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# Macroeconomic Factors affecting CO<sub>2</sub> Emissions in Malaysia: ARDL Approach

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**Abstract:** Environmental degradation has always been discussed by previous studies. This is because environmental degradation can have impacts on human health. The global temperature is expected to continue to increase in the next 100 years. Therefore, it is important to investigate the determinants of CO<sub>2</sub> emissions in the long run and short run in Malaysia. Data ranging from 1985 to 2014 were collected and the ARDL approach was employed. The results show that economic growth can be detrimental to the environment in both of the long run and short run. The results also show that population can have deleterious effects on the environment in the long run only. Therefore, enhancing economic growth and increasing the number of population should be controlled to ensure that the environment can be preserved.

## 1. Introduction

The issue of the environment has always been addressed by previous studies due to the upward trend in CO<sub>2</sub> emissions. An inexorable intensification of CO<sub>2</sub> emissions has rung alarm bells as serious global warming and climate change ensue [1]. According to IPCC (2007), the global temperature is expected to increase in the next 100 years [2]. Therefore, it is imperative for governments to ascertain the determinants of CO<sub>2</sub> emissions to ensure sustainability. Energy consumption is always perceived to be one of the factors that contribute to the problem [3]. Burning energy sources such as oil, gas and coal will release CO<sub>2</sub> emission, thus harming the environment [4]. In generating economic activities, energy is inevitably consumed. Hence, the importance of energy is on a par with that of capital and labour in all economic sectors such as transportation, industries and agriculture. In most developing countries, every year, energy consumption exhibits a steady increase owing to their economic development. They are enormously dependent on non-renewable instead of renewable energy. This is because substituting non-renewable with renewable energy can pose a great challenge to developing countries [5].

Economic growth can harm the environment if economic activities are generated by non-renewable energy. Numerous countries, regardless of their status whether developed or developing countries, boost economic growth in tandem with the aggravation of environmental problems. Ouahrani et al. (2011) stated that in generating energy to boost economic growth, countries have to burn fossil fuels, thus release CO<sub>2</sub> emissions [6]. Other than economic growth, population can also contribute to higher CO<sub>2</sub> emissions. The increase in the number of population has reflected the increase in CO<sub>2</sub> emissions. Urban



areas suffer from higher pollution compared to rural areas [15]. One of the factors is that a large number of population in urban areas. According to the World Development Indicators (WDI), CO<sub>2</sub> emissions intensify as the rate of urbanisation escalates. Al-mulali et al. (2013) stated that urbanisation which plays an important role in economic development generates more pollution [1]. In addition, Hassan and Salim (2015) laid emphasis on the relationship between population and environmental problems [7].

A marked increase in trade is always claimed to have a desirable impact on the economy as it can provide more job opportunities and boost GDP per capita [14]. It, on the other hand, can have a deleterious impact on the environment. The quality of air can be degraded if production is boosted to export to the world. Some developing countries impose less strict regulations on pollution [8]. Therefore, production takes precedence over the environment. Lau et al. (2014) ascertained trade openness can be detrimental to the environment [9]. A reduction in environmental degradation can be attributed to foreign direct investment. This is because more funds can be obtained to finance environmentally friendly activities and new green technology to produce output. However, Lau et al. (2014) argued that foreign direct investment can increase output and thus results in environmental degradation [9].

Despite a vast array of literature investigating the factors of CO<sub>2</sub> emissions such as energy consumption, economic growth, foreign direct investment and population. However, they explored all of the factors in separate studies (whereby some treated energy consumption, economic growth, and FDI only as their interest factors, and some treated energy consumption, economic growth and trade openness as their interest factors). Hence, this study attempts to explore all the determinants of CO<sub>2</sub> emissions in one study.

