

## Article

# Asymmetric Impact of Institutional Quality on Environmental Degradation: Evidence of the Environmental Kuznets Curve

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**Abstract:** This paper aims to discover the asymmetry impacts and co-integration between gross domestic product, financial development, energy use and environmental degradation by featuring institutional quality covering the Malaysia economy during the period from 1984 until 2017 using a nonlinear auto-regressive distributed lag model. The results confirm the existence of the Environmental Kuznets Curve hypothesis for both linear and nonlinear analyses, thus verifying the relevance of symmetric and asymmetric EKC hypotheses for Malaysia. Further, this study verifies the attributes of financial development and institutional quality that mitigates the concern on CO<sub>2</sub> emissions, but contradicting results were produced on energy use. The implication of this finding provides new guidelines for Malaysia authorities to consider the asymmetries in formulating environment-related policies to maintain environmental quality and achieve their sustainable development goals.

**Keywords:** Environmental Kuznets Curve; carbon dioxide emissions; environmental degradation; financial development; energy use; institutional quality



**Citation:** Abd Razak, F.D.; Khalid, N.; Ali, M.H. Asymmetric Impact of Institutional Quality on Environmental Degradation: Evidence of the Environmental Kuznets Curve. *Sustainability* **2021**, *13*, 12507. <https://doi.org/10.3390/su132212507>

Academic Editor: Bertrand Hamaide

Received: 19 October 2021

Accepted: 8 November 2021

Published: 12 November 2021

**Publisher's Note:** MDPI stays neutral with regard to jurisdictional claims in published maps and institutional affiliations.



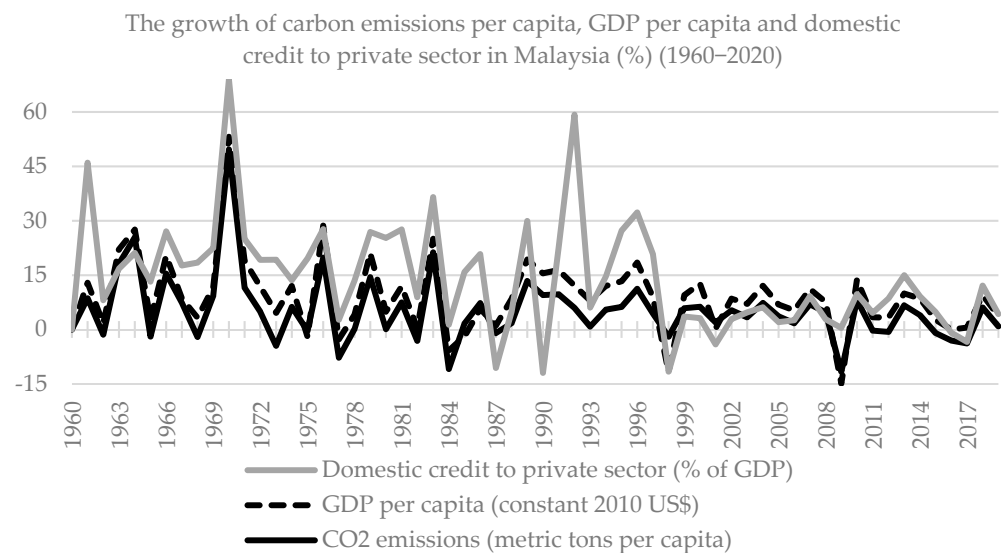
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## 1. Introduction

Economic growth is the crucial objective of developing countries because it is the greatest indicator for eradicating poverty and in increasing the quality of life. The challenge for countries is to combine economic growth policies with sustainable development strategies. Much emerging evidence has revealed significant positive relationships between economic growth and environmental deterioration, especially in developing countries [1]. According to the Environmental Kuznets Curve (EKC) hypothesis, developing countries are at the beginning of the development stage and offer cheap labour, transportation, and trading cost, which together with lenient environmental standards tends to create a pollution haven [2]. The impact of environmental deterioration may only decrease with economic growth. Energy use is considered to be a necessary feature of economic growth in developing countries, where almost 89% of cumulative energy needs are fulfilled by non-renewable energy such as petroleum and natural gas. The development trend poses a serious threat to sustainable development because of its contribution to greenhouse gases (GHG) emissions.

Over the last 30 years, Malaysia has experienced robust economic growth rates and an extraordinary level of financial development among the developing countries. Unfortunately, Malaysia is paying the cost for these tremendous economic and financial development activities in the form of environmental deterioration. For instance, the annual growth rate of carbon emission has gone up at least 6% from 2000 until 2019, thus making the country highly prone to the dangers of climate change and pollution. The growth of GDP and carbon emissions per capita in Malaysia for the year 1960 to 2020 is shown in Figure 1. Both indicators appear to move in tandem over that period, and

both similarly showed a marked decline in 2020 due to the Coronavirus pandemic [3]. In the Paris Agreement of 2015, Malaysia has pledged to cut 45% of its GHG emissions intensity against the GDP by 2030, as compared to the emission intensity and GDP in 2005. This transition requires not only wider implementation of greener technologies but also substantial financial, institutional, and behavioural changes.



**Figure 1.** Annual growth rate of CO<sub>2</sub> emission per capita, GDP per capita and domestic credit to private sector (1960–2020); Source: Author’s own calculation based on data from World Bank.

Amidst the danger of global warming, numerous possible solutions have been identified, including the development of the financial system, uncompromising government regulations, adoption of technological innovation, renewable energy and increasing efficiency. The development of the financial sector can harmonize pollution abatement efforts and affect the dynamics of environmental quality through mobilization and utilization of funds. A healthy financial system provides better access to financial services, and this will decrease the cost of doing business. A stable financial system is essential for smooth transaction in economic activities and facilitates trading activities which lead to greater economic growth. Numerous empirical researches have highlighted the significance of financial development in preserving the environment through judicious allocation of financial resources, especially on improving research and development and eco-friendly projects. Moreover, financial development has been reported, supported by empirical evidence, to play a significant role in adoption of greener technologies, thus mitigating the environmental impacts of economic growth in the case of China [4], Japan, Korea, Singapore [5], and several developing countries [6]. Similarly, the importance of financial development has also been highlighted; namely, in nurturing good governance in encouraging firms to adopt environmentally friendly projects that can simultaneously reduce pollution [7]. It is also important to emphasise that in the development of the financial sector, the consequent enhancement of economic growth harbours potential capability to cause irrevocable harm to the environment. Adopting a systematic financial system will ease the liquidity process that may lead to higher investment opportunities and low borrowing costs which consequently encourage firms to increase production, hence resulting in high energy demand and eventually increased rate of carbon emission [8].

Second is the role of institutional quality which has been more widely emphasized in the context of the analysis factors influencing financial development but not in the framework of finance-emission nexus. Institutional quality constitutes a key determinant of a country’s economic and financial development as it ensures capital allocation to the most efficient investment especially in environmentally friendly development projects. High quality institutions create an ecosystem where all parties have the capacity to effectively

play their role in protecting the environment. For example, environmental quality can be expected when local governments are able to implement environmental regulations effectively. In other words, a high institutional quality, comprised of sturdy corporate governance, effective control of corruption, strong monitoring of a stable banking system and easily accessible financial information, is expected to set an environmentally friendly standard for financial development. The Environmental Performance Index (EPI) is used to measure the proximity of a country to establishing environmental policy targets and the country's achievement in addressing environmental pollution [9]. In 2020, Malaysia ranked 68th from 180 countries on the EPI ranking and 53rd out of 61 countries on greenhouse gas (GHG) emissions by the Climate Change Performance Index (CCPI) [10]. From this, perspective policy space is considered important in the overall effort to alleviate pollution.

This study investigates the impact of economic growth, financial development, institutional quality, and energy use on carbon emissions in the case of Malaysia for the year 1984 until 2017. Based on the EKC hypothesis, there is a nonlinear relationship between economic growth and carbon emissions, and it can be illustrated by an inverted U-shaped curve. This hypothesis has been backed up by numerous numbers of scholars [1,2,4–6,11–13]; hence, it motivates this study to validate the presence of the same hypothesis in Malaysia. Moreover, as seen in Figure 1, there were similar trends of growth between economic growth and carbon emissions in Malaysia. Since 1984, Malaysia's annual economic growth is at five percent on average, and it endured uninterrupted except for financial crises that hurt the country in 1999 and 2009, and recently in 2020–2021 with the shocks of the coronavirus pandemic. Nevertheless, there is a clash between these two objectives—increasing economic growth against lowering carbon emissions—and this conflict is exacerbated when it concerns energy use as it acts as an engine of growth. In this condition, countries will be hesitant to mitigate carbon emissions and moderate energy use for the sake of economic growth. Therefore, scholars and authority have been discovering attributes to achieve these two objectives without deteriorating the environment. Malaysia also is a common example of this condition because its energy consumption is from non-renewable energy sources, especially petroleum and natural gas, while maintaining its persistent economic growth.

