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The Green Effect: Exploring the Impact of Innovation and Foreign Direct Investment on Environmental Quality in Malaysia

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ABSTRACT

Do innovation and foreign direct investment (FDI) matter in greening the eco-system, and why not? They can lead to new technologies and knowledge, better efficient renewable energy, and reduced energy consumption; in turn this presumably reduces carbon emissions. In this study, we capture the short-and long-term impact of innovation and FDI, among other macro-variables, on the environmental quality in Malaysia using time series data over the period 1990-2020. Our empirical models find that both innovation and FDI have significant and positive impact on environmental quality in Malaysia, although it is only significant in the short-run for the first one, while significant in the long-run for the latter ones. The disappointing findings from our study is that both economic growth and urbanization show negative impact on environmental quality as CO_2 tends to increase with higher levels of GDP and urbanization. An important policy recommendation that we can draw from this paper is that Malaysian policy-makers should, and foremost, focus on designing growth and urbanization policies, regulations and procedures that are environmentally induced to achieve decoupling goal in its development path. We believe that attracting more focused FDI that supports clean and green economy, better innovations and policies to replace traditional energy with clean and renewable ones, could achieve decoupling goal that leads to a reduction in CO_2 emissions and improve environmental quality while keep growing in the world economy, including Malaysia.

Keywords: Carbon Emissions, Innovation, FDI, GDP, Environment, Malaysia
JEL Classifications: F43; F63; O11; O4; Q01; Q56

1. INTRODUCTION

The Malaysian government has been successful in attracting foreign direct investment (FDI) through policies and initiatives such as the Malaysia Investment Development Authority (MIDA), which promotes and facilitates FDI. Despite a decline in FDI inflows due to the COVID-19 pandemic, Malaysia remains an attractive destination for foreign investors due to its strategic location, skilled workforce, and business-friendly environment. In terms of FDI inflows, Malaysia received US$5.6 billion in 2020. The manufacturing and service sectors have been the key recipients of FDI, with multinational companies setting up facilities in the country. The Malaysian government has also continued to offer tax incentives, streamlined procedures for investment, and improved infrastructure to encourage FDI (Ridzuan et al. 2018a). However, challenges remain in terms of reducing dependence on certain sectors, addressing concerns related to foreign ownership and control, and managing environmental and social impacts. Innovation plays a crucial role in Malaysia's economic development alongside FDI. By promoting innovation, Malaysia can attract more foreign investment in high-tech industries, which will help to reduce its dependence on certain sectors and diversify its economy. Therefore, the Malaysian government should also invest in research and development and provide support to local startups and SMEs to foster innovation and technological advancement in the country.

Foreign investment and innovation can both have significant impacts on the environment. While foreign investment can bring new technologies and knowledge that lead to more sustainable production practices, it can also result in increased environmental degradation if investors prioritize profits over environmental concerns. Thus, being one of the favored investment destinations among ASEAN countries, it is imperative to investigate the impact of FDI inflows on environmental quality in Malaysia. Similarly, innovation can lead to more sustainable practices, but its relationship with CO_2 emissions needs to be studied more comprehensively in the context of Malaysia. Host countries should enforce strict environmental regulations and standards and promote sustainable investment practices through incentives and collaboration with local communities and firms. The need to investigate the impact of FDI on environmental quality is also being addressed by recent researcher such as Ridzuan et al. (2017); Ridzuan et al. (2018b); Ridzuan et al. (2022); Pujiati et al. (2023); and Shaari et al. (2022);

