefficient	Std. Error	*z*	*P*-value
LnUrban population				
LD	–6.350	4.90	–1.30	0.195
L2D	–9.068**	4.58	–1.98	0.048
L3D	–4.687	4.34	–1.08	0.280
Constant	–0.811***	0.12	–6.41	0.000
DLnElectricity consumption per capita				
LnCO_2 per capita				
LD	0.090	0.11	0.79	0.429
L2D	–0.105	0.11	–0.93	0.350
L3D	–0.062	0.10	–0.57	0.568
LnGDP per capita				
LD	–0.021**	0.01	–1.97	0.049
L2D	0.018	0.01	1.14	0.253
L3D	0.010	0.01	0.59	0.552
LnElectricity consumption per capita				
LD	0.130	0.22	0.58	0.559
L2D	0.596*	0.36	1.65	0.099
L3D	–0.752***	0.27	–2.77	0.006
LnEnergy use per capita				
LD	1.138***	0.02	46.60	0.000
L2D	–0.117	0.26	–0.45	0.654
L3D	0.327	0.32	1.00	0.316
LnUrban population				
LD	0.985	1.93	0.51	0.610
L2D	0.008	1.80	0.00	0.996
L3D	–0.808	1.71	–0.47	0.636
Constant	0.051	0.04	1.04	0.299
DLnEnergy use per capita				
LnCO_2 per capita				
LD	5.675	3.57	1.59	0.112
L2D	4.355	3.51	1.24	0.215
L3D	2.333	3.39	0.69	0.492
LnGDP per capita				
LD	0.185	0.33	0.56	0.577
L2D	–0.192	0.51	–0.37	0.709
L3D	0.206	0.55	0.37	0.709
LnElectricity consumption per capita				
LD	–0.700	6.96	–0.10	0.920
L2D	–8.390	11.27	–0.74	0.457
L3D	9.613	8.45	1.14	0.256

(*continued on next page*)

Table 7: (*continued*)

Variables	Coefficient	Std. Error	*z*	*P*-value
LnEnergy use per capita				
LD	0.736	0.76	0.97	0.333
L2D	1.767	8.17	0.22	0.829
L3D	16.811*	10.16	1.65	0.098
LnUrban population				
LD	–20.774	60.17	–0.35	0.730
L2D	–52.640	56.25	–0.94	0.349
L3D	–105.68**	53.28	–1.98	0.047
Constant	0.599	1.55	0.39	0.699
DLnUrban population				
$LnCO_2$ per capita				
LD	0.016	0.01	1.12	0.262
L2D	–0.001	0.01	–0.13	0.895
L3D	0.002	0.01	0.16	0.874
LnGDP per capita				
LD	–0.001	0.00	–1.34	0.179
L2D	–0.001	0.00	–0.09	0.930
L3D	0.002	0.00	1.08	0.282
LnElectricity consumption per capita				
LD	0.000	0.02	0.02	0.981
L2D	0.013	0.04	0.29	0.773
L3D	–0.015	0.03	–0.46	0.644
LnEnergy use per capita				
LD	0.005**	0.00	1.97	0.049
L2D	0.007	0.03	0.23	0.818
L3D	0.043	0.04	1.07	0.287
LnUrban population				
LD	–0.129	0.24	–0.54	0.589
L2D	–0.029	0.22	–0.13	0.895
L3D	0.256	0.21	1.20	0.229
Constant	0.008	0.00	1.38	0.169

Source: Author's calculation, 2021
Notes: LD, L2D, and L3D mean lag 1, lag 2, and lag 3, respectively; ***, ** and * denote statistical significance at 1%, 5%, and 10%, respectively

In the long run, GDP per capita and energy use per capita have a significant and positive influences on CO_2 emissions in Vietnam while urban population contributes to reduced CO_2 emissions. The results also indicate that electricity consumption has no effect on CO_2 emissions in Vietnam (Table 8).