As has been discussed above, financial development and institutional quality have been identified to curb carbon emissions in the literature review. An apparent reason for this study to use financial development as a significant attribute in describing carbon emissions is that the occurrence of healthy and stable financial sectors may support in the financing of environmentally friendly technologies, attracting economic agents to participate in environmentally friendly projects, hence helping the country to embracing a cleaner energy consumption system [4–8]. In the utmost pertinent literature to this study, Lv and Li [4] have utilized data from developing countries, and they brightly claim that healthy financial sectors lead to a lower carbon emission. This finding inspires this study to obtain 'domestic knowledge' systematically on how financial development can mitigate carbon emissions in the case of Malaysia by considering the strong growth in Malaysian financial systems. However, the strong financial system needs to be supported by healthy government institutions. As claims by Khan et al. [7], institutional quality plays a dynamic role in affecting financial development and environmental quality as it prevents the misuse of resource allocations. Furthermore, a weak government might dampen economic growth and the implementation of environmental policies. Thus, these arguments have motivated this study to validate the integration of carbon emissions, economic growth, energy use, financial development, and institutional quality in the case of Malaysia.

This study addressed a few knowledge gaps in the literature on the implication of financial development on carbon emissions. First, this study contributes to the literature on the finance–emissions nexus by incorporating the interaction of institutional quality. With reference to the past literature, this study contends that financial development alone is insufficient to promise a better quality of environment unless it is complemented with a sound quality of the relevant institutions. Compared to earlier reports, this study exclusively

focuses on Malaysia where empirical literature on drivers of environmental deterioration is notably lacking. Likewise, literature that deliberates on carbon emission is equally limited in the Malaysia context, thus rendering the support for the EKC hypothesis inconclusive. Second, Malaysia's institutional quality may be able to shed its lights in explaining the performance of the domestic financial system in the environmental context. Third, this study is proposing a fresh dimension in the political economic perspectives regarding the finance–emissions nexus. The Non-Linear Autoregressive Distributed Lag (NARDL) was employed to confirm the effects of carbon emissions, financial development, institutional quality, and energy use, either as causality or as asymmetric influence. In this respect, the NARDL method on either a short- or long-term basis may be able to investigate the asymmetric impacts of finance–emissions, especially on a developing country like Malaysia. Furthermore, the classic EKC hypothesis may lead to a biased outcome because it focuses only on economic factors but overlooks the institutional elements which are widely considered as the pillars of economic development. From the indeterminate nature of findings in the literature, information on the effect of different proxies of institutional quality on the nexus of finance–emissions is decidedly scarce. Fourth, this motivates in-depth analyses of individual countries, such as Malaysia, rather than as multiple countries, thus enabling a more feasible outcome in contributing to the development of national policies.

This paper is organised as follows: Part 1 provides the introduction. Part 2 reviews the related literature and deals with development of hypotheses. Part 3 discusses the estimation models and Part 4 deals with the source of data, variables, and the estimations. Part 5 deliberates on the empirical results and Part 6 presents the conclusions and policy implications.

## 2. Literature Review

The relationship between economic growth, financial development, institutional quality, and energy use with carbon emissions is investigated in the study. The four sections of the extant literature and relationship between variables organized in this section on the review are as follows: (1) carbon emission and economic growth, (2) carbon emission and financial development, (3) institutional quality and emission nexus, and (4) carbon emissions and energy use. Additionally, the literature analysis will focus on the Malaysia setting as a developing country.

Fundamentally, the EKC hypothesis stands for the following: At first, an increase in income per capita of a country will deteriorate environmental quality, and after that, any further increase in income per capita will improve environmental quality. This mixed relationship between income per capita and environment quality has been validated by a mushrooming number of studies by applied econometricians that mirrors the pioneer study of Grossman and Krueger [14]. Even though these studies aim to validate the EKC hypothesis, the results are deferred due to the methodologic approaches, selection of the data and variables, location of studies, and time. There are two types of analysis that are commonly used, which are time series analysis and panel data analysis. Time series analysis is referring to investigations on individual country, and panel data analysis is referring to investigation of multiple countries with similar characteristics. Based on Table 1, the methodologic approaches have an extensive variety—for instance, and Fully Modified OLS (FMOLS) [6], Autoregressive Distributed Lag (ARDL) [15–17], Vector Error Correction Method (VECM) [16,17], and Dynamic Ordinary Least Square (DOLS) [18,19], This study employs ARDL as it is beneficial for the analysis of long-term relationships from the dynamics of short-term.

**Table 1.** Summary of the literature on finance–emissions nexus.

References	Country/Period	Empirical Model/Methods	Financial Development Proxies	Results	EKC Hypothesis
[6]	34 upper middle-income developing countries	FMOLS, Kao cointegration	Domestic credit provided by the financial sector. Domestic credit to the private sector by banks.	<b>Long-run:</b> FD on RE (positive effect) GDP on RE (negative effect) CP on RE (no effect)	Not tested
[15]	China (1994–2016)	ARDL-ECM	Sum of total assets and liabilities in foreign countries as a share of GDP.	<b>Short-run:</b> FD and GDP on CO <sub>2</sub> (positive effect) URB on CO <sub>2</sub> (negative effect) <b>Long-run:</b> FD and GDP on CO <sub>2</sub> (positive effect) URB on CO <sub>2</sub> (negative effect)	No
[16]	United Arab Emirates (1975–2011)	ARDL, VECM, Granger causality	Domestic credit to private sector	FD, ELC, URB, TRD improves EQ	Yes
[17]	India (1990–2018)	ARDL, VECM, Gregory-Hansen cointegration	Domestic credit to the private sector as a GDP share	<b>Short-run:</b> ELC and GDP on CO <sub>2</sub> (positive effect) FD on CO <sub>2</sub> (no effect) <b>Long-run:</b> FD on CO <sub>2</sub> (negative effect) EC on CO <sub>2</sub> (positive effect) ELC and GDP on CO <sub>2</sub> (positive effect) GDP <sup>2</sup> and ICT on CO <sub>2</sub> (negative effect)	Yes

Notes: EQ (Environmental Quality), SO<sub>2</sub> (Sulphur Dioxide Emissions), CO<sub>2</sub> (Carbon Dioxide Emissions), FD (Financial Development), RD (Research and Development), SUR (Seemingly Unrelated Regression), GDP (Per Capita GDP), TRD (Trade Openness), URB (Urbanization), ELC (Electricity consumption), ICT (Information Communication Technology), RE (Renewable energy), CP (Consumer Price), ARDL (Autoregressive Distributed Lag), ECM (Error Correction Method), VECM (Vector Error Correction Method), FMOLS (Fully Modified Ordinary Least Square).

### 2.1. Carbon Emission and Economic Growth

Based on the EKC hypothesis, economic growth and the environment is a dual dichotomous nature in which at the beginning, growth will deteriorate the environment quality but will subsequently improve it upon reaching and surpassing a certain threshold level. Most recently, Noda [20] conducted an inclusive literature survey and concluded that the results of EKC empirical research is rather mixed and contradictory due to differences in explanatory variables, the choice of models and time. This implies that in the context of the EKC hypothesis, one size does not fit all. Numerous scholars have supported the EKC hypothesis [21] while others did not [22,23]. The EKC literature commonly treated income per capita as a proxy for economic growth and in the form of either linear, quadratic, or cubic relationship. He and Lin [24] and Shahbaz [25] have utilized the ARDL approach to confirm the EKC hypothesis with an inverted U-shaped curve because the linear and quadratic forms of income have significant corresponding positive and negative parameter estimates. On the contrary, the literatures have also recorded that the economic growth and emission nexus is rather an N-shaped curve [26,27]. The report argued that carbon emission will continue to increase in the future and will not decrease with further economic growth thus indicating that the EKC hypothesis is inconclusive, especially in the findings from developing countries. For example, Laverde-Rojas et al. [28] used VECM in their analysis and maintained that the EKC does not exist in Colombia because the country is facing challenges in overcoming institutional constraints in its approach to derive environmental benefits. Similarly, Kurniawan [1] conducted a pooled mean group estimator analysis sourced from 140 developing countries and reported no evidence to support the EKC but



conversely produced empirical evidence of a long-run relationship between economic growth and carbon emission. In Malaysia, Suki, Sharif and Afshan utilize the Quantile Autoregressive Distributed Lag (QARDL) method, and others [29–31] showed evidence to validate the EKC hypothesis, while in contrast some scholars like Ali and Rahman [32] disproved it. The positive impact of economic growth on carbon emission over the last 30 years is shown in Figure 1.

## 2.2. Carbon Emission and Financial Development

The discussion on mechanism and channels through which the impact of financial development on economic growth affects the environment is rather limited even in specialised literature, especially in the developing economies. As depicted in Table 1, findings on the impact of financial development on carbon emissions are quite mixed and contradictory. In general, there are records of positive effects or relatively negative impacts, and even no impact at all of financial development on carbon emissions. In a nutshell, the perplexing findings signify ambiguous results from city level data financial development [33], varying financial scale and efficiency involving other factors [34] and conducted over different time scopes.