In recent years, there has been an increased interest in investigating the relationship between innovation and CO_2 emissions, particularly in the context of various countries (Nikzad and Sedigh, 2017). However, limited attention has been paid to this relationship in the context of Malaysia. While previous studies have investigated the correlation between "green" patents and CO_2 emissions in various countries, they have primarily focused on a specific set of patents related to emissions capture, as demonstrated by Du et al. (2019) and Su and Moaniba (2017). In contrast, our study takes a more holistic approach by analyzing the relationship between all types of patents and CO_2 emissions in Malaysia, offering a more comprehensive understanding of the interplay between innovation and the environment in this specific context. We maintain that this approach can contribute significantly to the development of sustainable strategies and policies in Malaysia, which faces significant environmental challenges. The goal of this research is to investigate the impact of innovation, foreign direct investment and other potential macroeconomics variables that can influence the level of environmental quality in Malaysia. Using time series data over the period 1990-2020, we document that both innovation and FDI have significant and positive impact on environmental quality in Malaysia, although it is only significant in the short-run for the first one, while significant in the long-run for the latter ones. In contrast, our study shows that both economic growth and urbanization increase carbon emissions. We conclude by advising Malaysian policy-makers build their growth and environmental policies based on decoupling concept that leads to a reduction in CO_2 emissions and improve environmental quality while achieving economic growth.

The reminder of paper is organized as follows: In section two, we provide a comprehensive literature review, which serves as the foundation for the subsequent sections. Detailed research methodology is presented In section 3 along with data collection, analysis, and interpretation. We then present and discuss the results of the empirical models in Section four, and Section five concludes the paper with a summary of the key findings and relevant policy implications.

2. LITERATURE REVIEW

Malaysia happens to be one of the biggest and fastest-growing economy in the Southeast Asian region. The last few decades of the Malaysian Economy have seen large population growth coupled with Industrialization and urbanization, which has been continuously putting pressure on energy consumption. The resultant carbon emissions have been a cause of worry for policymakers.

In the recent past, numerous studies have been carried out to investigate the role of economic growth and carbon emissions. The role of economic growth (GDP) on carbon emissions has been discussed in detail for Malaysia by various studies (Ali et al., 2020; Awan et al., 2022; Azlina et al., 2014; Begum et al., 2015; 2020; Farabi et al., 2019; Gul et al., 2015; Heidari et al., 2015; Fong et al., 2008; Lau et al., 2014b; Loganathan et al., 2014; Raihan and Tuspekova, 2022; Saboori et al., 2012; Saidur et al., 2007; Zhu et al., 2016).

Similarly, the role of energy use, demand, and consumption (renewable vs. non-renewable energy) has been explored in many studies (Ali et al., 2020; Azlina et al., 2014; Begum et al., 2015; Chandran and Tang, 2013; Farabi et al., 2019; Gul et al., 2015; Fong et al., 2008; Raihan and Tuspekova, 2022; Saidur et al., 2007; Shahbaz et al., 2015; Sharif Hossain, 2011; Zhu et al., 2016).

The role of energy consumption in economic growth resulting in environmental degradation has been widely explored. Now, there has been a focus on the use of renewable energy for a clean environment.

Different studies have investigated how various factors can influence and impact carbon emissions. Many of them have either considered Malaysia in the region-specific studies like OECD, South Asian, Asian, ASEAN etc. Many other studies have selectively looked at Malaysia in isolation to analyse how the carbon emission is affected in presence of certain factors which either intensify it or help to reduce it. But there exist very few studies which have looked at most of the parameters like - the role of Economic Growth (GDP), Foreign Direct Investment (FDI), Trade openness (TO), Innovation (INV), Urbanization (URB), Renewable Energy (RE) on the carbon emissions for the developing country like Malaysia.

2.1. Parameters Affecting the CO_2 Emissions

2.1.1. Trade openness

Studies suggest mixed evidence and offer different views over role of trade openness and carbon emissions. Some scholars argue that more free trade agreements give rise to higher economic growth which result into high carbon emissions. While others opine that technology transfer can boost trade through cleaner technologies adoption and reduce carbon emissions (For example; Ertugrul et al., 2016; Lau et al., 2014a; Nurgazina et al., 2021; Ridzuan et al., 2018b; Shahbaz et al., 2015, 2016; Sharif Hossain, 2011; Sohag et al., 2015; Solarin and Shahbaz, 2015).

