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Does Technological Innovation Advance Environmental Sustainability in ASEAN Countries?

Tabish Nawab[1], Muhammad Azhar Bhatti[2], Muhammad Atif Nawaz[3]
[1] PhD Scholar/ Teaching Assistant, Department of Economics, Ibn Haldun University, Istanbul, Turkey.
Email: tabish.nawab@ibnhaldun.edu.tr
[2] Associate Lecturer, Department of International Trade, The Islamia Univesity of Bahawalpur, Pakistan.
Email: azhar.bhatti219@gmail.com
[3] Lecturer, Department of Economics, The Islamia University of Bahawalpur, Pakistan.
Email: atif.nawaz@iub.edu.pk

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ABSTRACT

Environment degradation is a very important issue in developing nations and a lot of research had done to examine the factors of environmental degradation but these studies were missed some important factors which are covered by this study. By examining the effect of economic growth and energy in the presence of renewable energy consumption and technology innovation on environment degradation for ASEAN nations. Panel ARDL (which is PMG and MG) is used to estimate the model, and the advantage of this model is it gives both the long and short-run estimates of the model which helps to understand the situation in both short as well as long run. The results confirm that economic growth, Population, trade, and renewable energy increase the carbon emission level in ASEAN nations. While technology innovation decreased carbon emission levels which means technology innovation helps to keep the environment healthy and clean. Hence, economic growth helps the nations to improve their energy mode from non-renewable to renewable energy, which meets the energy demand by keeping the environment clean.

Corresponding Author's Email: tabish.nawab@ibnhaldun.edu.tr

1. Introduction

In both developing and developed countries, the energy demand increased due to rapid technological progress and economic development. Economic growth increased by the use of energy consumption, and it also caused environmental degradation (Saidi & Mbarek, 2016). In the last few years, globally environmental pollution is a detrimental issue due to a boost in greenhouse gases (DOĞAN & Seker, 2016). Industrials sector growth boost the carbon emission level and also GHG emission levels (Chen, Chen, Hsu, & Chen, 2016). Furthermore, energy relating to CO_2 emissions anticipated will be raised by 40% to 110% till 2030 IPCC (2007). Thus, it is needed to explore the factors related to energy consumption that affect the carbon emission level (CO2) and maintain the low carbon emission and boosts the development level.

Most of the past studies focused on energy usage, economic growth and carbon emission CO2. According to the literature, it's difficult to estimate the impact of energy use on environmental degradation (Ozturk & Acaravci, 2013; Zhang, 2011). Further explained that economies should divert their attention toward renewable energy forsake to reach sustainable growth. In the future, we will depend on renewable and nonrenewable energy consumption (Sadorsky, 2009). Globally in 2014, almost the portion of renewable energy use is almost 19.2 percent. According to the International Energy Agency (IEA) renewable energy is the most significant indicator which grows the global level of energy consumption. For example, in the USA's economy, renewable energy is the determinantal role to increase electricity demand. To tackle the environmental degradation problem, some environmental economists (Amini, Nabi,

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& Haghifam, 2013; Boroojeni et al., 2016) studied that renewable energy has a significant role to produce carbon-free consumption. Dogan (2016) examined the affiliation among renewable and nonrenewable energy on the development of the economy. Hence, there needs to be approximate the impact of renewable energy on carbon discharge besides the theoretical averaged relationship of ASEAN countries among carbon emissions. Average Economic growth and carbon emission level in ASEAN nations are discussed in a table and figure 1 (World Bank, 2020).

Table 1: Average of CO2 Emission and GDP of selected ASEAN countries

Country	Avg (CO2)	Avg (GDP)
Darussalam	20.5509	10.2779
Cambodia	0.340701	6.54341
Indonesia	1.67491	7.64046
Malaysia	7.21213	8.90891
Myanmar	0.364657	6.30465
Philippines	0.956038	7.50303
Singapore	9.2266	10.5949
Thailand	4.10528	8.30799
Vietnam	1.49569	6.98721

Table 1 shows that the average carbon emission of ASEAN countries with their economic growth (GDP) of the period of 2000 to 2018. The selected ASEAN countries Brunei Darussalam's average carbon emission is 20.55 metric tons and growth is 10.27 which is highest in the selected ASEAN countries, Singapore has the second-highest with 9.22 and 10.59 and at the third is Malaysia and Cambodia has the lowest carbon emission and economic growth with 0.34 and 6.54 (World Bank, 2020).