The relationship between financial developments on carbon emissions, which describes an inverted U-shaped curve, is still debatable. For instance, Yin et al. [35] adopted the Seemingly Unrelated Regression (SUR) model in the context of China and concluded that financial development is helpful in improving water quality but may incur more emissions. Government regulations play a critical role in improving environmental quality together with the joint effect of financial development. Some studies considered the two dimensions of financial development, namely financial depth and financial breadth, as better proxies in representing the overall financial development and structure [36]. Firstly, financial depth reflects the quality of financial development that can support local economic development. It is measured from the percentage of total amount of securities on GDP, domestic credit provided by the financial sector, and domestic credit advanced to the private sector by banks (both in percentage of GDP). Secondly, financial breadth reflects the soundness of banking institutions and scale of finance that can be measured using the number of financial institutions involved, number of domestically listed companies and number of financial employees. Most researchers, however, found that financial depth, rather than financial breadth, exerts significantly greater influence on environment quality, and this consequently supports the EKC hypothesis [37].

Development in the financial sector should hypothetically reduce carbon emission due to the following reasons: First, a well-developed financial system will assist the efficient allocation of credit for environment-friendly technologies [38]. Schumpeter regarded finance as a root cause that can spark innovation [39]. Integration of innovation into all phases of development will involve an introduction to a whole new or modified process of production, practices or systems which benefit the environment [40]. In addition, improving a greener production process has potential to lower emissions through increased efficiency in energy consumption. Second, a manageable and sophisticated financial sector can lead to low borrowing costs that will motivate local and national governments as well as local producers to participate in environmental projects [41]. Hence, this will help countries to adopt and convert into a cleaner energy consumption structure.

## 2.3. Institutional Quality-Emission Nexus

Salman et al. [42] classified the context of institutions into two: (1) informal constitutional limitations reflected by authorizations, societies, and customs, and (2) formal procedures that can be reflected by means of institutional quality index, i.e., accountability, corruption control, government effectiveness and rule of law. This study is focused on the latter with greater attention centering institutional quality impact on the environment. In general, high-quality institutions enable all parties to effectively contribute to environmental protection. Local governments soundly implementing environmental regulations will

improve environmental quality [43]. In the scope of the EKC hypothesis, the environment tends to improve as better and more effective institutions reduce environmental cost of high economic growth. Stringent policies and healthier law and regulation enable countries to flatten the EKC curve and decrease pollution whilst achieving economic growth. Thus, institutional quality can be the key factor for pollution control and is complementary to the finance–emissions nexus. Ali et al. [44] who measured institutional quality using corruption, rule of law, and bureaucratic quality had highlighted reduced carbon emission in developing countries, as consistent with findings by Salman [42] and Lau [45]. Hunjra [46] demonstrated a negative moderate effect of institutional quality on the finance–emissions nexus for selected five South Asian countries. The study suggested that better governance reduces the trade-off impacts of financial development on the environment because stronger financial structure provides more capital on environmentally friendly projects.

Theoretically, a country with a higher institutional quality index will be successful in reducing carbon emissions because of the increase in government effectiveness. The first reason for this is that better governance with high control of corruption and higher score of rules of law will directly improve effectiveness in the implementation of environment-related policies. This will leave local producers and citizens with only one choice, that is to obey the rules by using greener production and consumption methods. Second, a more honest local and national government can credibly moderate the negative impact of financial development on the environment. In the prevalence of better governance, financial sectors are more convinced into allocating capital to environmentally friendly projects [4]. Furthermore, the presence of a more translucent political system is beneficial for environmentally friendly projects because it will enforce smooth contracts and decrease uncertainty and the risk of expropriation [47]. In the case of Africa, Ibrahim and Sare [48] discovered that the reasons behind an underdeveloped financial sector are weak governance, poor political and economic stability altogether with lack of institutional quality.

#### 2.4. Carbon Emissions and Energy Use

The relationship between energy use and CO<sub>2</sub> emissions under various research methodologies is amply reported in the literature. Studies on the nexus between these two attributes have produced consistent conclusions where energy consumption is the main contributor to the rise in CO<sub>2</sub> emissions. For instance, Wasti and Zaidi [49] proxied as an indicator the kilogram of oil equivalent per capita for energy use and provided evidence of bi-directional causality between energy use and CO<sub>2</sub> emissions in Kuwait. Recent studies by Shaari et al. [13] for OIC countries and by Yuping et al. [33] in Argentina claimed that energy use boosts CO<sub>2</sub> emissions both in the short- and long-term. A similar effect was recorded by Aftab et al. [34] in a study in Pakistan. They highlighted that energy use promotes CO<sub>2</sub> emissions in the long-term.

### 3. Research Methodology

This part presents the data, research design, empirical specification, and estimation strategy to estimate finance–emission nexus.

#### 3.1. Model Specifications

This study endeavours to validate the EKC hypothesis using data spanning 1984 to 2017 and to investigate the nexus between CO<sub>2</sub> emissions and other variables which include financial development, institutional quality, and energy use in the Malaysian context. Informed by the EKC hypothesis, the first model is developed as shown below:

$$CO_2 = f(GDP_t, GDP_t^2, FD_t, ENERGY_t, IQ_t) \quad (1)$$

CO<sub>2</sub> = carbon dioxide emissions per capita,  
GDP = Gross Domestic Product per capita,  
FD = financial development,

*ENERGY* = energy use,  
*IQ* = institutional quality, and  
*t* = the year.

Note: *GDP* and *GDP*<sup>2</sup> were introduced into the model as independent variables along with financial development, institutional quality, and energy use.

All variables were transformed to natural logarithm form to omit the problem of heteroscedasticity. In summary, a long-run model of CO<sub>2</sub> emissions is presented in the Equation (2):

$$\ln CO_2 = \alpha_0 + \beta_1 \ln GDP_t + \beta_2 \ln GDP_t^2 + \beta_3 \ln FD_t + \beta_4 \ln ENERGY_t + \beta_5 \ln IQ_t + \varepsilon_t \quad (2)$$

*lnCO*<sub>2</sub> = logarithm of carbon dioxide emissions per capita,  
*lnGDP* = logarithm of Gross Domestic Product per capita,  
*lnGDP*<sup>2</sup> = logarithm of the square Gross Domestic Product per capita,  
*lnFD* = logarithm of financial development,  
*lnENERGY* = logarithm of energy use,  
*lnIQ* = logarithm of institutional quality, and  
*ε*<sub>*t*</sub> = noise errors.

To accept the EKC hypothesis in the Malaysia context, the conditions that need to be met are (1) the coefficient of  $\beta_1$  is positive and (2) the coefficient of  $\beta_2$  is negative.

### 3.2. Data Description

As shown in Table 2, all data were compiled from the World Bank database, except data for institutional quality which were obtained from the International Country Risk Guide database for the period of 1984–2017. All measurements follow precedence in the existing literature, specifically the following: (1) For CO<sub>2</sub> emissions, the amount per capita was used [50]; (2) financial development used domestic credit to the private sector [6,16,17]; and (3) institutional quality applied government stability, corruption, and law and order [18,19]. All data covered the period 1984–2017, with sourcing restricted by data availability. The descriptive statistics of the attributes of this study are shown in Table 3.

**Table 2.** Data information.

Variable Code	Variable Name and Details	Unit	Source
CO <sub>2</sub>	CO <sub>2</sub> emissions	Metric tons per capita	World Bank
GDP	Gross Domestic Product	constant 2010 US\$ per capita	World Bank
GDP <sup>2</sup>	Square of Gross Domestic Product	constant 2010 US\$	World Bank
FD	Financial development: Domestic credit to the private sector	% of GDP	World Bank
ENERGY	Energy use	kg of oil equivalent per capita	World Bank
IQ	Government' ability to implement declared projects. It is the sum of three subcomponents: popular support, government unity and legislative strength [51].	Scored from zero to twelve. A low rating represents very high risk, and a higher rating represents very low risk.	International Country Risk Guide
COR	Corruption (COR): Corruption in the form of favouritism, job reservations, and questionably close connexions between business and politics [51].	Scored from zero to six. A low rating represents the highest possible level of corruption, and a high rating indicates a lower level of corruption.	International Country Risk Guide
LO	Law and Order (LO): Law signifies the forte of the legal system and, Order represents compliance on the law [51].	Scored from zero to six points. A low rating represents a high crime rate where the law is routinely ignored, and high rating represents public respect for the law.	International Country Risk Guide



Table 3. Descriptive statistics.