2.2. Urbanization

Industrialization gives rise to urbanization which creates a pressure on the urban areas through higher energy demand, transportation, industrial factory clusters, and poor urban dwellings which put pressure on the environment by use of more fossil fuels and higher carbon emissions (Awan et al., 2022; Bekhet and Othman, 2017; Ridzuan et al., 2018b; Shahbaz et al., 2015, 2016; Sharif Hossain, 2011; Udemba et al., 2022).

2.3. Innovation

Environmental innovations help in reducing the energy consumption through the use of cleaner technologies which further reduce carbon emissions. They can take place in form of renewable energy developments, energy efficient buildings and electric vehicles, deploying Carbon capture and storage (CCS) technologies for industrial clusters and power plants etc, which play crucial role in environmental quality preservation (Ali et al., 2016; Chen and Lee, 2020; Erdoğan et al., 2020; Raihan et al., 2022; Saudi et al., 2018; Suki et al., 2022; Zhang et al., 2017).

The table below (Table 1) presents some of those notable studies which has focused upon Malaysia.

3. METHODOLOGY

The functional form of the environmental quality model for Malaysia is obtained through the following general procedure:

$$CO2_t = f(GDP_t, FDI, TO_t, INV_t, URB_t, RE_t) \quad (1)$$

Where

CO_{2t} represents environmental quality,

GDP_t represents economic growth,

FDIt represent foreign direct investments inflows,

TOt represents trade openness,

$LINV_t$ represents innovation,

URB_t represents urbanisation,

RE_t represents renewable energy

The variables have been carefully selected based on the model introduced in the previous studies. However, to the best of our knowledge, the set of the variables as listed in equation 1 is being applied for the 1st time in the context of Malaysia.

To estimate the short-run and long-run elasticities, the variables in equation 1 are transformed into log-linear forms (LN). This transformation is known to produce consistent and reliable estimations, as stated by Shahbaz et al. (2010). Therefore, the log version of Equation 1 is obtained as follows:

$$LNCO2_t = \delta_0 + \alpha_1 LNGDP_t + \beta_2 LNFDI_t + \sigma_3 LNTO_t + \phi_4 LNINV_t + \lambda_5 LNURB_t + v_6 LNRE_t + \mu_t \quad (2)$$

$$\begin{aligned}\Delta LNCO2_t = {} & \beta_0 + \theta_0 LNCO2_{t-1} + \theta_1 LNGDP_{t-1} + \theta_2 LNGDP^2{}_{t-1} + \\ & \theta_3 LNDI_{t-1} + \theta_4 LNFDI_{t-1} + \theta_5 LNENY_{t-1} + \theta_6 LNTO_{t-1} \\ & + \theta_7 LNINF_{t-1} + \sum_{i=1}^{a} \beta_i \Delta LNCO2_{t-i} + \sum_{i=0}^{b} \gamma_i \Delta LNGDP_{t-i} \\ & + \sum_{i=0}^{c} \delta_i \Delta LNGDP^2{}_{t-i} + \sum_{i=0}^{d} \lambda_i \Delta LNDI_{t-i} + \\ & \sum_{i=0}^{e} \vartheta_i \Delta LNFDI_{t-i} + \sum_{i=0}^{f} \psi_i \Delta LNENY_{t-i} + \\ & \sum_{i=0}^{g} \tau_i \Delta LNTO_{t-i} + \sum_{i=0}^{h} \vartheta_i \Delta LNINF_{t-i} + \upsilon_t \end{aligned} \quad (3)$$

The ARDL model based on the Unrestricted Error Correction Model (UECM) is stated below:

In Equation (3) above, the first difference operator (Δ) is used to capture the short-run effects, and ut represents the white-noise disturbance term. For the UECM model to be valid, its residuals should be serially uncorrelated, and the model should be stable. Diagnostic tests are used to validate these assumptions, as shown in the analysis section.