Table 8
Estimation of the VECM in the long run

Variables	Coefficient	Std. Error	*z*	*P*-value
LnCO_2 per capita	1			
LnGDP per capita	0.979***	0.05	18.15	0.000
LnElectricity consumption per capita	0.167	0.21	0.78	0.435
LnEnergy use per capita	0.528*	0.31	1.66	0.096
LnUrban population	–11.162***	1.59	–7.00	0.000
Constant	25.479			

Source: Author's calculation, 2021
Note: *** and * denote statistical significance at 1% and 10%, respectively

Table 9
Results of the Granger causality Wald test

Directional relationship	Probability	Conclusion
CO_2 emissions → GDP per capita	0.01 < 0.05	Reject H_0
CO_2 emissions → Electricity consumption	0.053 > 0.05	Accept H_0
CO_2 emissions → Energy use	0.04 < 0.05	Reject H_0
CO_2 emissions → Urbanisation	0.38 > 0.05	Accept H_0
GDP per capita → CO_2 emissions	0.00 < 0.05	Reject H_0
GDP per capita → Electricity consumption	0.00 < 0.05	Reject H_0
GDP per capita → Energy use	0.12 > 0.05	Accept H_0
GDP per capita → Urbanisation	0.41 > 0.05	Accept H_0
Electricity consumption → CO_2 emissions	0.10 > 0.05	Accept H_0
Electricity consumption → GDP per capita	0.03 < 0.05	Reject H_0
Electricity consumption → Energy use	0.00 < 0.05	Reject H_0
Electricity consumption → Urbanisation	0.14 > 0.05	Accept H_0
Energy use → CO_2 emissions	0.65 > 0.05	Accept H_0
Energy use → Economic growth	0.57 > 0.05	Accept H_0
Energy use → Electricity consumption	0.32 > 0.05	Accept H_0
Energy use → Urbanisation	0.34 > 0.05	Accept H_0
Urbanisation → CO_2 emissions	0.35 > 0.05	Accept H_0
Urbanisation → Economic growth	0.04 < 0.05	Reject H_0
Urbanisation → Electricity consumption	0.17 > 0.05	Accept H_0
Urbanisation → Energy use	0.43 > 0.05	Accept H_0

Source: Author's calculation, 2020

Table 9 shows there is a directional relationship running from CO_2 emissions to GDP per capita and energy use; a directional relationship running from GDP per capita to CO_2 emissions; a bi-directional relationship running from GDP per capita to electricity consumption; a directional relationship running from electricity consumption to energy use; and a directional relationship running from urbanisation to economic growth.

Discussion

In the short run, evidence points to GDP, electricity consumption, and energy use have significant and positive relationships with CO_2 emissions in Vietnam. This is consistent with that of Thanh and Khuong (2017) and Phong et al. (2018). This implies that economic growth, electricity consumption, and energy use are drivers leading to environmental degradation in Vietnam and therefore, the government should concentrate on economic growth, electricity consumption, and energy use along with environmental protection targets.

The study also found that electricity consumption and energy use are drivers of GDP, while CO_2 emissions and urban population negatively affect GDP of Vietnam. The finding is consistent with that of Long et al. (2018), reflecting that the Vietnam economy still depends heavily on electricity consumption and energy use. However, CO_2 emissions should be controlled because it reduces GDP. The government should consider policies on urbanisation since the expansion of urban population may result in decreased economic growth.

The GDP has been to shown to have a significant and negative effect on electricity consumption, but energy use positively influences electricity consumption in Vietnam. These imply that the Vietnamese economy can be improved to reduce its dependence on electricity consumption.

Additionally, the study find urbanisation does not increase energy consumption in Vietnam. However, an increase of energy use may generate the development of urban population. Therefore, policies on urbanisation should be considered along with energy policies.

The finding also suggest GDP per capita and energy use per capita have significant and positive influences on CO_2 emissions in Vietnam, while urban population contributes to reduction in CO_2 emissions. The Johansen co-integration test indicates that there is a long run relationship between CO_2 emissions, economic growth, electricity consumption, energy use, and urbanisation. This is supported by Ha and

Ngoc (2020) and Morelli and Mele (2020), implying that policies on economic growth and energy consumption should be considered by the government along with the target on environmental protection because economic growth and energy use are identified as emitters in Vietnam. Although urban population reduces CO_2 emissions, urbanisation policies should be carefully managed by the government since it decreases economic growth of this country.

