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The Nexus of Population, Gross Domestic Product Growth, Electricity Generation, Electricity Consumption and Carbon Emissions Output in Malaysia

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ABSTRACT

This study aimed to examines the nexus of population, gross domestic product (GDP) growth, electricity generation, electricity consumption, and carbon emissions output using the time series data. This study employed the time series analysis, Pearson correlation, and regressions analysis to identify the pattern, relationship among variables and determine the significant predictors contributing carbon emissions in Malaysia. The results shown a growing trend in GDP, population, electricity generation, consumption, and emissions output in Malaysia. The correlation analysis presented a positive linear relationship among GDP, population, electricity generation, electricity consumption, and emissions output. The growing trend in population and GDP has significantly resulted in high rate of electricity generation and consumption that leads to greater carbon emissions in Malaysia. The multiple linear regressions suggest that population plays an important role to influence the carbon emissions in power generation sector from 1970 to 2014. We summarized the aspect of generations, consumption, and emissions productions are highly dependent on human aspects and driven by the inhabitants of the country. According to these findings, it can be concluded that electrical power in Malaysia is human-dependent energy system. Therefore, sustainable energy generation and consumption are crucial as renewable energy is generating zero emissions. A more holistic policy and strategy is required to encourage sustainable resources at the same time reducing carbon emissions towards sustainable energy consumption in Malaysia.

Keywords: Electricity Generation, Consumption, Emissions, Malaysia
JEL Classifications: Q41, C39

1. INTRODUCTION

As a global scenario, the increasing human population and energy consumption have placed pressure on the natural environment that leads to environmental changes (Chen et al., 2014). The changes include settlement pattern, lifestyle, and energy consumption especially in urban areas. The growing population requires more energy resources and forest areas to be cleared for residential areas. Thus, it leads to several environmental issues including growing waste generation and greenhouse gases emissions. In 2050, the world population is anticipated to skyrocket at 6.5 billion which is an increase of 3.5 billion from 2010 (Kennedy et al., 2014). Meanwhile, World Population Prospect (2017) indicated that in mid-2017, the current world population is around 7.5 billion. More than half of the world's population live in Asia (4.5 billion), 17% in Africa (1.3 billion), 10% in Europe (742 million), 9% in Latin America and the Caribbean (646 million), and the remaining 6% in Northern America (361 million) and Oceania (41 million). In 2018, the global electricity demand rose by 4% whereby coal and natural gas remain as the primary electricity supply, driving up

CO_2 emissions from the sector by 2.5% (IEA, 2019). Therefore, it is significant to understand the nexus among population, gross domestic product (GDP), electricity generation, consumption, and emissions to provide a strategy for sustainable energy consumption and emissions reduction.

Previous studies found that electricity generation, consumption, and emissions outputs are related to various factors such as economic growth, population changes, energy price, technology innovation, exports, and foreign direct investment as well as factors related to human such as socioeconomic status, psychology, and housing characteristics. Tang (2008) and Chandran et al. (2010) examined the relationship between electricity consumption and GDP using an autoregressive distributed lag (model). Chandran et al. (2010) found that there is a statistically significant long-run elasticity of electricity consumption on GDP while the short-run shown unidirectional flow from electricity consumption to GDP. They concluded that Malaysia is an energy-dependent country. Meanwhile, Tang (2008) summarised that electricity consumption and economic growth are not co-integrated in Malaysia. Tang and Tan (2013) investigated the relationship between electricity consumption, economic growth, energy prices, and technology innovation in Malaysia from 1970 to 2009. The result shows that income positively affects electricity consumption, while energy price and technology innovation affects in long-run. They suggested that policymakers should increase the investment in electricity infrastructure. Chen et al. (2007) estimated the relationship between GDP and electricity consumption in 10 Asian developing countries. The result indicates that there is a unidirectional short-run causality running from economic growth to electricity consumption and a bidirectional long-run causality between electricity consumption and economic growth. Yoo (2006) investigated the causal relationship between electricity consumption and economic growth among 4 ASEAN countries (Indonesia, Malaysia, Singapore, and Thailand) from 1971 to 2002. The result shows bidirectional causality between electricity consumption and economic growth in Malaysia and Singapore, while a unidirectional causality between electricity consumption and economic growth in Indonesia and Thailand.