Table 1: Previous literature studies on Malaysia

No.	Authors	Variables	Methodology	Time period	Outcome
1.	Raihan et al., 2022	CO_2, GDP, RE, TI	DOLS method	1990-2019	RE and TI reduces CO_2
2.	Suki et al., 2022	CO_2, ecological footprint. TI, RE	Bootstrap ARDL approach	1980-2018	Both RE and TI reduce CO_2
3.	Ali et al., 2016	EC, GDP, TI, M2	ARDL	1985 and 2012	TI has negative relationship on environment
4.	Saudi et al., 2018	CO_2, RENE, ENC, Y and INO	ARDL	1980-2017	Both RE and TI reduce CO_2
5.	Ali, 2020	Population, GDP, Electricity Generation, Consumption And CO_2	multiple regressions model	1970-2014	Population plays important role in CO_2 emissions
6.	Bekhet and Othman, 2018	CO_2, RE and GDP	VECM Granger causality	1971-2015	inverted N-shaped EKC hypothesis is confirmed
7.	Awan et al., 2022	CO_2, urbanization and GDP	Quantile ARDL, KRLS	1965-2018	U-shape linkage between urbanization and the environment

The final version of the model in Equation (3) can also be viewed as an autoregressive distributed lag (ARDL) model of order (a, b, c, d, e, f, g, h, i). The model suggests that environmental degradation ($LNCO_2$) is influenced by its past values and other disturbances or shocks.

The long-run elasticity can be calculated by dividing the coefficient of the one lagged explanatory variable (multiplied by a negative sign) by the coefficient of the one lagged dependent variable. The short-run effects are captured by the coefficients of the first differenced variables.

The null hypothesis of no co-integration in the long-run relationship is represented by:

H_0: $\theta_0=\theta_1=\theta_2=\theta_3=\theta_4=\theta_5= \theta_5=\theta_6=0$ (there is no long-run relationship), is tested against the alternative of

H_1: $\theta_0\neq\theta_1\neq\theta_2\neq \theta_3\neq\theta_4\neq\theta_5\neq\theta_6\neq\theta_7\neq 0$ (there is a long-run relationship exists),

The F-test is a commonly used method to determine the existence of co-integration in the long-run relationship. If the calculated F-statistic is less than the critical value of the lower bound, the null hypothesis of no co-integration cannot be rejected. However, if the calculated F-statistic exceeds the critical value of the upper bound, at a minimum of 10% significance level, the null hypothesis of no co-integration is rejected.

This study utilized annual data from 1990 to 2020 (30 years) as the sample period, and Table 2 provides a summary of the data and its sources.

Table 2: Sources of data

Variables	Description	Sources
$LNCO_2$	CO_2 emissions (metric tons per capita)	WDI
LNGDP	GDP per capita (constant 2015 US$)	WDI
LNFDI	Foreign direct investment, net inflows (% of GDP)	WDI
LNTO	Trade (% of GDP)	WDI
LNINV	Patent (Domestic+International/Population)	WDI
LNURB	Urbanization	WDI
LNRE	Renewable energy	WDI

WDI stands for World Development Indicator 2022

4. EMPIRICAL RESULTS AND DISCUSSION

In Table 3, the ADF and PP unit root tests were employed to assess the stationarity of all variables. The results indicate that, with the exception of $LNCO_2$ and LNINV, most variables are not significant at the given level. $LNCO_2$ and LNINV are found to be stationary at the 1% significance level. All variables exhibit stationarity at the first difference level in both ADF and PP unit root tests, except for LNRE. Based on the results of these tests, it can be concluded that the data is a mix of stationary and non-stationary. These unit root tests provide support for conducting the cointegration analysis using ARDL estimation.