CONCLUSION AND POLICY IMPLICATIONS

This paper was aimed at examining the causal relationship between CO_2 emissions, economic growth, electricity consumption, energy use, and urbanisation in Vietnam between 1982 and 2016 using VECM. In the short run, it has been empirically found that GDP, electricity consumption, and energy use have significant and positive relationships with CO_2 emissions in Vietnam. Results indicated that electricity consumption and energy use are drivers contributing to an increase in GDP while CO_2 emissions and urban population negatively affect GDP. It was also observed that GDP has a significant and negative impact on electricity consumption, but energy use positively affects electricity consumption in Vietnam. Further, urban population has a negative influence on energy use while energy use has a positive relationship with urban population. In the long run, the results suggest that GDP and energy use per capita have significant and positive influences on CO_2 emissions in Vietnam, while urban population contributes to reducing CO_2 emissions. Results of the Johansen co-integration test showed there is a long run relationship between CO_2 emissions, economic growth, electricity consumption, energy use, and urbanisation.

Policies are recommended to enhance economic growth and achieve sustainable development in Vietnam. First, economic growth and energy use should be considered by the government along with environmental protection targets since economic growth and energy use are drivers leading to the increase in CO_2 emissions. Second, productivity and structure of the Vietnam economy should be improved and transformed to reduce the dependence on electricity consumption and energy use. Either the green economy or the circular economy may become feasible alternatives for Vietnam to rejuvenate the economy. Third, policies on "low carbon" should be considered by the government because an increase in CO_2 emissions can slow down economic growth. Although the urban population contributes to reducing CO_2 emissions, policies on urbanisation should be carefully managed since the expansion of urban population decreases economic growth in Vietnam.

REFERENCES

Asian Development Bank (ADB) (2015). *Southeast Asia and the economics of global climate stabilization*. Asian Development Bank, Manila.

Adeola, O., & Ikpesu, F. (2016). An empirical investigation of the impact of bank lending on agricultural output in Nigeria: A vector autoregressive (VAR) approach. *The Journal of Developing Areas*, *50*(6), 89–103. https://doi.org/10.1353/jda.2016.0140

Al-Mulali, U., Saboori, B., and Ozturk, I. (2015). Investigating the environmental Kuznets curve hypothesis in Vietnam. *Energy Policy*, *76*, 123–131. https://doi.org/10.1016/j.enpol.2014.11.019

Alom, K., Uddin, A. N. M., & Islam, N. (2017). Energy consumption, CO_2 emissions, urbanization and financial development in Bangladesh: Vector error correction model. *Journal of Global Economics, Management and Business Research*, *9*(4), 178–189. https://ssrn.com/abstract=4381658

Alshehry, A. S., & Belloumi, M. (2015). Energy consumption, carbon dioxide emissions and economic growth: The case of Saudi Arabia. *Renewable and Sustainable Energy Reviews*, *41*, 237–247. https://doi.org/10.1016/j.rser.2014.08.004

Azlina, A. A., & Mustapha, N. N. (2012). Energy, economic growth and pollutant emissions nexus: The case of Malaysia. *Procedia-Social and Behavioural Sciences*, *65*, 1–7. https://doi.org/10.1016/j.sbspro.2012.11.082

Bilgili, F., Öztürk, İ., Koçak, E., Bulut, Ü., Pamuk, Y., Muğaloğlu, E., & Bağlıtaş, H. H. (2016). The influence of biomass energy consumption on CO_2 emissions: A wavelet coherence approach. *Environmental Science and Pollution Research*, *23*(19), 19043–19061. https://doi.org/10.1007/s11356-016-7094-2

Bilgili, F., Kuşkaya, S., Toğuç, N., Muğaloğlu, E., Kocak, E., Bulut, Ü., & Bağlıtaş, H. H. (2019). A revisited renewable consumption-growth nexus: A continuous wavelet approach through disaggregated data. *Renewable and Sustainable Energy Reviews*, *107*, 1–19. https://doi.org/10.1016/j.rser.2019.02.017

Bilgili, F., Kuşkaya, S., Ünlü, F., & Gençoğlu, P. (2020). Does waste energy usage mitigate the CO_2 emissions? A time-frequency domain analysis. *Environmental Science and Pollution Research*, *27*(5), 5056–5073. https://doi.org/10.1007/s11356-019-07253-w

Bilgili, F., Lorente, D. B., Kuşkaya, S., Ünlü, F., Gençoğlu, P., & Rosha, P. (2021a). The role of hydropower energy in the level of CO_2 emissions: An application of continuous wavelet transform. *Renewable Energy*, *178*, 283–294. https://doi.org/10.1016/j.renene.2021.06.015