Begum et al. (2017) used a correlation analysis to study the relationship between energy consumption and CO_2 emissions in Malaysia. The study revealed a strong correlation between energy consumption and CO_2 emissions probably due to the high population and GDP growth in Malaysia. Yildirim et al. (2014) findings indicate that taking into account cross-sectional dependence has a substantial effect on the achieved results. The conservation hypothesis is supported for Indonesia, Malaysia and the Philippines. Although a bidirectional relation is found in the case of Thailand, since there is no positive effect of energy consumption on GDP, the conservation hypothesis is supported. In the pattern of Singapore, the neutrality hypothesis is supported. According to the study of Ahmed et al. (2017), there is bidirectional causality between energy consumption and trade openness and uni-directional causality running from energy consumption, trade openness and population to CO_2 emission. The results enumerate that the energy consumption and population density will increase in long-run and foresee further environmental degradation in the region.

In this paper, the time series analysis, correlation, and multiple linear regressions were carried out to study the pattern and nexus of population, GDP growth, electricity generation, consumption, and carbon emissions in Malaysia using the time series data.

2. ELECTRICITY GENERATION IN MALAYSIA (1978-2017)

Figure 1 presents the trend pattern of electricity generation by the types of power station from 1978 to 2017. Electricity generation can be defined as the generated electric power that produced from various types of power station including hydro generation, thermal stations, and co-generation plants. The total electricity generation in Malaysia has increased significantly. The primary supply of electricity generation in Malaysia is natural gas and coal as mainly supplied to the thermal stations. The generation from thermal stations tremendously increased from 633 ktoe in 1978 to 11416 ktoe in 2017. The sharp increment in electricity generation is probably due to the increase in population and high demand from industrial and commercial sectors as it is in line with the economic development in Malaysia. Coal has taken over from natural gas as main fuel input for electricity generation in 2010 until present as the initiative to reduce the national dependence on oil and gas (Shekarchian et al., 2011). A total import of coal in 2010 was 13013 ktoe and settled at 19181 ktoe in 2017, followed by natural gas and hydropower (Malaysia Energy Statistic Handbook, 2017). Meanwhile, the electricity generation from hydropower also increased from 77 ktoe in 1978 to 2287 ktoe in 2017. This is probably due to the new installed capacity from mini hydro power stations mainly in Sabah and Sarawak (Hamzah et al., 2017). However, the increments are still low. Compared to co-generation plants, the total generation fluctuated from 1978 to 2017 and remained as the lowest electricity generations power plants in Malaysia.

Figure 2 indicates the total coal and natural gas imports in Malaysia. From 1978 to 2009, natural gas remains as the main fuel input in Malaysia with the total contribution in mix electricity generation of 21 ktoe in 1978 and continues skyrocketed to hit a peak at 13,390 ktoe in 2009. On the other hand, the share of natural gas has slowly decreased about 40.4% behind coal that contributed 47.2% input in 2015, followed by hydropower (Malaysia Energy Statistic Handbook, 2017). According to these figures, the share of coal and hydropower will continue to increase particularly for hydropower when the total installed capacity was increased from 20710 MW in 2015 to 22910.55 MW in 2016 as a result of high energy demand and newly operated power stations (NEB, 2016). Meanwhile, Indonesia and Australia remain as the main coal exporters for Malaysia.