## 2. Literature Review

A large number of previous studies have investigated the factors that can influence CO<sub>2</sub> emission in various countries. Various methods have been applied, for example Chang (2010), Hussain et al. (2014) and Vidyarthi (2013) employed the Johansen co-integration and their findings are mixed [3,4,10]. Chang (2010) explored the determinant of energy consumption and economic growth on CO<sub>2</sub> emissions and the results showed that an increase in economic growth be determinant to the environment. However, the use of energy such as oil and coal does not affect the environment [10-11]. The findings were supported by Hossain et al. (2012) that economic growth influence CO<sub>2</sub> emissions but energy consumption does not [12]. Vidyarthi (2013) also proved that as energy consumption and economic growth increase, CO<sub>2</sub> emissions will increase simultaneously [3]. Wang, et al. (2011), Alshehry and Belloumi (2014) also found the energy consumption determinant of CO emission in Saudi Arabia [12,13].

Several studies have been conducted to examine the FDI factor of CO<sub>2</sub> emissions [9,14-19]. Their findings are consistent despite different methods. Kiviyiro and Arminen (2014) employed the ARDL approach and confirmed that FDI can cause CO<sub>2</sub> emissions. Pao and Tsai (2011) also found that FDI plays an important role in exaggerating environmental problems not only in the short run but also in the long run. Pao and Tsai (2011), Tang and Tan (2014) and Chandran and Foon (2013) employed Johansen co-integration and also found that there is a positive relationship between FDI and CO<sub>2</sub> emissions.

The population factor of CO<sub>2</sub> emission has also been explored by a large number of previous studies such as Wang et al. (2014), Al-mulali, et al. (2012), Hassan and Salim (2015). They looked at the different perspective of population. For example, Wang, et al. (2014) explored the effects of population in urban areas and the results found that larger urbanisation causes larger CO<sub>2</sub> emissions [13]. Al-mulali, et al. (2012) also examined the effects of urbanisation on CO<sub>2</sub> emissions and the results were consistent [1]. Hassan and Salim (2015) explored the effects of population ageing on CO<sub>2</sub> emissions and the results showed that population ageing can decrease CO<sub>2</sub> emissions in the long run [7].

Several studies also examined the effects of trade on CO<sub>2</sub> emissions such as Hossain (2012), Halicioglu (2009), Ibrahim and Rizvi (2015), Hossain (2011) and Kasman and Selman (2015) [8,11,18,21]. Hossain (2012) employed the ARDL approach and the results showed that trade openness can have a long-run effects on CO<sub>2</sub> emissions [12]. Halicioglu (2009) also used the same method and supported that foreign trade can affect CO<sub>2</sub> emissions in Turkey [18]. Ibrahim and Rizvi (2015)

employed a panel data analysis, namely Pedorni cointegration and investigated in ASEAN-5 countries such as Thailand and Malaysia [8]. The findings are also consistent that trade openness is the factor of CO<sub>2</sub> emissions.

### 3. Methodology

In this study, secondary data has been used from 1985 to 2014. The data on CO<sub>2</sub> emissions, real GDP, FDI, population and trade have been collected from the World Bank. There are several tests that will be conducted, namely unit root test, bound test, long-term and short coefficient tests using the ARDL approach, diagnostic test and CUSUM and CUSUMQ tests [16]. The root unit test is conducted to examine the stationarity of all the data. This test is important before a bound test can be performed. This study employed unit root based on Augmented Dickey Fuller (ADF). ADF is the most popular approach by previous studies. The analysis is conducted at level and first difference. All the data on each variable have been logged to have a linear estimation. Therefore, the model specification for this study is shown in the following equation

$$\ln\text{CO2}_t = \alpha_1 + a_2\ln\text{EC}_t + \alpha_3\ln\text{GDP}_t + \alpha_4\ln\text{FDI}_t + \alpha_5\ln\text{POP}_t + \alpha_6\ln\text{T}_t + \varepsilon_t \quad (1)$$

Where,

$\ln\text{CO2}$  = log of carbon dioxide emissions (CO<sub>2</sub>)

$\ln\text{EC}$  = log of energy consumption

$\ln\text{GDP}$  = log of real Gross Domestic Product (GDP)

$\ln\text{FDI}$  = log of foreign direct investment (FDI)