	LCO2PC	LGDPCC	LGDPCC2	LFD	LN ENERGY	GS	COR	LO
Mean	1.533	8.770	77.019	4.690	7.535	8.083	3.335	3.981
Median	1.596	8.838	78.108	4.687	7.633	9.000	3.000	4.000
Max.	2.049	9.261	85.774	5.066	8.008	11.000	5.000	5.000
Min.	0.826	8.218	67.542	4.240	6.904	2.000	2.375	3.000
Std dev.	0.399	0.323	5.621	0.205	0.356	2.320	0.841	0.750
Skewness	−0.442	−0.366	−0.322	−0.233	−0.476	−0.972	0.317	0.055
Kurtosis	1.862	1.936	1.921	2.893	1.902	3.621	1.736	1.760

### 3.3. Research Methodology

This study conducted a series of econometric techniques to identify symmetric and asymmetric relationships amongst selected attributes. The first step was the unit root test and stationary testing using several analyses comprising Augmented Dicker–Fuller (ADF), Phillips–Perron (PP), Lee–Strazicich (LEE) and Kwiatkowski–Phillips–Schmidt–Shin (KPSS) Test. The second step was to identify the linear and nonlinear relationships between all attributes using symmetric and asymmetric cointegration tests which included the Autoregressive Distributed Lag Model (ARDL) by Pesaran et al. [52] and the Non-Linear Autoregressive Distributed Lag Model (NARDL) by Shin et al. [53]. Finally, a diagnostic and stability test was carried out to verify whether the ARDL and NARDL models were stable and reliable.

#### 3.3.1. Research Hypotheses

This study proposes to examine the symmetric and asymmetric relationship of carbon emissions, economic growth, energy use, financial development, and institutional quality. Hence, to statistically prove the theoretical predictions, this study empirically tests the following hypotheses using the case of Malaysia.

**Hypothesis 1 (H1).** *There is a symmetric relationship between economic growth and carbon emissions.*

**Hypothesis 2 (H2).** *There is an asymmetric relationship between economic growth and carbon emissions.*

**Hypothesis 3 (H3).** *There is a symmetric relationship between financial development and carbon emissions.*

**Hypothesis 4 (H4).** *There is an asymmetric relationship between financial development and carbon emissions.*

**Hypothesis 5 (H5).** *There is a symmetric relationship between institutional quality and carbon emissions.*

**Hypothesis 6 (H6).** *There is an asymmetric relationship between institutional quality and carbon emissions.*

**Hypothesis 7 (H7).** *There is a symmetric relationship between energy use and carbon emissions.*

**Hypothesis 8 (H8).** *There is an asymmetric relationship between energy use and carbon emissions.*

### 3.3.2. Autoregressive Distributed Lag Model (ARDL)

The ARDL was employed as the estimation procedure which included three series of econometric steps: first, investigation of stationarity by employing unit root test analysis; second, bound tests to confirm the presence of cointegration; third, diagnostic and stability tests via autoregressive conditional heteroscedastic (ARCH) for heteroscedasticity, Jarque–Bera for normality test, and Breusch–Godfrey for serial correlation. It was followed by CUSUM and CUSUMSQ tests in confirming the stability of these models.

The prevailing method of ARDL was used in this study to estimate the symmetric relationships between CO<sub>2</sub> emissions, GDP, financial development, energy use, and institutional quality, as follows:

$$\begin{aligned} \Delta \ln CO_2 = & \alpha_0 + \sum_{i=1}^n \varnothing \Delta \ln CO_{2t-i} + \sum_{i=0}^n \alpha_1 \Delta \ln GDP_{t-i} + \sum_{i=0}^n \alpha_2 \Delta \ln GDP_{t-i}^2 + \sum_{i=0}^n \alpha_3 \Delta \ln FD_{t-i} \\ & + \sum_{i=0}^n \alpha_4 \Delta \ln ENERGY_{t-i} + \sum_{i=0}^n \alpha_5 \Delta \ln IQ_{t-i} + \gamma \ln CO_{2t-1} + \beta_1 \ln GDP_{t-1} \\ & + \beta_2 \ln GDP_{t-1}^2 + \beta_3 \ln FD_{t-1} + \beta_4 \ln ENERGY_{t-1} + \beta_5 \ln IQ_{t-1} + \varepsilon_t \end{aligned} \quad (3)$$

$\Delta CO_2$ ,  $\Delta GDP$ ,  $\Delta GDP^2$ ,  $\Delta FD$ ,  $\Delta IQ$ ,  $\Delta ENERGY$  = respective difference values.

$\varnothing$  and  $\alpha_1$  to  $\alpha_5$  = short term dynamic relationship

$\gamma$ ,  $\beta_5$  to  $\beta_5$  = long-run dynamic relationship.

$n$  = lag period of the explained variable and explanatory variable.

A joint significance test, Wald and F-statistic will be used to determine whether there is a cointegration relationship under the following hypothesis:  $H_0: \varnothing = \alpha_1 = \alpha_2 = \alpha_3 = \alpha_4 = \alpha_5 = 0$ , and  $H_1: \varnothing = \alpha_1 \neq \alpha_2 \neq \alpha_3 \neq \alpha_4 \neq \alpha_5 \neq 0$ . The null hypothesis is rejected under condition where cointegration exists. The next step was the investigation of causality. The lagged error correction term was derived from the cointegration equation as follows:

$$\begin{aligned} \ln CO_2 = & \alpha_0 + \sum_{i=1}^n \varnothing \Delta \ln CO_{2t-i} + \sum_{i=0}^n \alpha_1 \ln GDP_{t-i} + \sum_{i=0}^n \alpha_2 \ln GDP_{t-i}^2 + \sum_{i=0}^n \alpha_3 \ln FD_{t-i} + \sum_{i=0}^n \alpha_4 \ln ENERGY_{t-i} \\ & + \sum_{i=0}^n \alpha_5 \ln IQ_{t-i} + \varepsilon_t \end{aligned} \quad (4)$$

Finally, the short-run coefficients were estimated using the error correction model (ECM) per the ARDL method:

$$\begin{aligned} \Delta \ln CO_2 = & \alpha_0 + \sum_{i=1}^n \varnothing \Delta \ln CO_{2t-i} + \alpha_1 \sum_{i=0}^n \Delta \ln GDP_{t-i} + \alpha_2 \sum_{i=0}^n \Delta \ln GDP_{t-i}^2 + \alpha_3 \sum_{i=0}^n \Delta \ln FD_{t-i} \\ & + \alpha_4 \sum_{i=0}^n \Delta \ln ENERGY_{t-i} + \alpha_5 \sum_{i=0}^n \Delta \ln IQ_{t-i} + \varnothing \ln CO_{2t-1} + \beta_1 \ln GDP_{t-1} \\ & + \beta_2 \ln GDP_{t-1}^2 + \beta_3 \ln FD_{t-1} + \beta_4 \ln ENERGY_{t-1} + \beta_5 \ln IQ_{t-1} + \eta ECT_{t-i} + \varepsilon_t \end{aligned} \quad (5)$$

where  $\eta$  denotes the error correction term coefficient, implying the dependent attribute's speed of adjustment after a change in the other attributes in the short-term. It indicates how fast the dependent attributes return to the long-run equilibrium following shocks to the other attributes in the short-run.

### 3.3.3. Non-Linear Autoregressive Distributed Lag Model (NARDL)

The asymmetric impacts of the independent variables were tested using NARDL version conditional error correction that was reformulated from the ARDL model. Equation (6) was formulated to capture the nonlinear relationship amongst the selected attributes. This study employed the NARDL for bound test approach as proposed by Shin et al. [53].

$$\begin{aligned} \Delta \ln CO_2 = & \alpha_0 + \sum_{i=1}^n \varnothing \Delta \ln CO_{2t-i} + \sum_{i=0}^n \alpha_1 \Delta \ln GDP_{t-i} + \sum_{i=0}^n \alpha_2 \Delta \ln GDP_{t-i}^2 + \sum_{i=0}^n \alpha_3 \Delta \ln FD_{t-i} \\ & + \sum_{i=0}^n \alpha_4 \Delta \ln ENERGY_{t-i} + \sum_{i=0}^n \alpha_5^+ \Delta \ln IQ_{t-1}^+ + \sum_{i=0}^n \alpha_5^- \Delta \ln IQ_{t-1}^- + \gamma \ln CO_{2t-1} + \beta_1 \ln GDP_{t-1} \\ & + \beta_2 \ln GDP_{t-1}^2 + \beta_3 \ln FD_{t-1} + \beta_4 \ln ENERGY_{t-1} + \beta_5^+ \ln IQ_{t-1}^+ + \beta_5^- \ln IQ_{t-1}^- + \varepsilon_t \end{aligned} \quad (6)$$

From Equation (6), the term (+) and (−) respectively represents the asymmetric impacts of the variable related to  $IQ$  for  $CO_2$  emissions. The variable related to  $IQ$  takes the notation (+) and (−) which, respectively, represent the partial sum of positive and negative changes. Positive and negative values of attributes of  $IQ$  were formulated in Equations (7) and (8) and measured as follows:

$$\ln IQ_{t-1}^+ = \sum_{k=1}^t \Delta \ln IQ_k^+ = \max(\Delta IQ_k, 0) \quad (7)$$

$$\ln IQ_{t-1}^- = \sum_{k=1}^t \Delta \ln IQ_k^- = \min(\Delta IQ_k, 0) \quad (8)$$

where  $IQ^+$  represents the partial sum for positive change in  $IQ$ , while  $IQ^-$  represents the partial sum for negative change in  $IQ$ .  $IQ-CO_2$  emissions impacts can be considered to be asymmetric in the condition of changes of the positive or negative results in  $IQ$  inflows. Bound testing was employed using the F-statistic to test the long-run cointegration between attributes with the null hypothesis of no cointegration:  $H_0: \emptyset = \beta_1 = \beta_2 = \beta_3 = \beta_4 = \beta_5 = 0$  and  $H_1: \emptyset \neq \beta_1 \neq \beta_2 \neq \beta_3 \neq \beta_4 \neq \beta_5 \neq 0$ . Further, in testing the possibilities of a long-run relationship, this study analysed the null hypothesis of long-run symmetry  $\beta = \beta^+ = \beta^-$  and  $\alpha = \alpha^+ = \alpha^-$  for  $CO_2$  emissions using standard Wald test. The NARDL estimation and the test for diagnostic and stability testing were carried out, similar to the testing applied in the ARDL model to verify stability, reliability and freedom from any estimation bias.