To confirm the existence of a long-run relationship in the ARDL model, an ARDL cointegration test based on F-statistic was conducted. As shown in Table 4, the bound test's F-statistic is 4.634, which is significant at the 1% level. This result confirms the presence of a long-run relationship in the model, and the null hypothesis is rejected in favor of the alternative hypothesis for the bound test.

The study's primary findings are presented in Table 4, which outlines the long-term elasticity of the proposed model's variables and their impact on environmental quality in Malaysia.

Table 3: Unit root test results

Variable	ADF unit root Ttst			
	Intercept		Intercept+Trend	
	Level	1st Difference	Level	1st Difference
$LNCO_2$	−1.977 (0)	−5.847 (0)***	−3.474 (4)*	−5.832 (0)***
LNGDP	−0.389 (0)	−1.577 (0)	−3.827 (0)***	−3.737 (0)**
LNFDI	−1.900 (0)	−2.854 (3)	−4.860 (0)***	−4.784 (0)***
LNTO	−1.552 (0)	−2.068 (1)	−5.508 (1)***	−5.758 (1)***
LNINV	−2.712 (0)*	−2.897 (0)	−6.581 (0)***	−6.560 (0)***
LNURB	−0.389 (0)	−2.266 (0)	−5.519 (0)***	−5.411 (0)***
LNRE	−1.112 (0)	−1.846 (0)	−1.932 (0)	−1.415 (0)
Variable	**PP Unit root test**			
	Intercept		Intercept+Trend	
	Level	1st Difference	Level	1st difference
$LNCO_2$	−2.174 (7)	−4.590 (8)***	−9.519 (28)***	−12.576 (28)***
LNGDP	−0.389 (0)	−1.774 (1)	−3.740 (3)***	−3.643 (3)**
LNFDI	−2.095 (2)	−2.172 (1)	−4.860 (0)***	−4.784 (0)***
LNTO	−1.299 (3)	−2.703 (2)	−7.461 (0)***	−9.085 (4)***
LNINV	−2.603 (3)	−2.857 (1)	−6.881 (4)***	−7.034 (6)***
LNURB	−0.340 (3)	−2.348 (1)	−5.593 (4)***	−5.480 (4)***
LNRE	−1.177 (2)	−1.846 (0)	−1.939 (1)	−1.415 (0)

***, ** and * denote significance at 1%, 5% and 10%, respectively

The analysis revealed that LNGDP, LNFDI, and LNRE have a significant long-term impact on environmental quality, while LNTO, LNINV, and LNURB do not. The study finds that a 1% increase in LNGDP leads to a 1.81% increase in carbon emissions. This result aligns with previous studies conducted in Malaysia such as Ridzuan et al. (2019). Additionally, LNFDI and LNRE is found to have a negative relationship with $LNCO_2$, with a 1% increase in LNFDI and LNRE resulting in a reduction of carbon emissions by 0.216% and 0.207%, respectively. The study also reveals evidence supporting the Pollution Halo Hypothesis (PHH), which suggests that higher foreign investment could bring cleaner technologies to the host country, resulting in lower carbon emissions levels. Previous studies, such as Ridzuan et al. (2022) and Ridzuan et al. (2018), support this argument; in which the use of renewable energy, such as solar, hydro, and biomass, is found to decrease carbon emissions levels and align with the country's sustainable development goals. This finding is supported by previous studies, such as Voumik et al. (2023a; 2023b), Yusoff et al. (2023), Shaari et al. (2021), Borhan et al. (2021), and Kumaran et al. (2020).