$\ln\text{POP}$  = log of population

$\ln\text{T}$  = log of trade

$\varepsilon$  = error correction term

$t$  = time of year

Next, this study employs the Leg Autoregressive Lags (ARDL) approach which was introduced by Pesaran et al. (2001). This approach is appropriate to examine the factors (population, energy consumption, economic growth, FDI and trade) affecting CO<sub>2</sub> emissions. The advantages of this approach are that it can be used for a study with a small sample size [20]. Another advantage of using this approach is that we can have the mixed integration for the results of unit root test. However, the ARDL method can be proceeded if the series of data produced is I (2) or more because Pesaran et al. (2001) stated that the ARDL boundary test is subject to the assumption that the variables are integrated with I (0), I (1), or mixed. Therefore, the model is as follows:

$$\begin{aligned} \Delta\ln\text{CO2}_t = & \alpha_1 + \delta_1\ln\text{CO2}_{t-1} + \delta_2\ln\text{EC}_{t-1} + \delta_3\ln\text{GDP}_{t-1} + \delta_4\ln\text{FDI}_{t-1} + \delta_5\ln\text{T}_{t-1} + \delta_6\ln\text{POP}_{t-1} + \\ & \sum_{i=1}^{a1} \delta_7\Delta\ln\text{CO2}_{t-i} + \sum_{i=1}^{a2} \delta_8\Delta\ln\text{EC}_{t-i} + \sum_{i=1}^{a3} \delta_9\Delta\ln\text{GDP}_{t-i} + \sum_{i=1}^{a4} \delta_{10}\Delta\ln\text{FDI}_{t-i} + \\ & \sum_{i=1}^{a5} \delta_{11}\Delta\ln\text{T}_{t-i} + \sum_{i=1}^{a6} \delta_{12}\Delta\ln\text{POP}_{t-i} + u_t \end{aligned} \quad (2)$$

Where,  $\Delta$  is the first difference operator.  $\delta$  is a long-run coefficient and  $t$  is time of year.  $u$  is the error correction term. As for the short-run effect, the equation is as follows:

$$\begin{aligned} \Delta\ln\text{CO2}_t = & \delta_1 + \sum_{i=1}^{a1} \delta_2\Delta\ln\text{CO2}_{t-i} + \sum_{i=1}^{a2} \delta_3\Delta\ln\text{EC}_{t-i} + \sum_{i=1}^{a3} \delta_4\Delta\ln\text{GDP}_{t-i} + \sum_{i=1}^{a4} \delta_5\Delta\ln\text{FDI}_{t-i} + \\ & \sum_{i=1}^{a5} \delta_6\Delta\ln\text{T}_{t-i} + \sum_{i=1}^{a6} \delta_7\Delta\ln\text{POP}_{t-i} + \Phi_t\text{ECT}_{t-1} + e_t \end{aligned} \quad (3)$$

Where  $\delta$  is a short-run coefficient,  $\Phi$  is the speed of adjustment for the long-run error correction.

### 4. Results

Based on table 1, all the variables ( $\ln\text{CO2}$ ,  $\ln\text{EC}$ ,  $\ln\text{FDI}$ ,  $\ln\text{GDP}$ ,  $\ln\text{POP}$ , and  $\ln\text{T}$ ) are not stationary at level for both intercept with and without trend except for FDI. However, all the variables are stationary at first difference for both intercept with and without trend. Based on these findings, the ARDL approach can be employed.

**Table 1.** Unit Root Test

Variables	Intercept		Intercept + Trend	
	Level	First Difference	Level	First Difference
lnCO <sub>2</sub>	-1.671 (0.435)	-5.250*** (0.000)	-1.407 (0.838)	-5.526*** (0.001)
lnEC	-1.224 (0.651)	-5.700*** (0.000)	-1.584 (0.775)	-4.530*** (0.006)
lnFDI	-4.670*** (0.001)	-1.540 (0.495)	-4.680*** (0.004)	-1.263 (0.870)
lnGDP	-0.879 (0.781)	-4.490** (0.001)	-1.176 (0.898)	-4.658*** (0.004)
lnPOP	-0.891 (0.773)	-6.219* (0.000)	-2.018 (0.562)	-6.130* (0.000)
lnT	-2.156 (0.226)	-3.669** (0.010)	-0.755 (0.959)	-5.308*** (0.001)

Note: \*, \*\* and \*\*\* indicate the rejection of the null hypothesis of non-stationary at 1%, 5% and 10% significance level respectively.