## 4. Results and Discussion

### 4.1. Unit Root and Stationarity Tests

In regard to ascertaining the order of integration of each variable, the time series properties were examined by utilizing Augmented Dickey–Fuller (ADF) test, Phillips–Perron (PP) test, and Lee–Strazicich (LEE) test. These three-unit root tests describe that the attributes contain a unit root as its null hypothesis. The null hypothesis of nonstationary is produced at the 1, 5 and 10% significance level correspondingly. Table 4 displays the outcomes of unit root tests, and all the attributes have undergone the stationary test with constant and time trends. The outcomes of the tests demonstrate that all the data series are nonstationary at level. However, the outcomes of the ADF tests on the first difference clearly stands that all data series are stationary after the first difference at the 1, 5 and 10% significance level correspondingly, thus rejecting the null hypothesis. Thus, the overall outcomes of the ADF tests explain that all the attributes' series were integrated series of order I (1). The outcomes of ADF, PP, and LEE unit root tests have been verified by employing another related test which is Kwiatkowski–Phillips–Schmidt–Shin (KPSS) test. The null hypothesis for the KPSS test is that attributes have no unit root. The results for the KPSS test revealed that all attributes are significant at level I (0) except for the attributes of government stability and law and order. By these outcomes of the unit root tests, it implies that the attributes' series were an integrated series of only order I (0) and I (1). Hence, the requirement for the application of the ARDL approach is assured where none of the attributes are integrated at I (2).

**Table 4.** Unit root tests.

Methodology	ADF	PP	KPSS	LEE	
Attribute	t-Stat.	t-Stat.	t-Stat.	t-Stat.	Break-Years
At Level I (0)					
LCO2PC	0.180	0.180	0.935 ***	−2.013	1995, 2003
LGDPPC	−1.703	−1.648	0.972 ***	−4.552	1983, 1991
LGDPPC2	−1.127	−1.010	0.975 ***	−4.485	1983, 1991
LFD	−2.836 *	−2.749 *	0.835 ***	−4.900	1981, 2001
LNENERGY	−1.059	−1.586	0.829 ***	−4.337	1965, 1988
GS	−2.214	−2.236	0.182	−6.444	1966, 1983
COR	−2.058	−2.040	0.624 ***	−5.178	1968, 1976
LO	−2.100	−2.379	0.090	−4.766	1967, 1976
At First Difference I (1)					
LCO2PC	−9.053 ***	−9.053 ***	0.134	−8.936 ***	2004, 2008
LGDPPC	−6.044 ***	−5.992 ***	0.278	−5.974	1983, 1996
LGDPPC2	−6.129 ***	−6.140 ***	0.142	−6.234 *	1983, 1996
LFD	−2.991 **	−6.974 ***	0.527 **	−6.801 **	1965, 1997
LENERGY	−6.944 ***	−7.266 ***	0.204	−7.715 ***	1964, 1968
GS	−4.596 ***	−5.069 ***	0.172	−11.854 ***	1965, 1985
COR	−5.107 ***	−5.130 ***	0.225	−6.466 ***	1964, 1976
LO	−8.156 ***	−3.682 ***	0.062	−5.627	1966, 1974

Note: \*\*\*, \*\* and \* show significance at the 1, 5 and 10% level respectively. Null hypothesis for ADF test: Attribute has a unit root. Null hypothesis for PP test: Attribute has a unit root. Null hypothesis for KPSS test: Attribute has no unit root. Null hypothesis for LEE test: Attribute has a unit root.

#### 4.2. Autoregressive Distributed Lag (ARDL) Methodology

In selecting the optimum number of lags, five lag selection criteria were followed: (1) sequential modified (LR), (2) Final Prediction Error (FPE), (3) Akaike Information Criteria (AIC), (4) Schwarz Information Criterion (SC) and (5) Hannan–Quinn Information Criteria (HQ). The optimum number of lags will capture the dynamic of the series. The result of different selection criteria is shown in Table 5 where the two-lag length is identified as the desirable condition for cointegration testing. This lag selection under vector autoregressive (VAR) is confirmed as illustrated in the polynomial graph in Figure 2. All the dots are within the circle (except for one dot for government stability (GS) and law and order (LO)), which therefore signify the appropriateness of lag length two for decision and policy reliability.

**Table 5.** Lag Selection for the ARDL model.

	Lag	LogL	LR	FPE	AIC	SC	HQ
GS	0	138.378	NA	$4.37 \times 10^{-12}$	−9.129	−8.846	−9.040
	1	322.978	280.082	$1.64 \times 10^{-16}$	−19.377	−17.397	−18.757
	2	398.377	83.198 *	$1.54 \times 10^{-17}$ *	−22.094 *	−18.417 *	−20.943 *
COR	0	141.663	NA	$3.48 \times 10^{-12}$	−9.356	−9.073	−9.267
	1	324.058	276.736	$1.52 \times 10^{-16}$	−19.452	−17.472 *	−18.832
	2	379.518	61.197 *	$5.66 \times 10^{-17}$ *	−20.794 *	−17.116	−19.642 *
LO	0	115.092	NA	$2.18 \times 10^{-11}$	−7.523	−7.240	−7.435
	1	304.250	286.997	$5.97 \times 10^{-16}$	−18.086	−16.106 *	−17.466
	2	355.117	56.129 *	$3.05 \times 10^{-16}$ *	−19.111 *	−15.434	−17.959 *

Note: \* = lag order selected by the criterion. LR (sequential modified LR test statistics), FPE (Final Prediction Error), AIC (Akaike Information Criteria), SC (Schwarz Information Criterion), HQ (Hannan–Quinn Information Criteria).

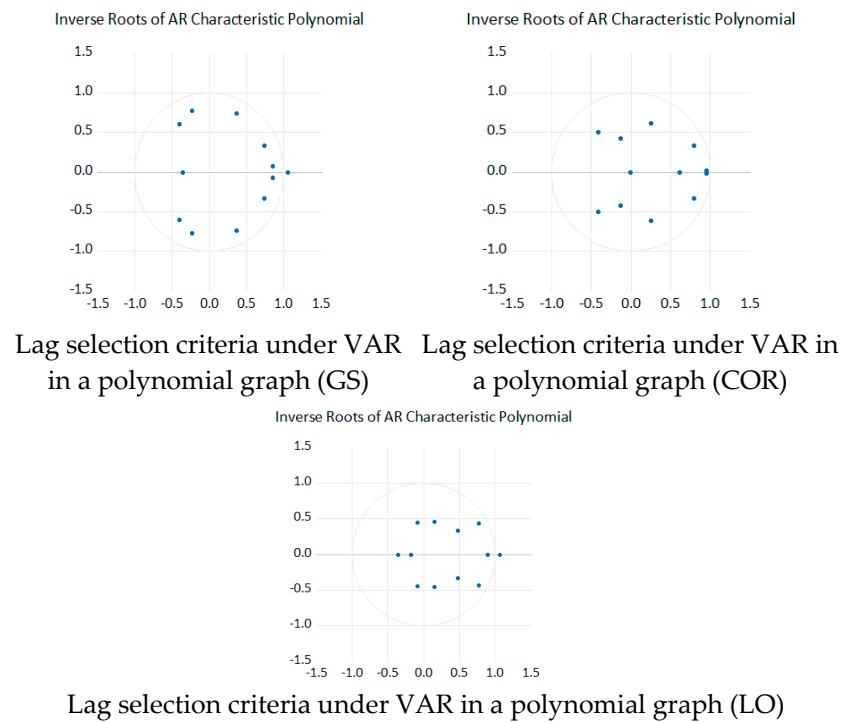


Figure 2. Lag selection criteria under VAR in a polynomial graph, created by author.