The short-run elasticities of the model are presented in Table 5. The results show that LNGDP has a positive relationship with $LNCO_2$ in the short run, and a 1% increase in LNGDP leads to a 1.399% increase in carbon emissions, which is slightly lower than the magnitude of the long-run elasticities. LNURB also exhibits a positive and significant relationship with $LNCO_2$. The increase in the rate of urbanization has led to the expansion of development areas through deforestation, resulting in higher environmental degradation. In contrast, LNTO and LNINV have a negative relationship with $LNCO_2$. A higher degree of trade liberalization and a larger number of patents representing the adoption of green technology can reduce carbon emissions by 0.149% and 1.242%, respectively. The error correction term (ECT) has a negative and significant relationship, indicating that all the variables tested in the model will converge in the long run. This is important because it suggests that the policy recommendations made in this study are practical and reliable.

After conducting the analysis, we perform various diagnostic tests to ensure the validity of the model's output. Table 7 confirms that the proposed model has no serial correlation, normality issue, or heteroscedasticity effect in disturbances. Furthermore, the model's specifications are well specified, as evidenced by the P-values of all tests being greater than the 10% significance level. Passing all diagnostic tests allows us to have greater confidence in the reliability of both the short and long-run elasticities estimated by the model.

To ensure the reliability of the model, CUSUM and CUSUMSQ tests were performed following the methodology proposed by Brown et al. (1975). Both the CUSUM and CUSUMSQ graphs confirm that the model is structurally stable at a 5% significance level. This is indicated by the blue line remaining between the two dotted red lines, which indicates that the parameters of the

Table 4: Bound test

Lag model: (2, 0, 2, 2, 1, 2, 2)		
F-statistic	4.634***	Upper bound
Critical value	Lower bound	
10%	2.12	3.23
5%	2.45	3.61
1%	3.15	4.43

*** denotes significance at 1%

Table 5: Long-run estimation results

Variable	Coefficient	Standard error	t-statistic	Prob
LNGDP	1.818141	0.707358	2.570328	0.0260
LNFDI	−0.216335	0.111958	−1.932291	0.0795
LNTO	0.003395	0.183739	0.018476	0.9856
LNINV	−0.058709	0.078988	−0.743265	0.4729
LNURB	0.935115	0.656466	1.424469	0.1821
LNRE	−0.207834	0.089782	−2.314876	0.0409
C	−13.840003	5.868812	−2.358229	0.0379

***, ** and * denote significance at 1%, 5% and 10%, respectively

Table 6: Short-run estimation results

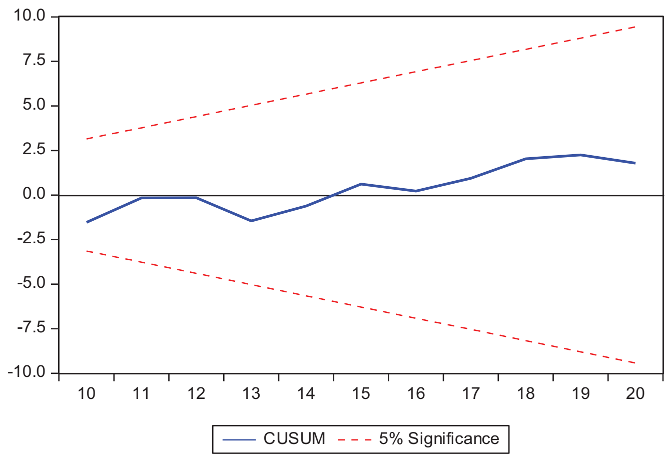
Variable	Coefficient	Standard error	t-Statistic	Probability
$\Delta LNCO_2$-1	0.357457	0.155366	2.300743	0.0420
ΔLNGDP	1.399781	0.231041	6.058587	0.0001
ΔLNFDI	0.005314	0.020754	0.256071	0.8026
ΔLNFDI-1	0.092337	0.027382	3.372126	0.0062
ΔLNTO	−0.161583	0.069384	−2.328827	0.0400
ΔLNTO-1	0.149245	0.090921	1.641482	0.1290
ΔLNINV	−0.149940	0.052076	−2.879257	0.0150
ΔLNURB	1.242071	0.432171	2.874025	0.0151
ΔLNURB-1	0.585269	0.192663	3.037784	0.0113
ΔLNRE	0.043694	0.031210	1.399986	0.1891
ΔLNRE-1	−0.133865	0.097419	−1.374116	0.1968
ECT	−0.769897	0.247281	−3.113450	0.0099