The Bound test must be conducted prior to the ARDL test. This test is important to check the presence of co-integration. The results of the Bound test are reported in table 2. The results show that the value of test statistic (5.498) is higher than lower bound and upper bound at 1%. Therefore, there is an existence of a co-integration between the CO<sub>2</sub> emission and other macroeconomic variables. Then, we can proceed to a long-run estimation to see which factor can affect CO<sub>2</sub> emission in the long run.

**Table 2.** ARDL Bounds Test

Test Statistic	Value	k
F-statistic	5.498*	5
Critical Value Bounds		
Significance	I(0) Bound	I(1) Bound
10%	2.26	3.35
5%	2.62	3.79
2.5%	2.96	4.18
1%	3.41	4.68

Note: \* indicates significance at 1%,

Table 3 shows the results of long-run estimation using the ARDL approach. The results show that economic growth is significantly connected with CO<sub>2</sub> emission.

**Table 3.** Long Run Coefficients using the ARDL Test

Variable	Coefficient	Prob.
LNEC	-0.2816	0.7313
LNFDI	-0.0218	0.4580
LNGDP	1.9405*	0.0070
LNPOP	3.3049**	0.0181
LNT	0.2717	0.1867
C	33.5738***	0.0546

Note: \*, \*\* and \*\*\* indicate the rejection of the null hypothesis of non-stationary at 1%, 5% and 10% significance level respectively.

It means that a 1% increase in economic growth can cause CO<sub>2</sub> emission to rise by 1.94% in the long run. The findings of this study are similar to the findings by Vidyarthri (2013) and Wang et al. (2011) [3,12]. Apart from that, population is also significantly associated with CO<sub>2</sub> emission. A 1% increase in population can cause CO<sub>2</sub> emission to increase by 3.3% in the long run. Other than that, energy consumption, FDI and trade do not have any significant effect on CO<sub>2</sub> emission in the long run.

Table 4 shows the results for short-run estimation using the ARDL Approach. The results show that economic growth is related to CO<sub>2</sub> emission as it is significant at 5%. It suggests that a 1% increase in economic growth can cause CO<sub>2</sub> emission to increase by 1.03% in the short run. This result is similar to the results by Vidyarthri (2013) [3]. Besides, energy consumption, FDI, population and trade are not significantly related to CO<sub>2</sub> emission in the short run. The value of ECT is negative and significant, thus it confirms the existence of co-integrated relationship. Its coefficient is -0.5314 and this means that the deviations from the long-run equilibrium among the variables are corrected by 5.31% within a year.

**Table 4.** Short Run Coefficients using ARDL Test

Variable	Coefficient	Prob.
D(LNEC)	0.4201	0.1806
D(LNFDI)	-0.0116	0.4557
D(LNGDP)	1.0312**	0.0320
D(LNPOP)	14.8828	0.2257
D(LNT)	0.14434	0.1244
ECT	-0.5314**	0.0256

Note: \*\* indicates significance at 5%.