The bound F-test was conducted between the attributes of Model 1, Model 2, and Model 3 for the cointegration test, and the results are given in Table 6. The F-statistic of Model 1 (7.4835), the F-statistic of Model 2 (15.5718), and the F-statistic of Model 3 (9.1436) exceed the 10% upper bound critical value. With reference to Narayan [54], these results confirm that there exists a significant long-run relationship between the attributes in Model 1, Model 2, and Model 3. Once cointegration evidence has been found, the long-term and short-term ARDL coefficients for the three models, with significant cointegration, are estimated. Table 6 reports the long-run coefficients of the ARDL estimates, while Table 7 reports the short-run coefficients. The coefficients of the lagged Error Correction Term ( $ECT_{t-1}$ ) for all the three models are negative and statistically significant, implying a highly stable long-run relationship between attributes in all the three models. Moreover, this coefficient is used to measure the speed of adjustment from short-run fluctuations to the long-run equilibrium. The result specifies that the deviation of variables from the short-run to the long-run equilibrium is regulated by 53.81% per year in Model 1, 10.80% per year in Model 2 and 81.04% annually in Model 3.

Table 6. The ARDL long-run results.

Attributes	Model 1	Model 2	Model 3
LGDPC	11.34187 ** (4.5003)	5.1373 *** (1.299)	5.6820 *** (1.9534)
LGDPPC2	−0.6671 ** (0.2669)	−0.2636 *** (0.0719)	−0.3037 ** (0.1099)
LFD	−0.0440 (0.0763)	−0.1058 *** (0.0320)	−0.1632 *** (0.0540)
LENERGY	1.2911 *** (0.0763)	0.4689 *** (0.1056)	0.7377 *** (0.1342)
GS	−0.1855 ** (0.2824)		
COR		−0.0717 *** (0.0124)	
LO			−0.0105 (0.0111)
Selection Model	1,1,1,1,0	1,1,1,0,0,0	1,1,1,1,1,0
R-square	0.997	0.997	0.997
Adjusted R-square	0.996	0.996	0.996
F-stat.	729.443	1044.437	750.442
ARDL Bound Test Estimate			
F-stat.	7.483465 *	15.57181 *	9.143613 *



Table 6. Cont.

Attributes	Model 1		Model 2		Model 3	
Narayan (2005) Critical Values						
	I (0)	I (1)	I (0)	I (1)	I (0)	I (1)
10% Significance Level	4.537	6.370	4.537	6.370	4.537	6.370
5% Significance Level	3.125	4.608	3.125	4.608	3.125	4.608
1% Significance Level	4.537	6.370	4.537	6.370	4.537	6.370
Diagnostic Testing						
Normality	0.000 ***		0.803		0.939	
Serial correlation	0.162		0.763		0.072	
Heteroscedasticity (BPG)	0.939		0.897		0.669	
ARCH	0.865		0.803		0.803	
CUSUM	Stable		Stable		Stable	

Note: \*\*\* = significant at 1%, \*\* = significant at 5% and \* = significant at 10%. Standard errors are presented in brackets. Jarque–Bera (normality) test; Breusch–Godfrey LM serial correlation test; Breusch–Pagan–Godfrey heteroscedasticity test; LM-ARCH heteroscedasticity test; Cumulative sum (CUSUM) stability test; Cumulative sum of square (CUSUM-SQ.) stability test.

Table 7. The ARDL short-run results.

Attributes	Model 1	Model 2	Model 3
C	−29.9669 *** (3.9817)	−28.1023 *** (2.6256)	−24.0215 *** (2.8877)
D (LGDPPC)	−22.3680 *** (3.8751)	−7.0390 *** (2.4580)	−13.0812 *** (2.9251)
D (LGDPPC2)	1.2821 *** (0.2189)	0.4165 *** (0.1415)	0.7581 *** (0.1664)
D (LFD)	−0.0811 ** (0.0365)		−0.2001 *** (0.0405)
D (GS)	−0.03649 *** (0.0715)		
D (LO)			−0.0438 *** (0.0974)
ECT (−1)	−0.5381 *** (0.0715)	−0.1080 *** (0.1009)	−0.8104 *** (0.0974)

Note: \*\*\* = significant at 1%, and \*\* = significant at 5%. Standard errors are in brackets.

The ARDL long-run relationship between economic growth (LGDPPC) and CO<sub>2</sub> emissions is positive and significant in the Malaysian context for Model 1 (at 5% significance level), Models 2 and 3 (at 5% significance level respectively). It indicates that any 1% increase in GDP will increase CO<sub>2</sub> emissions by 11.34% for Model 1, 5.14% for Model 2 and 5.68% for Model 3. For the square term of per capita income, denoted by LGDPPC2, negative and significant coefficient results are found for the long-run, hence verifying the existence of the EKC hypothesis for the case of Malaysia in all the three models. Consequently, this validates the occurrence of an inverted U-shaped curve because the CO<sub>2</sub> emissions in Malaysia are affected positively by linear GDP and influenced negatively by the quadratic GDP. However, a contrary result is depicted in the short-run as it recorded a relatively negative and significant relationship between linear GDP and CO<sub>2</sub> emissions and a relatively positive and significant relationship between quadratic GDP and CO<sub>2</sub> emissions in all the three models. Therefore, an inverted U-shaped curve is not found in the short-run, which thus validates the EKC hypothesis as a long-run occurrence for Malaysia.

In the short-run, the result shows that energy use has no significant effect on CO<sub>2</sub> emissions, but for the long-run, it recorded a significant and positive relationship in all the three models. As per the result, a 1% increase in energy use in the long-run will increase CO<sub>2</sub> emissions by 1.29%, 0.47% and 0.74% for Model 1, 2 and 3, respectively. This result supports the finding by Aftab et al. [34], Wada et al. [55], Nathaniel and Adeleye [56], and Atsu and Adams [57] that energy use is the significant contributor to the rise in CO<sub>2</sub> emissions.

This study focused on the relationship between institutional quality and CO<sub>2</sub> emissions and utilized more than a few measures of institutional variables. However, of these, only government stability, corruption and law of order demonstrated consistent and significant coefficients in the case of Malaysia. Thus, in line with the literature, only these three attributes will be analysed for the relationship between institutional quality and CO<sub>2</sub> emissions. Referring to Model 1, government stability (GS) was shown to generate a significantly negative impact on CO<sub>2</sub> emissions both in the long- and short-run. Corruption (COR), which was included in Model 2, indicates a significantly negative effect on CO<sub>2</sub> emissions but only in the long-run. In Model 3, however, law and order (LO) proved to negatively influence CO<sub>2</sub> emissions only in the short-run. As predicted, institutional quality is thus verified to be the vital indicator to the reduction in CO<sub>2</sub> emissions in Malaysia. These outcomes are consistent with Salman [42], Lau [45], and Hunjra [46] who suggest that a country with high institutional quality is successful in monitoring and mitigating CO<sub>2</sub> emissions.

The influence of financial development on CO<sub>2</sub> emissions produced mixed results. These were subsequently incorporated as different institutional quality attributes into the model, but the sign of the coefficients was still negative. In the long-run, financial development relationships with CO<sub>2</sub> emissions were found to be significantly negative if only the attributes of corruption and law and order were included, as shown in Model 2 and Model 3, respectively. Nevertheless, financial development non significantly influenced CO<sub>2</sub> emissions in the long-run as government stability was incorporated in Model 1. This is contrary to the short-run result. For every 1% increase in financial development will decrease CO<sub>2</sub> emissions by 0.08% as specified by Model 1. Similarly, a significant negative short-run relationship is detected in Model 3, when the law-and-order attribute was incorporated into the model. To recapitulate, financial development was validated to be one of the attributes that may decrease CO<sub>2</sub> emissions in the country. This finding is consistent with Khan et al. [7], Sahoo et al. [17], Dauda et al. [40], and Ahmed et al. [41], which suggests that a developed financial system might assist firms in alleviating financial constraint, which in turn would enable them to adopt environmentally friendly technologies with which to decrease CO<sub>2</sub> emissions.

The diagnostic test results for the ARDL model are shown in the lower part of Table 6. The probability chi-square values for the Breusch–Pagan–Godfrey heteroscedasticity test and ARCH test were found to be not significant, hence the null hypothesis of homoscedasticity was retained. Further, the probability of chi-square values for normality test were found significant, suggesting normality in the model. However, from the Breusch–Godfrey Serial, the probability of chi-square values from the Correlation LM test were not significant because no such serial correlation in the model was detected. The robustness and dynamic stability of the models were further tested through cumulative sum of recursive residuals (CUSUM) and cumulative sum of recursive residuals square (CUSUMSQ). From Figure 3, it is clear that the residual values are all positioned between the confidence lines, which thus implies the stability of our ARDL models.



**Figure 3.** ARDL CUSUM and CUSUMSQ graphs, created by author.

#### 4.3. Nonlinear Autoregressive Distributed Lag Methodology (NARDL)

This study adopted the NARDL approach by Shin et al. [53] to explore asymmetry issues that might exist between the attributes employed. The F-statistic value of Model 1 (8.4090), the F-statistic of Model 2 (8.9723), and the F-statistic of Model 3 (10.545) exceed the 10% upper bound critical value. According to Narayan [54], these results confirm that there exists a significant long-run relationship between the attributes in Model 1, Model 2 and Model 3. Therefore, this study consequently proceeded with the long-run and the short-run NARDL estimation on all the three models.