Bilgili, F., Kuşkaya, S., Gençoğlu, P., Kassouri, Y., & Garang, A. P. M. (2021b). The co-movements between geothermal energy usage and CO_2 emissions through high and low frequency cycles. *Environmental Science and Pollution Research*, *28*, 63723–63738. https://doi.org/10.1007/s11356-020-11000-x

Bilgili, F., Koçak, E., Bulut, Ü., & Kuloğlu, A. (2017). The impact of urbanization on energy intensity: Panel data evidence considering cross-sectional dependence and heterogeneity. *Energy*, *133*, 242–256. http://dx.doi.org/10.1016/j.energy.2017.05.121

Burnett, J. W., Bergstrom, J. C., & Wetzstein, M. E. (2013). Carbon dioxide emissions and economic growth in the US. *Journal of Policy Modelling*, *35*(6), 1014–1028. https://doi.org/10.1016/j.jpolmod.2013.08.001

Chu, X. N., & Nguyen, V. T. (2017). Vietnamese urbanization: Actual situation and solutions for sustainable development. *Advances in Natural and Applied Sciences*, *11*(12), 41–49.

Global Fuel Economy Initiative (GFEI) (2010). *Improving vehicle fuel economy in the ASEAN region*. [Working Paper No. 1/10]. GFEI.

Ha, N. M., & Ngoc, B. H. (2020). Revisiting the relationship between energy consumption and economic growth nexus in Vietnam: New evidence by asymmetric ARDL cointegration. *Applied Economics Letters*, 1–7. https://doi.org/10.1080/13504851.2020.1789543

Hsiao, C. (2014). *Analysis of Panel Data* (3rd ed.). Cambridge University Press.

International Energy Agency (2018). *Global energy & CO_2 status report 2017*. International Energy Agency.

Jian, J., Fan, X., He, P., Xiong, H., & Shen, H. (2019). The effects of energy consumption, economic growth and financial development on CO_2 emissions in China: A VECM approach. *Sustainability*, *11*(4850), 1–16. https://doi.org/10.3390/su11184850

Khan, M. K., Teng, J. Z., & Khan, M. I. (2019). Effect of energy consumption and economic growth on carbon dioxide emissions in Pakistan with dynamic ARDL simulations approach. *Environmental Science and Pollution Research*, *26*(23), 23480–23490. https://doi.org/10.1007/s11356-019-05640-x

Khobai, H., & Roux, P. L. (2017). The relationship between energy consumption, economic growth and carbon dioxide emission: The case of South Africa. *International Journal of Energy Economics and Policy*, *7*(3), 102–109.

Kuşkaya, S., & Bilgili, F. (2020). The wind energy-greenhouse gas nexus: The wavelet-partial wavelet coherence model approach. *Journal of Cleaner Production*, *245*(118872), 1–14. https://doi.org/10.1016/j.jclepro.2019.118872

Li, F., Dong, S., Xue, L., Liang, Q., & Yang, W. (2011). Energy consumption-economic growth relationship and carbon dioxide emissions in China. *Energy Policy*, *39*(2), 568–574. https://doi.org/10.1016/j.enpol.2010.10.025

Li, H., Li, B., & Lu, H. (2017). Carbon dioxide emissions, economic growth, and selected types of fossil energy consumption in China: Empirical evidence from 1965 to 2015. *Sustainability*, *9*(5), 697.

Long, P. D., Ngoc, B. H., & My, D. T. H. (2018). The relationship between foreign direct investment, electricity consumption and economic growth in Vietnam. *International Journal of Energy Economics and Policy*, *8*(3), 267–274.

Lütkepohl, H., Saikkonen, P., & Trenkler, C. (2001). Maximum eigenvalue versus trace tests for the cointegrating rank of a VAR process. *The Econometrics Journal*, *4*(2), 287–310. https://doi.org/10.1111/1368-423X.00068

Ministry of Natural Resources and Environment (MONRE) (2020). *Technical Report on Vietnam's Updated Nationally Determined Contribution of Vietnam*. MONRE, Ha Noi, Vietnam.

Morelli, G., & Mele, M. (2020). Energy consumption, CO_2 and economic growth nexus in Vietnam. *International Journal of Energy Economics and Policy*, *10*(2), 443–449. https://doi.org/10.32479/ijeep.8248

Musunuru, N. (2017). Causal relationships between grain, meat prices and exchange rates. *International Journal of Food and Agricultural Economics*, *5*(4), 1–10. https://doi.org/10.22004/ag.econ.266439

Nguyen, T. K. A. (2012). Structural decomposition analysis of CO_2 emission variability in Vietnam during the 1986–2008 period. *VNU Journal of Science, Economics and Business*, *28*(2), 115–123.