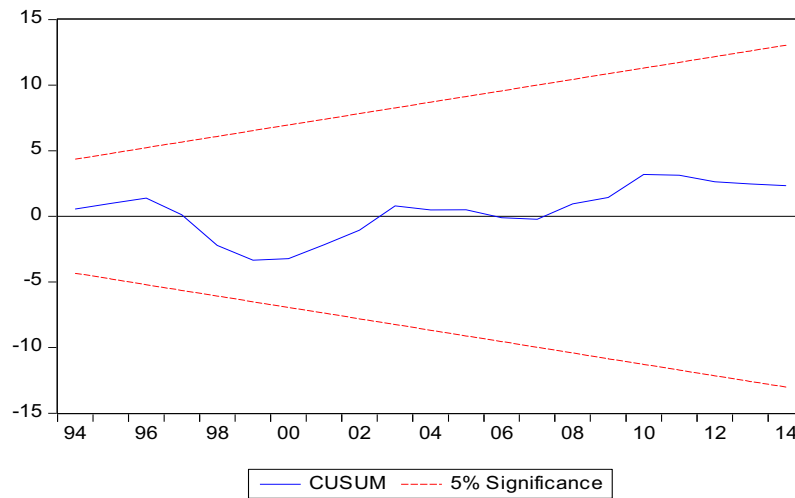
Several diagnostic tests are conducted such as Breusch-Godfrey Serial Correlation LM test, Heteroskedasticity test based on Breusch-Pagan-Godfrey and Ramsey Reset test. The results show in table 5 related that only the test of Ramsey Reset shows significance, however the other two diagnostic tests do not show any significance. Thus, we can conclude that the model is good.

**Table 5.** Diagnostic Test Results

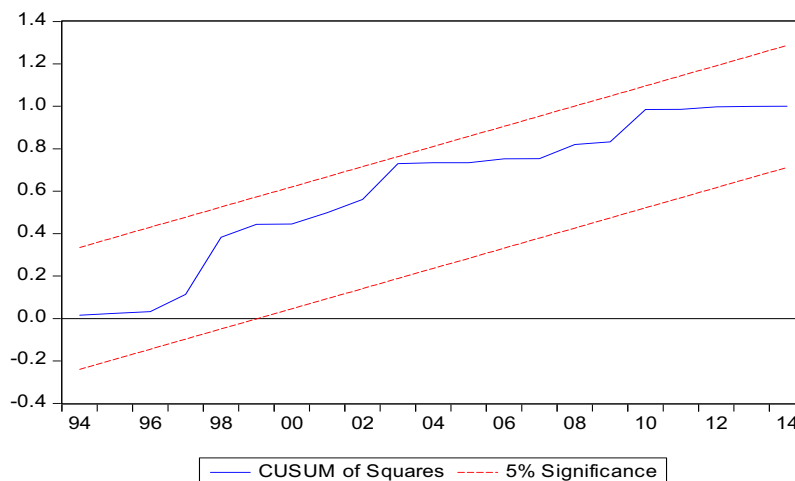
Test statistic	F-statistic (Probability )
Breusch-Godfrey Serial Correlation LM Test:	0.4668 (0.6340)
Ramsey Reset	6.8770 (0.0163)
Heteroskedasticity Test: Breusch-Pagan-Godfrey:	1.0925 (0.4062)

Note: \*\* indicates significance at 5%

Figure 1 and figure 2 show the Cumulative Sum of Recursive Residual (CUSUM) and The Cumulative Sum of Square of Recursive Residual (CUSUMSQ). Based on the figure, it can be seen that the plots fall within the boundaries, which suggests that the model is stable.



**Figure 1.** Cumulative Sum of Recursive Residual (CUSUM)



**Figure 2.** Cumulative Sum of Square of Recursive Residual (CUSUMSQ)

## 5. Conclusion

This study aims to investigate the macroeconomic determinants of CO<sub>2</sub> emissions in long run and short run in Malaysia from 1985 to 2014. The bound test is employed and there is an existence of a co-integrated relationship between the CO<sub>2</sub> emission and other macroeconomic variables. Then, the long run estimation using ARDL is performed and the results show that economic growth and population can be the determinants of CO<sub>2</sub> emissions in the long run. In the short run, only economic growth can affect CO<sub>2</sub> emissions, while the other variables are not significant. These findings can shed light on the macroeconomic factors of CO<sub>2</sub> emissions in Malaysia. Policy makers should continue to encourage firms to use renewable resources as the use of non-renewable energy is not detrimental to the environment. The results also show that there is no long- and short-run relationship between trade and CO<sub>2</sub> emissions. It suggests that increasing trade to boost economic growth does not trigger any environmental issue. However, policies remain complex as the results show that economic growth and population can cause environmental degradation. Therefore, policy makers should formulate policies meticulously to ensure that enhancing economic growth and increasing population will not affect the environment.

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