On the other hand, electricity consumption also shows a dramatic increment from 1978 to 2017. The total electricity consumption in 1978 was 604 ktoe and escalated to 1715 ktoe in 1990. The consumption continues skyrocket to 5263 ktoe in 2000 and stopped at 12607 ktoe in 2017 (Malaysia Energy Statistic Handbook, 2017). The increment was in line with the increment in total population, rapid industrial sector, and increasing demand from the commercial sector particularly in urban areas. The trend of sectorial electricity consumption can be referred and discussed in the next section.

3. SECTORIAL ELECTRICITY CONSUMPTION (1978-2017)

Figure 3 portrays the trend of sectorial electricity consumption that has tremendously increased since 1978–2017. Malaysia has undergone remarkable growth and obtained a stable GDP of 6.5% per annum since 1972 and has accelerated electricity consumption in the industrial sector (11th Malaysia Plan 2015). The industrial sector is the main user of electricity consumption with a share of 53.47%, 45.22%, and 52.67% in 1978, 1988, and 1998, respectively. The total consumption from the industrial sector continued to increase from 3687 ktoe in 2008 to hit a peak at 6145 ktoe in 2017. The increasing trend in the industrial sector is expected to absorb 50% of the projected energy demand of 116 Mtoe (Keong, 2005; Chandran et al. 2010). This is in line with the discussion by Saidur et al. (2009) that mentioned the main electricity consumption in industrial sector was electric motors and pumps. Separately, the electricity consumption from the commercial sector also increased from 1978 to 2017. The total electricity consumption from the commercial sector was 281 ktoe in 1978 increased to 763 ktoe in 1988 and sharply decreased to settled at only 283 ktoe in 1989. The consumption slowly increased in 1990 to 1996 and dropped again in 1997. The total consumption for the commercial sector continued to increase and hit a peak at 3762 ktoe in 2017. High electricity consumption in the commercial sector is mainly contributed from space cooling, water heating, lighting and other use. As demonstrated in Figure 4, electricity consumption user by the sub-sector of commercial sector public administration followed by selected services, human health, wholesale and retail trade and others.

Figure 1: Electricity generation by power stations (ktoe)

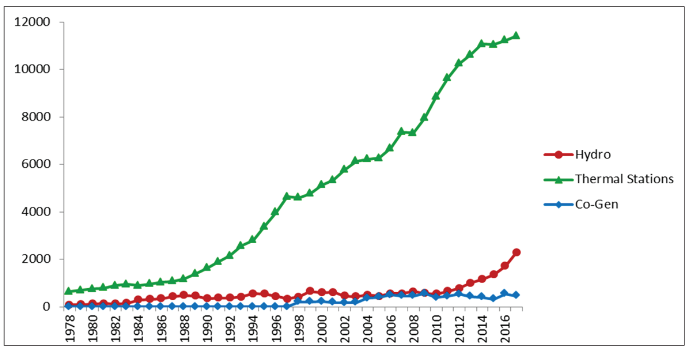


Figure 2: Coal and natural gas imports in Malaysia (ktoe)

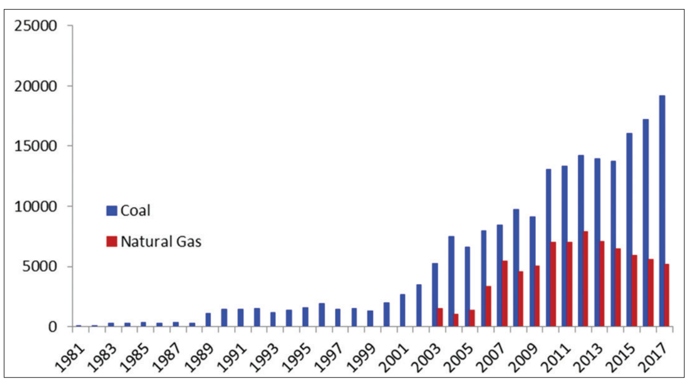
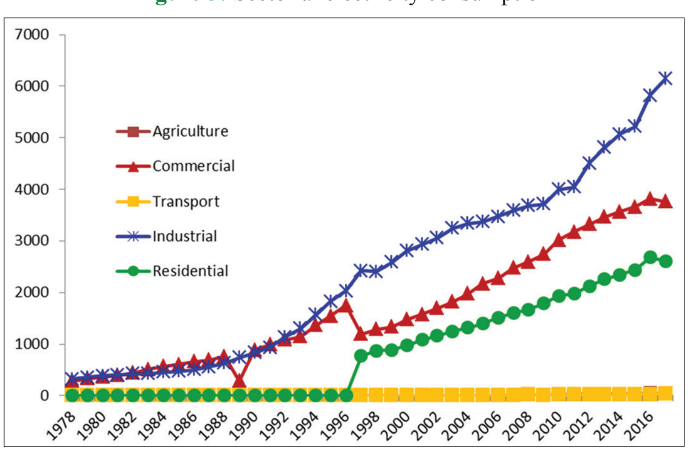