Nguyen, H. T., Aviso, K. B., Le, D. Q., & Tokai, A. (2018). Main drivers of carbon dioxide emissions in Vietnam trajectory 2000–2011: An input-output structural decomposition analysis. *Journal of Sustainable Development*, *11*(4), 129–147. https://doi.org/10.5539/jsd.v11n4p129

Nnaji, C. E., Chukwu, J. O., & Nnaji, M. (2013). Electricity supply, fossil fuel consumption, CO_2 emissions and economic growth: Implications and policy options for sustainable development in Nigeria. *International Journal of Energy Economics and Policy*, *3*(3), 262–271.

Nugraha, A. T., & Osman, N. H. (2019). CO_2 emissions, economic growth, energy consumption, and household expenditure for Indonesia: Evidence from cointegration and vector error correction model. *International Journal of Energy Economics and Policy*, *9*(1), 291–298. https://doi.org/10.32479/ijeep.7295

Phong, L. H., Van, D. T. B., & Bao, H. H. G. (2018). The role of globalization on carbon dioxide emission in Vietnam incorporating industrialization, urbanization, gross domestic product per capita and energy use. *International Journal of Energy Economics and Policy*, *8*(6), 275–283. https://doi.org/10.32479/ijeep.7065

Phrakhruopatnontakitti, P., Watthanabut, B., & Jermsittiparsert, K. (2020). Energy consumption, economic growth and environmental degradation in 4 Asian Countries: Malaysia, Myanmar, Vietnam and Thailand. *International Journal of Energy Economics and Policy*, *10*(2), 529–539. https://doi.org/10.32479/ijeep.9229

Rehman, A., Rauf, A., Ahmad, M., Chandio, A. A., & Deyuan, Z. (2019). The effect of carbon dioxide emission and the consumption of electrical energy, fossil fuel energy, and renewable energy, on economic performance: Evidence from Pakistan. *Environmental Science and Pollution Research*, *26*(21), 21760–21773. https://doi.org/10.1007/s11356-019-05550-y

Sasana, H., & Aminata, J. (2019). Energy subsidy, energy consumption, economic growth, and carbon dioxide emission: Indonesian case studies. *International Journal of Energy Economics and Policy*, *9*(2), 117–122. https://doi.org/10.32479/ijeep.7479

Thanh, L. T., & Khuong, N. D. (2017). Factors affecting CO_2 emission in Vietnam: A panel data analysis. *Organizations and Markets in Emerging Economies*, *8*(2), 244–257. https://doi.org/10.15388/omee.2017.8.2.01

World Bank (2011). *Natural resources management, Viet Nam Development Report 2011*. http://siteresources.worldbank.org/INTVIETNAM/Resources/ VDR2011 EnglishSmall.pdf

World Bank (2021a). *World Development Indicators. CO_2 emissions per capita in Vietnam*. https://databank.worldbank.org/reports.aspx?source=2&series=NV.AGR.TOTL.ZS&country=#

World Bank (2021b). *World Development Indicators: Electricity consumption per capita in Vietnam*. https://databank.worldbank.org/reports.aspx?source=2&series=NV.AGR.TOTL.ZS&country=#

World Bank (2021c). *World Development Indicators: Energy use per capita in Vietnam*. https://databank.worldbank.org/reports.aspx?source=2&series=NV.AGR.TOTL.ZS&country=#

World Bank (2021d). *World Development Indicators: GDP per capita in Vietnam*. https://databank.worldbank.org/reports.aspx?source=2&series=NV.AGR.TOTL.ZS&country=#

World Bank (2021e). *World Development Indicators: Urban population in Vietnam*. https://databank.worldbank.org/reports.aspx?source=2&series=NV.AGR.TOTL.ZS&country=#

Zimmer, A., Jakob, M., & Steckel, J. C. (2015). What motivates Vietnam to strive for a low-carbon economy? – On the drivers of climate policy in a developing country. *Energy for Sustainable Development*, *24*, 19–32. https://doi.org/10.1016/j.esd.2014.10.003