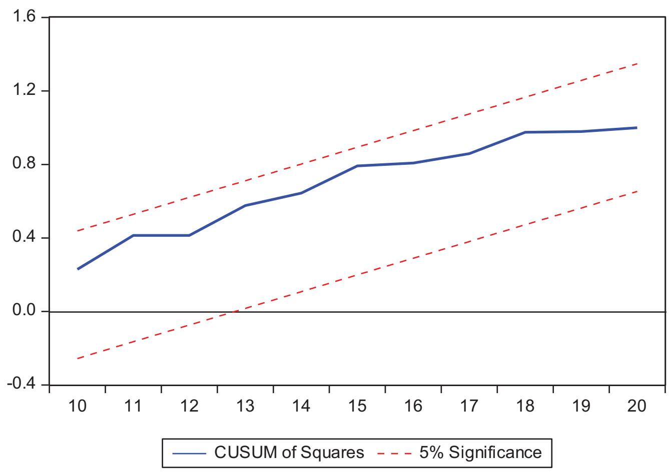
***, ** and * denote significance at 1%, 5% and 10%, respectively

Table 7: Diagnostic tests results

Test statistic	F-statistic	Probability
Breusch-Godfrey serial correlation LM	2.966	0.109
Ramsey reset stability	0.046	0.834
Heteroscedasticity	0.652	0.792
Jarque-Bera	1.7805	0.410

model are constant over time. Therefore, we can conclude that the model's goodness is ensured, and its results are reliable.





5. CONCLUDING REMARKS AND SOME POLICY IMPLICATIONS

It is argued that economic growth and urbanization could lead to higher greenhouse emissions. So how to achieve sustainable development goals and the 2015 Paris agreement target on climate change without ditching economic growth. In other words, can we reduce greenhouse emissions while keep growing? The matter of the fact is that linkage implies that efforts to deep greenhouse emission reductions will constrain economic growth; unless countries put in place right policies to target decoupling concept that implies a deep emission reduction is possibly achievable with little or neutral effect on economic growth.

In this study, we look at Malaysian experience in the past 30 years (1990-2020) to investigate the growth dynamics and to test the short-and long-term impact of innovation and FDI, among other macro-variables, on the environmental quality in Malaysia. We first find that economic growth (in both short-and long-term) and urbanization (short-term) lead to higher carbon emissions in Malaysia. On average, one percent increases in economic growth leads to 1.4 and 1.8 increases in carbon emissions in short-and long-term; respectively. On the other hand, FDI and renewable energy are found to be positive and significant with carbon emissions in the long-term model, while innovation has significant positive impact on carbon emissions in the short-term. The policy implication from the findings is that Malaysia should encourage further FDI, Innovations, trade openness and research and development towards renewable energy. Policymakers should then change the growth dynamic and the eco-system to adopt decoupling concept toward achieving reduction in carbon emissions without negative impact on economic growth. For instance, other than tax incentives, subsidies and grants to spur growth of renewable energy sector, Malaysia can negotiate free trade agreements with countries that are leading with renewable energy technology, thus allowing for greater access to new technology and markets for renewable energy products. Besides, Malaysia's government could also establish innovation hubs that can attract high-end research and development centres to conduct research on renewable energy. It indirectly encourages more collaboration between industrial players, academics and government to exchange knowledge, ideas and technology. Furthermore, a favourable environment is a must to promote environmental sustainability that can spur economic growth in the long run. Malaysia can position itself as a leader in the renewable energy sector in ASEAN's continent if more investors in renewable energy sector prefer to invest in Malaysia due to favourable and less bureaucracy environment.

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