Figure 3: Sectorial electricity consumption



The residential sector has becoming the third largest electricity consumer in Malaysia. However, the residential consumption data were only available starting from 1997. The trend analysis indicates that the total electricity consumption for this sector gained about 238.9% from 770 ktoe in 1997 to 2610 ktoe in 2017. These figures are expected to increase due to the growing number of population and housing land use demand. Meanwhile, the electricity consumption for agriculture and transportation sectors remained low probably due to the least demand from these sectors.

4. CO_2 EMISSIONS IN MALAYSIA (1970-2014)

Figure 5 shows the total carbon emissions in Malaysia from 1970 to 2014. The trend analysis portrays dramatic changes in CO_2 emissions in 44 years. In total, Malaysia has released about 4322956.627 kilo tonnes (kt) of CO_2 with average emission of 98249.01 kt/year. The study indicates that about 14601.99 kt of CO_2 has been released in 1970. The total emissions slowly increased and settled at 125374.7 kt in 1996. However, the emission dropped in 1999 and skyrocketed to reach 242821.4 kt in 2014 (World Bank, 2019). This is probably due to the global economic recession in 1999 and affected the whole economic sector in Malaysia. The same trend was also recorded in carbon emissions per capita. The graph below also shows the linear relationship between CO_2 per capita and the total carbon emissions in Malaysia. Although the trend was fluctuated, the emissions per capita were increased from 1.32 metric tonne per capita in 1970 to 8.13 metric tonne in 2014.

Figure 6 displays the percentage of CO_2 emissions from power generation in Malaysia. The largest carbon emission in Malaysia was contributed by the power generation sector (Begum et al. 2017). Power generations contributed about 16.57% out of 16677.52 kt of carbon emissions in 1971 and increased to release about 38.27% in 1990. Since 2008, power generation has contributed more than 50% from the total carbon emissions in Malaysia. A total 51.18%

Figure 4: Electricity consumption by sub-sector of commercial sector (2016)

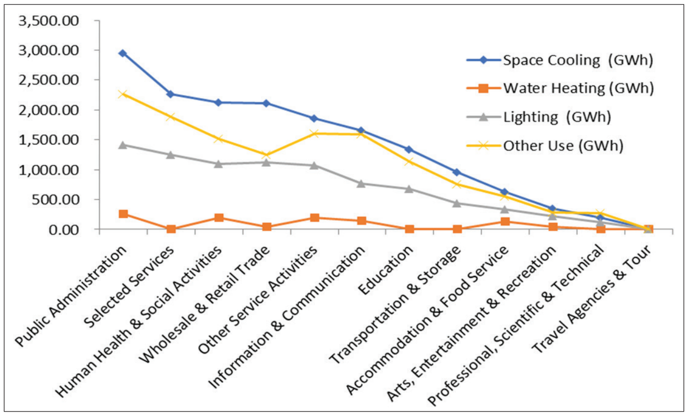
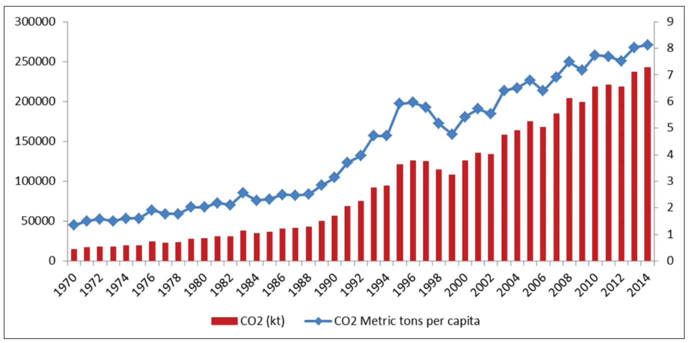