Figure 1: ASEAN countries Carbon emissions and economic growth.

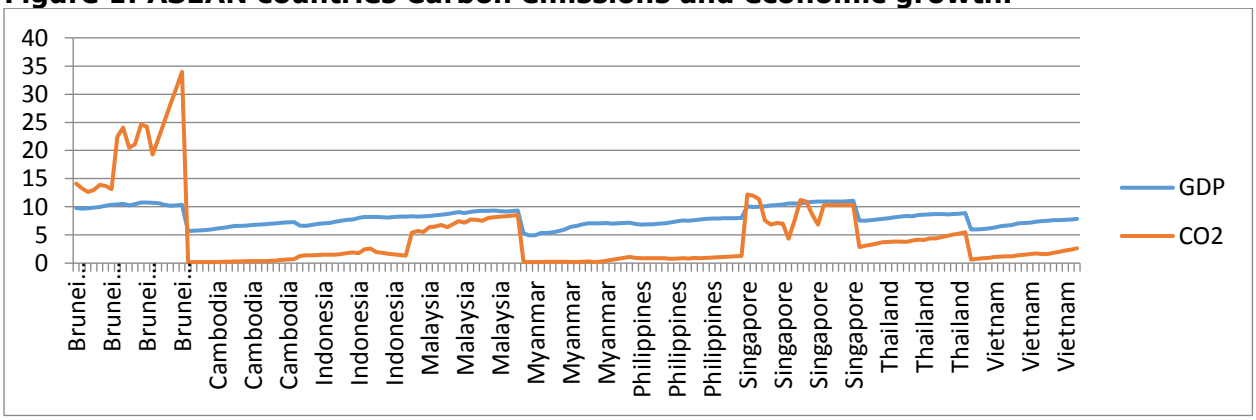

Figure 1 shows that there exists a positive affiliation between CO2 emissions and economic development. For example, over time, economic progress and carbon emissions from Cambodia, Malaysia, Myanmar, Philippines, Thailand, and Vietnam are increasing, and Brunei Darussalam and Singapore fluctuate, have increased, and both have decreased the trend from 2000 to 2018.

Technological innovation plays a significant role in environmental degradation because it improves the efficiency of energy Hang and Tu (2007); Zhou, Levine, and Price (2010), when they inspect the factors of CO2 emissions, it is an essential and worthy factor. To produce high output technology, it allows by using low energy levels (Sohag, Begum, Abdullah, & Jaafar, 2015b). Moreover, due to technological innovations, renewable energy effects efficiently energy consumption and fulfil energy demand in a short period of a spell. Therefore, the earliest research broadly discussed and examined the association between energy and economic progress in the context of carbon emission. The past studies did not study the influence of technological revolution to gears the energy level, for example, renewable energy and energy economic development.

This study increases the research target debates on technological innovation's impact on CO_2 emissions. According to the present literature Bilgili, Koçak, and Bulut (2016); Bölük and Mert (2014); Fang (2011); López-Menéndez, Pérez, and Moreno (2014); Muhammad A Nawaz and Hassan (2016) estimated results are biased due to traditional econometrics models which are unable to handle heterogeneous effect in the model. Some researchers used the multivariate models to estimate the affiliation among carbon emission and economic growth with significant controlled variables, due to variables biases the results are not unbiased of the energy growth hypothesis. To overcome this issue, this study explored the energy growth relationship in the context of panel regression and also included the all-important and significant controlled variables.

The present study has several overcome on the existing literature. Firstly, most current studies fail to examine the inspiration for energy consumption used in their model by source. We comprise nonrenewable and renewable energy causes individually on carbon emission with controlled indicators for ASEAN countries. So, this study gives the precise results of the energy, renewable energy environment of ASEAN countries. According to past studies, there exit the problem of omitted variables biases. This study, considered important indicators that affect the environment and solve omitted variables biases. According to previous studies, there is a lack of agreement to estimate energy and growth affiliation. This study overcomes this issue by the use of a proper econometrics model and technique, which gives better evidence for policymakers to make the appropriate policies to overcome environmental degradation in that region and make the environment healthy and clean.