Tables 8 and 9 indicate the NARDL estimates in the short- and long-run, with CO<sub>2</sub> emissions as the dependent variable. It was established that economic growth, financial development, and energy use—including institutional quality attributes such as government stability, corruption, and law and order—are important variables in explaining CO<sub>2</sub> emissions in Malaysia. The positive and significant coefficients of GDP and energy use denote that an increase in these factors will deteriorate the environment in the country. Conversely, however, an increase in financial development, government stability, corruption, and law and order improve environment quality. Some fascinating results from more sophisticated asymmetric analyses are given below:

1. The GDP and CO<sub>2</sub> emissions relationship is positive but only in the long-run, hence providing support to the argument that economic growth will increase environmental degradation in Malaysia. Specifically, in the long-run, the increase in GDP will proliferate CO<sub>2</sub> emissions to 15.30% on average. However, the square term of GDP is negative and similarly influences CO<sub>2</sub> emissions in the long-run. This finding shows that the EKC hypothesis is true only in the long-run in the country, and the results are similar to that of the ARDL. At the early stage of development, the environment is strongly subjected to pressure due to increasing economic activities and rising income. The pressure will, however, ease beyond a certain threshold of development.
2. Financial development is negatively associated with CO<sub>2</sub> emissions in the long-run. On average, 0.10% decline in CO<sub>2</sub> emissions is caused by financial development in the long-run. This result is analogous to the findings of Sahoo et al. [17], Zaidi [58], and Liu with Song [59], who established that the development in the financial sector might help decrease CO<sub>2</sub> emissions. This could reflect the ability of Malaysian financial institutions to lure industries to invest in environmental sustainability projects, implement environmentally friendly technologies and finance environmental sustainability projects at lower cost, hence resulting in lower environmental pollution.
3. Energy use is positively associated with CO<sub>2</sub> emissions in the short- and long-run in Malaysia. In the short-run, 0.51% rise in CO<sub>2</sub> emissions is caused by the increase in energy use. On average, the increase of energy use will increase by 0.67% CO<sub>2</sub> emissions in the long-run. The ARDL model highlighted the positive influence of energy use on CO<sub>2</sub> emissions. Despite its importance in the development process, energy is causing environmental impact through pollution, global warming, and climate change. These results are parallel with research by Ridzuan et al. [11], Begum et al. [12], and Shaari et al. [13], that claim energy use provides a negative effect to Malaysia environment quality.
4. The results show that government stability does affect CO<sub>2</sub> emissions only in the long-run, and it applies to both positive and negative shocks. The effects of both shocks on CO<sub>2</sub> emissions are negative (−0.1903 and −0.1875, respectively). Specifically, an increase in government stability will decrease CO<sub>2</sub> emissions by 0.19%, and conversely the decrease in government stability will increase it by 0.18%.
5. The influence of corruption on CO<sub>2</sub> emissions is also asymmetric, but only through its negative shocks. The positive shocks of corruption are not effective in decreasing CO<sub>2</sub> emissions in Malaysia under all conditions. The estimated long-run coefficients of negative shocks were measured at −0.08, which implied that a more severe level of corruption may lead to an increase in CO<sub>2</sub> emissions. These results are similar to Khan [7] and Hunjra [46] who posited that a country led by a clean government with integrity may be able improve environment quality.
6. The impact of law and order on CO<sub>2</sub> emissions was shown to be asymmetric both in the short- and long-run. In the long-run, CO<sub>2</sub> emissions were only affected by negative shock, while in the short-run, both positive and negative shocks were influential. In the long-run, the impact of negative shocks is negative at −0.03, implying that a 1% decrease in law-and-order results in 0.03% increase in CO<sub>2</sub> emissions. In the short-run, the impact of both positive and negative shocks is negative. A 1% increase in law and order thus results in 0.04% decrease in CO<sub>2</sub> emissions and a 1% decrease results in 0.06% increase in CO<sub>2</sub> emissions. In summary, the impact of law and order indicates that positive shocks do not affect CO<sub>2</sub> emissions in the long-run, and the impact of negative shocks is greater in the short-run than in the long-run. This finding is consistent with Lau et al. [46] who maintained that respectable institutional quality is imperative for monitoring CO<sub>2</sub> emissions.

**Table 8.** The NARDL long-run results.

Attributes	Model 1		Model 2		Model 3	
LGDPPC	15.2952 *** (4.838)		6.6406 *** (1.5417)		4.0873 ** (1.5342)	
LGDPPC2	−0.8940 *** (0.2864)		−0.3489 *** (0.0882)		−0.2175 ** (0.0840)	
LFD	−0.0874 (0.0850)		−0.0981 ** (0.0345)		−0.1589 *** (0.0392)	
LENERGY	1.2384 *** (0.2904)		0.3944 *** (0.1017)		0.6625 *** (0.1059)	
GS_POS	−0.1903 ** (0.0706)					
GS_NEG	−0.1875 * (0.0914)					
COR_POS			−0.0248 (0.0467)			
COR_NEG			−0.0806 *** (0.0126)			
LO_POS					0.0117 (0.0126)	
LO_NEG					−0.0295 *** (0.0090)	
R-squared	0.998		0.997		0.999	
Adjusted R-square	0.996		0.996		0.997	
F-stat.	752.081		711.738		924.573	
NARDL Bound Test Estimate						
F-stat.	8.4090 ***		8.9723 ***		10.5451 ***	
Narayan (2005) Critical Values						
	I(0)	I(1)	I(0)	I(1)	I(0)	I(1)
10% Significance Level	2.457	3.797	2.457	3.797	2.457	3.797
5% Significance Level	2.970	4.449	2.970	4.449	2.970	4.449
1% Significance Level	4.270	6.211	4.270	6.211	4.270	6.211
Diagnostic Testing						
Normality	0.247		0.824		0.483	
Serial correlation	0.0628 *		0.831		0.720	
Heteroscedasticity (BPG)	0.872		0.771		0.954	
ARCH	0.469		0.741		0.404	
CUSUM	Stable		Stable		Stable	
CUSUM-SQ	Stable		Stable		Stable	

Note: \*\*\* = significant at 1%, \*\* = significant at 5% and \* = significant at 10%. Jarque–Bera (normality) test; Breusch–Godfrey LM serial correlation test; Breusch–Pagan–Godfrey heteroscedasticity test; LM-ARCH heteroscedasticity test; Cumulative sum (CUSUM) stability test; Cumulative sum of square (CUSUMSQ) stability test. Standard errors are in brackets.

**Table 9.** The NARDL short-run results.

Attributes	Model 1	Model 2	Model 3
D (LGDPPC)	−33.1551 *** (4.1935)	−10.4366 *** (2.7202)	−10.4366 *** (2.7165)
D (LGDPPC2)	1.8936 *** (0.2361)	0.6059 *** (0.1545)	0.6059 *** (0.6059)
D (LENERGY)			0.5130 *** (0.0658)
D (GS_POS)	0.0147 (0.0200)		
D (COR_POS)		0.04606 (0.1299)	
D (LO_POS)			−0.0370 *** (0.0123)
D (LO_NEG)			−0.0552 *** (0.0092)
C	−39.8999 *** (4.1665)	−38.6419 *** (4.2243)	−25.2182 *** (2.5040)
ECT (−1)	−0.5079 *** (0.0573)	−1.1896 *** (0.1299)	−1.1517 *** (0.1143)

Note: \*\*\* = significant at 1%. Standard errors are in brackets.



The Wald test statistics suggest mixed findings, namely that the asymmetry between corruption and CO<sub>2</sub> emissions is significant only in the long-run, whereas its asymmetry with government stability and law and order are both for the short- and long-run. As shown in Table 10, the diagnostic test specifies no evidence on issues of heteroscedasticity, normality, and serial correlation issues. Additionally, Figure 4 demonstrates that the residual values shown in the graphs are all positioned between the confidence lines, thus implying the stability of our NARDL models.

Table 10. The NARDL Wald test results.

Models	Exogenous Attribute	Short-Run		Long-Run	
		F-Stat.	Probability	F-Stat.	Probability
Model 1	GS	11.544 ***	0.003	4.297 **	0.014
Model 2	COR	1.525	0.233	9.031 ***	0.002
Model 3	LO	5.816 **	0.013	12.720 ***	0.001

Note: \*\*\* = significant at 1%, \*\* = significant at 5%.



Figure 4. NARDL CUSUM and CUSUMSQ graphs, created by author.

In summary to the NARDL estimation, the asymmetric dynamic multiplier was conducted to illustrate the adjustment pattern of the attributes to their new long-run equilibrium following shocks in the short-run. Figure 5 illustrates the asymmetric dynamic multipliers assessed on Model 1–3, showing patterns of adjustment of CO<sub>2</sub> emissions to their new long-run equilibrium in response to positive and negative shocks on explanatory attributes, namely government stability, corruption and law and order. The fine dotted red lines in the graphics represent the lower and upper bands, indicating symmetry at the 95% confidence interval. The positive change curves (the continuous black line) provide information on the asymmetric adjustments of the dependent attribute (CO<sub>2</sub> emissions) to positive shocks on the explanatory attributes, and similarly the negative change curves (dashed black lines) show the asymmetric adjustment patterns of the dependent attribute (CO<sub>2</sub> emissions) to negative shocks on the explanatory attributes. The asymmetry curve is presented by the difference between the positive component and negative component curves, showing the linear mixture of the dynamic multipliers linked with positive and negative shocks on the explanatory attributes.