Figure 5: Trends of CO_2 emissions (1970-2014)

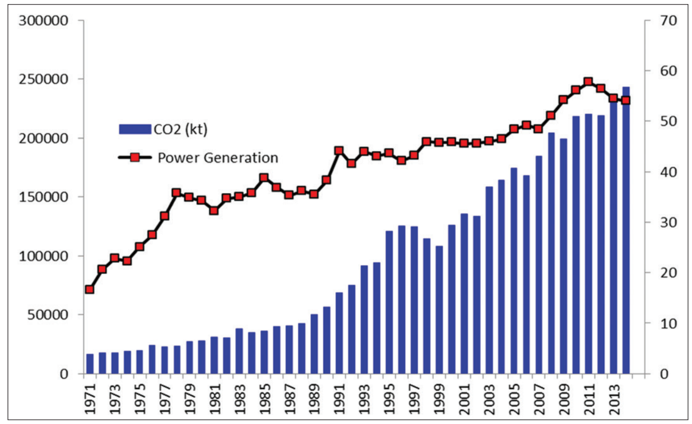


of CO_2 were released in 2008 and increased to the highest emissions in 2011 (57.70%). Total emissions were dropped at 54.03% in 2014 might be due to renewable energy generation after the introduction of national renewable energy policy and action plan, new energy policy, and 10th Malaysia plan in 2010 (Energy Commissions 2019). The carbon emission is anticipated to decrease in line with the renewables consumption in power generation. In the Ninth Malaysia plan, Malaysia targeted a situation where 300 MW (Peninsular) and 50 (Borneo) of energy is generated from renewable sources (Hashim and Ho 2011). The power generation by small hydroelectric resources also increased from 25629.78 MWh in 2012 to 68567.90 MWh in 2014. By 2018, the total power generation by small hydroelectric is expected increase to settle at 65377.23 MWh (SEDA PORTAL 2019).

5. DATA AND METHODS

Time series data such as population, GDP growth, electricity generation, and consumption were collected and extracted from Malaysia Energy Information Hub, while carbon emissions data were collected from international data sources such as World development indicators. This study considered data availability on energy in Malaysia. Thus, the data from the earliest to the latest data were chosen. The population, GDP growth, electricity generation, and electricity consumption from 1978 to 2017 and carbon emissions data from 1970 to 2014 were used (World Bank, 2019). Data were collected and analysed using IBM SPSS 22. The time series, correlation and multiple linear regressions were used to investigate the nexus among the variables. The Pearson correlation was carried out to measure the strength of linear relationship among the variables (Bluman, 2009).