The rest of the study is followed as section 2 represents the literature review, section 3 explained the data & methodology, section 4 interpreted the results, and finally, the last section concludes the policy recommendations.

2. Literature review

According to past literature, there exist main three groups which theoretically and empirically examined the connection of energy growth. The first group faces variable biases because they used the bivariate association among carbon emission and economic growth. The results confirm that these studies only used the bivariate Environment EKC hypothesis, which is (Al-Mulali & Ozturk, 2016; Al-Mulali, Saboori, & Ozturk, 2015; Al-Mulali, Solarin, & Ozturk, 2016; Dinda & Coondoo, 2006). So, they used economic growth and carbon emission and ignore the other important factors which affect the environment. Hence, it creates the omitted variables biases. And these studies also confirmed the omitted variables biases (Kasman & Duman, 2015; Lin & Moubarak, 2014; Sebri & Ben-Salha, 2014). To tackle the problem of biasness problem, these studies guide some important indictor in the EKC hypothesis (Dogan & Turkekul, 2016; Du, Wei, & Cai, 2012), which are energy consumption in the presence of the EKC hypothesis besides estimating the association of growth to carbon emission then confirmed that only the EKC theory is not valid. Some studies confirmed the EKC hypothesis (Li, Wang, & Zhao, 2016; Seker, Ertugrul, & Cetin, 2015) by the U-shaped environmental EKC hypothesis. But on the other hand, some studies contradict U shaped connection among growth and energy, which means opposite the EKC hypothesis (He & Richard, 2010). So according to the above-discussed studies they are failed to find out the exact relationship between growth and also failed to verify the EKC hypothesis.

The estimates between CO_2 emissions and energy consumption are also controversial. Few research studies concluded that carbon emission (CO_2) emissions boost the total energy consumption (Dogan & Seker, 2016; Kasman & Duman, 2015; Seker, Ertugrul, & Cetin, 2015; Wang, Li, Fang, & Zhou, 2016). On the other hand, some studies (Dogan & Seker, 2016; Kasman & Duman, 2015) found a unidirectional association between growth and carbon production. According to Omri (2013); Seker et al. (2015), CO_2 emissions, besides economic growth, have one-way (unidirectional) causation. And some studies applied the Granger causality examination, and results confirmed the positive connection among carbon emission to economic evolution in the presence of total energy consumption (Sadorsky, 2009). On the other hand, fossil fuel energy, the nonrenewable form of energy is discussed with the total energy used to estimate the energy growth relationship. According to these studies, they just include renewable energy in the environment EKC hypothesis.

While in the presence of efficiency in the innovation of technology, it boosts the growth and decrease in the carbon emission level, which is due to the introduction of renewable

energy consumption (Kula, 2014; Tugcu & Tiwari, 2016). These studies confirm the bidirectional connection among renewable energy use and economic development. These are some shreds of evidence that confirmed the bidirectional association between renewable energy and economic growth (N Apergis & Payne, 2015; Inglesi-Lotz, 2016). Further, these studies originated the renewable energy boosts the growth level, which confirmed that an increase in the carbon emission level (Al-Mulali et al., 2015; Al-Mulali et al., 2016; Jebli, Youssef, & Ozturk, 2016; Shafiei & Salim, 2014). A positive association between renewable energy and growth on carbon production owed to renewable energy and better economic condition promoted the environment healthily due to renewable energy consumption, which emits less amount of carbon emission. So renewable energy decreased carbon emissions in high-income countries (N Apergis & Payne, 2015; López-Menéndez et al., 2014). So, these studies confirmed the association between energy use, economic development, and carbon production are almost mixed.