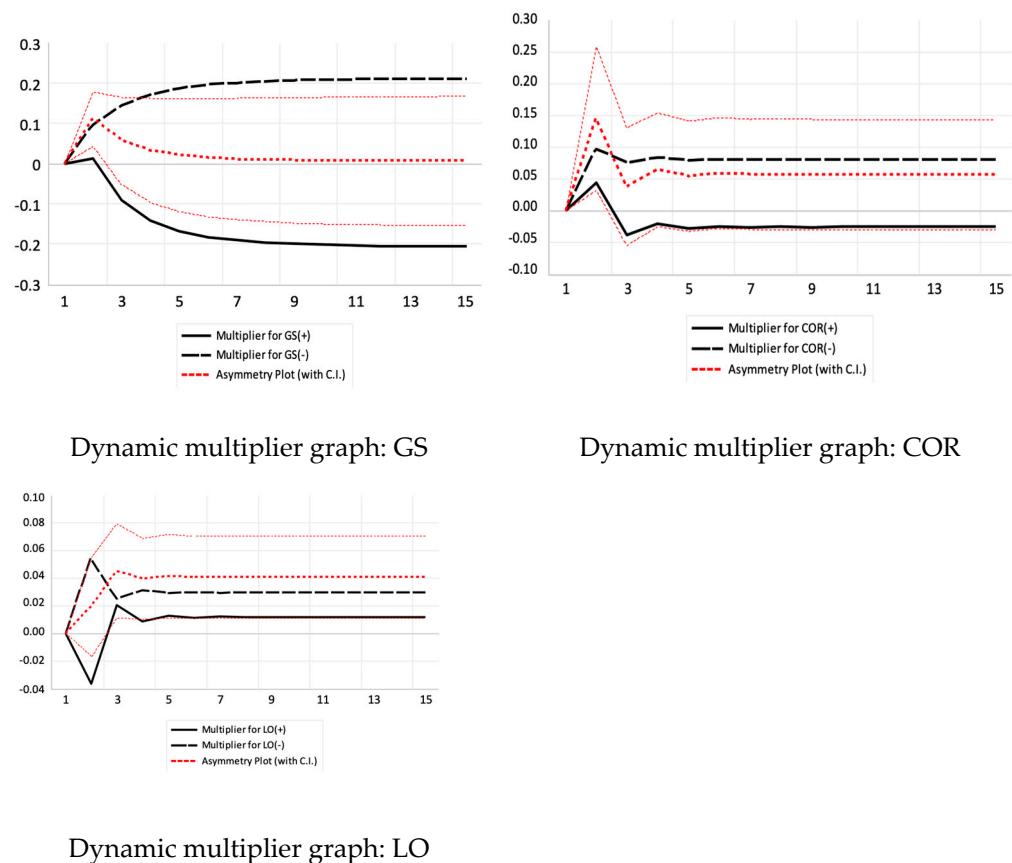


Figure 5. NARDL dynamic multiplier effect graphs, created by author.

## 5. Conclusions

This study analyses the symmetric and asymmetric nexuses of GDP per capita, financial development, energy use, and institutional quality with CO<sub>2</sub> emissions by using information sourced in Malaysia from 1984 to 2017. The Autoregressive Distributed Lag (ARDL) and the Non-Linear Autoregressive Distributed Lag (ARDL) methodologies were utilized to discover the short- and long-term nexuses amongst the attributes of the study. This study is quite dissimilar from those reported in the existing literature concerning Malaysia because it is among the first to incorporate and examine the individual effect of selected institutional quality attributes—namely government stability, corruption, and law and order—on CO<sub>2</sub> emissions in a single investigation. These three proxies for institutional

quality have provided consistent and significant coefficients in the Malaysian context. The main objective of this study was to validate the EKC hypothesis in the context of Malaysia under both symmetric and asymmetric approaches. This has been achieved. In the former approach, economic growth and energy use were shown to intensify CO<sub>2</sub> emissions only in the long-term and financial development, and institutional quality attributes mitigate this in the long- and short-term. Results from the asymmetric test were similar for economic growth and institutional quality in intensifying CO<sub>2</sub> emissions. Differences, however, were shown for effects of energy use (long- and short-term) and financial development (not influential in the long-term).

The test on Model 1 established that economic growth, energy use, institutional quality, and CO<sub>2</sub> emissions were statistically cointegrated when government stability was used as a proxy for institutional quality. However, financial development proved not significant in the long run for both the ARDL and NARDL models. This finding further strengthened the arguments by Acheampong and Boateng [8] who concluded that financial development has no direct impact on CO<sub>2</sub> emissions. The test on Model 2 revealed that economic growth, financial development, and energy use, in both symmetric and asymmetric approaches, significantly influenced CO<sub>2</sub> emissions when corruption was used as a proxy for institutional quality in the long- and short-run. However, a positive shock from corruption did not influence CO<sub>2</sub> emissions. This indicates that for any successful measures in controlling corruption, its effect on CO<sub>2</sub> emissions can only be captured in the longer term. Finally, in Model 3, law and order was cointegrated as attributes to institutional quality. The variables in ARDL and NARDL employed for the model—namely financial development, energy use, law and order—were proven statistically significant in both the long- and short-term, excluding the positive shocks for law and order. Therefore, for institutional quality to strongly influence CO<sub>2</sub> emissions, the country needs to strengthen its law and order. The bigger rating indicates higher public respect for the law especially on environment related issues, which translates into stronger mitigation on CO<sub>2</sub> emissions.

In these concerns, several policy implications can be suggested to Malaysian authorities. First, The Malaysian government should work together with private financial providers to develop a policy that can ease financial constraints through having residents, firms, and the industries to contribute to environmentally friendly technologies such as installing renewable energy sources. This may also reduce government burden on energy demand pressure whilst aiming for reduction in CO<sub>2</sub> emissions. Further, the study made it clear that to decrease CO<sub>2</sub> emission, intervention from a clean government is requisite especially on aspects of government stability, reducing corruption, and effective execution of law and order. The healthier governance thus allows for the country to deliver appropriate laws, rules, and regulations to end corruption, exclusively on environmental related projects, for consequent improvement on environmental quality.

This study contributes to the literature on environmental related areas ranging from economics, science, engineering, and energy use aspects. These above-mentioned research areas have one resemblance which is digging approaches to achieve sustainable development goals. In the path of achieving sustainable development goals, a strong policy framework is needed to continuously support the development of green technologies and less carbon-intensive economics activities. Furthermore, this development of green technology can indeed be achieved by receiving help from a stable financial system and a sound institutional quality especially in developing countries [7]. This is validated by the finding of this study that financial development and institutional quality were proven statistically significant in both the long- and short-term in mitigating carbon emissions in Malaysia. This study on an individual country apparently benefits in country-oriented implications; however, the limitation of the study is that its findings cannot be generalized for other developing countries because this study utilized a time series data on an individual country, Malaysia. Apparently, this study leaves space for future research particularly in the light considering other attributes that may influence carbon emissions such as innovation, urbanization, trade openness or population which cannot be covered in this study due to

data limitations. Furthermore, the current histrionic worldwide health tragedy which is the COVID-19 pandemic has now been an international debate regarding its negative effects on economic growth, social fabric, and human mobility [60,61]. Hence, it is worth considering this issue as one of the crucial elements in research fields of environmental economics and sustainable development. Regarding interconnection between economic and financial development, the literature can be extent by employing a fresh approach introduced by Diebold and Yilmaz [62] to measure the volatility spillover on global financial crisis. This is an interesting topic related to environmental economics because the global financial crisis has a long-term externalities effect not only on economic growth, but also for the environmental quality especially in developing countries [63].

**Author Contributions:** Conceptualization, F.D.A.R. and N.K.; methodology, F.D.A.R. and N.K.; software, N.K.; validation, N.K.; formal analysis, F.D.A.R., N.K. and M.H.A.; investigation, F.D.A.R., N.K. and M.H.A.; resources, F.D.A.R. and N.K.; data curation, F.D.A.R. and N.K.; writing—original draft preparation, F.D.A.R., N.K. and M.H.A.; writing—review and editing, F.D.A.R., N.K. and M.H.A.; visualization, N.K.; supervision, N.K. and M.H.A.; project administration, F.D.A.R., N.K. and M.H.A. All authors have read and agreed to the published version of the manuscript.

**Funding:** This research was funded by UNIVERSITI KEBANGSAAN MALAYSIA, grant number EP-2019-010.

**Institutional Review Board Statement:** Not applicable.

**Informed Consent Statement:** Not applicable.

**Data Availability Statement:** Data are available from sources as indicated in Table 2.

**Conflicts of Interest:** The authors declare no conflict of interest.

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