Figure 6: CO_2 emissions from power generation (% fuel combustion)



The correlation can be calculated based on equation below:

$$r=\frac{n(\sum xy)-(\sum x)(\sum y)}{[n(\sum x^2)-(\sum x)^2][n(\sum y^2)-(\sum y)^2]} \quad (1)$$

If the correlation coefficient is between (−1) and (1), it shows a strong correlation, while if the value is close to (0), there is no or weak correlation (Rosenthal, 2001). Multiple linear regressions are used to assess the linear relationship between two or more continuous or categorical variables and one continuous responsive variable (Lang, 2007). A multiple regressions model may be written as equation below:

$$y = \beta_0 + \beta_1 x_1 + \beta_2 x_2 \ \beta_p x_p + \varepsilon \quad (2)$$

A stepwise technique was used as it is a combination of forward and backward techniques (Hair et al., 2010; Ho, 2013). The criteria to reject null hypothesis is forward (≤0.050) or backward technique (≥0.1000) were used (Lay and Khoo, 2009).

6. RELATIONSHIP BETWEEN POPULATION, GDP, ELECTRICITY GENERATION, CONSUMPTION AND CO_2 EMISSIONS

Table 1 indicates the relationship among population, GDP, electricity generation, electricity consumption, and CO_2 emissions from power generation to provide a clearer picture of electricity industry in Malaysia. The Pearson correlation was used to investigate the relationship among the variables. All tested variables demonstrate a positive relationship and strongly dependent to each other. The study reveals a strong relationship among electricity generation, consumption, CO_2 emissions, population, and GDP at the significant level of 0.01. Electricity generation was significantly correlated with electricity consumption (r = 0.998), CO_2 emissions (r = 0.956), population (r = 0.978), and GDP (r = 0.956). The strong correlation also indicate between electricity consumption with CO_2 emissions (r = 0.954), population (r = 0.978) and GDP (r = 0.959) at the significant level of 0.01. CO_2 emissions also indicate a strong relationship with population (r = 0.963) and GDP (r = 0.937),

Table 1: Relationship between electricity generation, consumption and power generation emissions

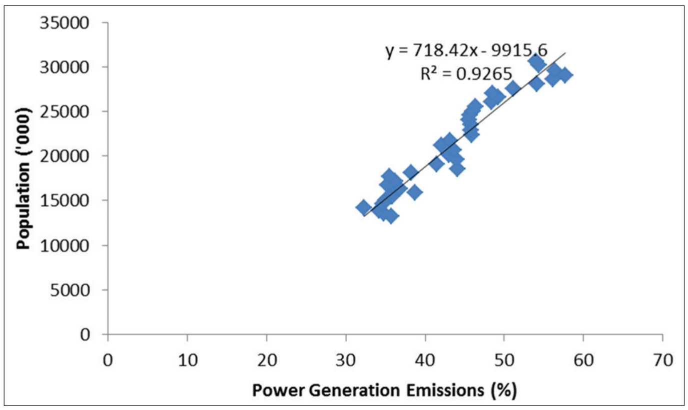
Variable	Electricity generation	Electricity consumption	CO_2 emissions	Population	GDP
Electricity generation	1				
Electricity consumption	**0.998****	1			
CO_2 emissions	**0.956****	**0.954****	1		
Population	**0.978****	**0.984****	**0.963****	1	
GDP	**0.956****	**0.959****	**0.937****	**0.982****	1

**significant at 0.01 level (2-tailed). n=37 years. GDP: Gross domestic product

Table 2: Regression model

Model	B	Standard error	Beta	t	Sig.	R^2
Constant	15.999	1.358		11.778	0.000	
Population	0.001	0.000	0.963	20.996	0.000	0.926

Figure 7: Scatter plot between power generation emissions and population



while the correlation between population and GDP also shows a strong relationship (r = 0.982).

The result reveals that greater electricity generation is driven by high electricity consumption and demand, whereas high electricity consumption contributes to greater CO_2 emissions. Furthermore, the increase in electricity generation, consumption, and emissions are influenced by the changes in population and GDP growth in Malaysia. Therefore, we concluded that electricity industry in Malaysia was highly depending on the linkage of population, GDP growth, electricity generation, electricity consumption and carbon emissions.