Some other studies discussed the influence of technology on the renewable energy usage associated with nonrenewable (fossil fuel) energy and boosted the environmental level. According to Chiu and Chang (2009), renewable energy, economic development and atmosphere levels are favourable. Moreover, Tang and Tan (2013) confirmed the EKC theory in the presence of renewable energy further these results indicate that renewable energy decreased fossil fuel energy consumption. Furthermore, they create a positive effect of research and development on growth and mitigate the carbon emission level. Investment in research and development improve the technology level which results in boosts in the economic growth level and ultimately decreases the carbon emission level (Jones, 2002). Hence, technological innovation is the central part of improving energy efficiency and reducing energy consumption (Sohag, Begum, Abdullah, & Jaafar, 2015a).

So, it is concluded that just economic growth is not sufficient to verify the EKC hypothesis; there need some supporting indicators. According to some studies, some controlled variables like renewable and total energy consumption in the EKC hypothesis model (Narayan & Smyth, 2009; Rafiq, Salim, & Nielsen, 2016; Zhu, Duan, Guo, & Yu, 2016). Due to the ignorance of some essential controlled indicators, the results are not unbiased and reliable. According to some studies, using some controlled variables to resolve omitted variables and outcomes is impartial and credible.

Hence, this study analyzes the impression of economic development on carbon emission in the presence of technological revolution and energy use, like renewable energy consumption with the appropriate panel cointegration econometrics model. The benefit of this methodology gives detailed estimates for sorting the problem of heterogeneity and omitted variable biases.

3. Methodology and data

This study overcome the omitted variable biases, which were discussed in the literature review. And most importantly this study wants to examine the influence of economic development on carbon emission in the presence of technological innovation, for ASEAN countries. Because literature confirms that economic growth has a significant effect on environmental degradation while technology innovation becomes an essential factor to save energy and enhances economic growth by reducing the carbon emission level by replacing fossil fuel with renewable energy.

According to do Valle Costa, La Rovere, and Assmann (2008); Silva, Soares, and Afonso (2013) they discussed the importance of technological innovation by developing the renewable energy sector, so the model becomes;

$$CO2 = f (REC, TECH, POP, GDPPCG, TRADE) \quad (1)$$

Where CO2 is a dependent variable which is proxied by carbon dioxide discharge metric ton, renewable energy is regulated by the "use of renewable energy of % total energy, total patent applications used a proxy for technology, and the population is measured by annual % of population and income is measured by per capita growth."

3.1 Panel Unit root

In this study, we have a panel of 6 ASEAN countries before moving to econometrics analysis. First of all, we examine the stationarity of variables to check the order of integration. The Levine Line Chu (LLC) is used to verify the unit root/order of integrating the series. The outcomes of the panel unit root test are shown in Table 2. Some variables are stationary at level, and some are first difference, which means there exists the mixed order of integration so, move to the panel ARDL panel, which is represented by (PMG) and (MG).

3.2 Mean Group

To estimate the long and short-run estimates this study use the PMG and MG panel econometrics models which are based on the Auto Regressive Distributive Lag (ARDL). The mean group model (MG) is derived from (Pesaran, Shin, & Smith, 1999). The problem of heterogeneity in the dynamic problem is solved by estimating MG, and another advantage is that the MG estimator provides a long-run coefficient for the panel data. Estimate long-term parameters by long-term averaging parameters estimated through ARDL models for individual countries. The ARDL model follows these guidelines:

$$Y_{it} = \alpha_{it} + \gamma_i Y_{i,t-1} + \beta_i X_{it} + \varepsilon_{it} \quad (2)$$

According to equation 2, i stand for the number of cross-sections, which are several countries, and i stands for the number of observations, which is $i = 1,2,3,\ldots\ldots..,N.$

3.3 Pooled Mean Group

For panel analysis, the most appropriate technique used dynamically is ARDL (p, q) with an error correction mechanism. Therefore the estimate of the average group (MG), which is represented by Pesaran and Smith (1995) and The Pooled Mean Group (PMG), is developed by (Pesaran et al., 1999). Its form of representation is shown below.

$$Y_{it} = \sum_{j=1}^{p-1} \gamma_i (Y_i)_{t-j} + \sum_{j=0}^{q-1} \sigma_i (X_i)_{t-j} + \phi_i (Y_i)_{t-1} + \mu_i + \varepsilon_{it} \quad (3)$$