7. THE EFFECTS OF PREDICTORS ON CO_2 EMISSIONS IN MALAYSIA

As carbon emissions are increasing in Malaysia, it is crucial to identify the underlying factor affecting the carbon emissions particularly from sectors that produced huge amount of emissions. All variables were treated as continuous variables in the model and the conversion into dummy variables is irrelevant. Table 2 summarises the result of regressions model. In this section, the multiple linear regression analysis was used to assess the effect of predictors (population, GDP, electricity generation, and electricity consumption) on the total emissions from power generation. The result indicate that population contributed 92.6% of the variation in the carbon emissions while other predictors were not affecting carbon emissions significantly. The model shows that population was the largest and significant contributor ($\beta = 0.963$, $P = 0.000$ [$P < 0.05$]) to the carbon emissions. The result suggests that as population increases, the more carbon emissions will be released. This is because high population rate leads to high energy consumption. Furthermore, for any increment in one unit of population will generate about 0.963% of carbon emissions in Malaysia. The contribution of population on carbon emissions can be expressed in the equation below:

$$Y = 15.999\ (\text{Constant}) + 0.001\ (\text{Population}) + 1.358\ (\text{Standard error})$$

Meanwhile, Figure 7 portrays the scatter plot between power generation emissions and population in Malaysia. The data points were calculated based on linear relationship. Data points were in line with the equation line and expressed strong relationship between two variables.

8. DISCUSSIONS AND CONCLUSION

The results are discussed based on the correlation and multiple linear regressions to provide better understanding on energy and its relationship. The study indicates that the variables (GDP, population, electricity generation, consumption, and emissions) are highly dependent to each other. High electricity generation leads to high electricity consumption. The increasing electricity consumption is driven by the improvement in GDP and population which lead to greater emissions output. Begum et al. (2017) also indicated that the high rates of energy consumption lead to the high production of carbon emissions whereas high growth in GDP and population affects energy consumption. Wang et al. (2016) also explained that the urbanisation process shows a positive contribution explaining the variability of carbon emissions. They added that mega agglomeration with high population rates, insufficient public transport, and inefficient motor vehicle will generate more carbon. Meanwhile, this study also found that population is the largest predictor affecting the carbon emissions in Malaysia particularly in power generation emissions. The results from correlation and multiple linear regressions are interrelated. This is because high population leads to high electricity consumption which significantly influences the carbon emissions. Zhu and Peng (2012) also obtained similar results that there is a significant relationship between the consumption level and carbon emissions, while the impact of population size on carbon emissions considered lower. Shi (2003) also reported similar results and mentioned for any 1% increase in the population contributed 1.42% in carbon emissions. However, Begum et al. (2015) contradicts this study and mentioned that population growth has no significant effect on per capita carbon emissions, while increasing GDP will decrease carbon emissions in Malaysia. Begum et al. (2015) focused on energy consumption as a whole process which included electricity and petroleum products, while our study only focusing on electricity consumption. We found that electricity generation, consumption and emissions output in Malaysia are highly dependent on human aspect. According to these findings, it can be concluded that electricity power in Malaysia is human-dependent energy. This is in line what has been reported by Chandran et al. (2010).

This study aimed to assess the nexus of Malaysia's GDP, population, electricity generation, electricity consumption and emissions output using time series analysis, Pearson correlation and multiple linear regressions. The most important finding of the study is that population, GDP, electricity generation, consumption, and carbon emissions increased significantly. The growing trend is probably due to the increasing population and economic growth. All variables are strongly correlated with each other. This means that any increment in population, GDP, electricity generations, consumptions, and emissions are interrelated to each other. In the regressions model, the population is the predictor to the carbon emissions in Malaysia. It means that any increasing emissions output is highly dependent on the growing of population. According to these findings, it can be concluded that electrical power in Malaysia is human-dependent energy. Therefore, a more holistic policy and strategy is required to encourage sustainable resources usage, energy efficiency appliances, and raise awareness level, at the same time reducing carbon emissions towards sustainable energy consumption in Malaysia.

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