In the above equation $X_{i,\ t\text{-}j}$ represents the rank of the matrix is $(k\ x\ 1)$, which is a set of descriptive variables of group i, which represents cross-sections and μ_i serves the panel data error term of the regression. If the panel data is unbalanced, p and q may vary across the countries/cross-sections. Under the conditions of the homogeneity and long-run relationship between the explained and explanatory indicators, PMG gives the best and consistent estimates instead of the MG estimates (Pesaran et al., 1999). So, according to PMG, our desired model will become like this:

$$CO2_{it} = \gamma_o + \sum_{i=1}^{p} \gamma_1 \Delta CO2_{i,t-1} + \sum_{i=0}^{p} \gamma_2 \Delta REC_{i,t-1} + \sum_{i=0}^{p} \gamma_3 \Delta TECH_{i,t-1} + \sum_{i=0}^{p} \gamma_4 \Delta POP_{i,t-1} + \sum_{i=0}^{p} \gamma_5 \Delta GDPPCG_{i,t-1} + \sum_{i=0}^{p} \gamma_6 \Delta TRADE_{i,t-1} + \gamma_7 CO2_{i,t-1} + \gamma_8 REC_{i,t-1} + \gamma_9 TECH_{i,t-1} + \gamma_9 POP_{i,t-1} + \gamma_{10} GDPPCG_{i,t-1} + \gamma_{11} TRADE_{i,t-1} + \epsilon_{it} \quad (4)$$

3.4 Hausman Test

The Hausman test was used to verify that the estimates' results are better and consistent between the PMG and the MG. Hausman's analysis's null hypothesis is that there is no variation among the estimates of PMG and MG. An alternative explanation belongs that does exist a gap between them.

$$Ho = There\ is\ no\ difference\ between\ the\ PMG\ and\ MG\ estimates\ and\ uses\ the\ PMG\ model$$
$$Ha = difference\ between\ PMG\ and\ MG\ estimates\ and\ use\ the\ MG\ model$$

4. Results and Discussion

According to table 3, GDP per capita and population are stationary at a level, and others that are CO2 Emission, energy, trade, and technology innovation are at first difference. The results of the Hausman test confirms that the estimates of the pooled mean group (PMG) are more efficient which are explained in table 4, as compared to Mean Group (MG).

Table 2: Summary statistics of variables

Variables	Obs	Mean	Std.	Min	Max
CO2	114	2.631	2.437	0.163	8.548
REC	114	34.753	20.833	3.819	83.020
TECH	114	4100.307	2654.911	13	9754
POPGDPCG	114	1.337	0.481	0.315	2.325
GDPPCG	114	4.264	2.110	-3.286	11.485
TRADE	114	117.970	44.778	37.421	220.407

According to table 4, ECT confirms that there exists a long-run relationship between renewable energy consumption, technology innovation, population, economic growth, trade and environment degradation. And the model moves to its equilibrium within 4 years. According to table 4, renewable energy consumption, economic growth and trade have a positive effect on the environment while technology innovation helps to keep the environment clean. So, in the case of ASEAN countries, renewable energy increases the carbon emission level because it has less share in the total energy consumption. So, the rise in renewable energy leads to growth in energy usage, which ultimately increases the carbon discharge level. Renewable energy is the vital aspect of decreasing the carbon emission level, but in the case of these selected ASEAN countries, it boosts the carbon emission level and also plays a vital role in environmental degradation, which is similar to these studies (Al-Mulali & Ozturk, 2016; Nicholas Apergis, Payne, Menyah, & Wolde-Rufael, 2010; Bölük & Mert, 2014; Jebli et al., 2016; Seker et al., 2015; Shafiei & Salim, 2014) and also recommended that positive affiliation among the renewable energy consumption besides carbon emission (Nicholas Apergis et al., 2010; Bölük & Mert, 2014; Farhani & Rejeb, 2012) and contradicted with these studies Menyah and Wolde-Rufael (2010) which explained that there exists the inverse affiliation among the renewable energy and carbon emission level.

Table 3: Panel Unit root test (Levin-Lin-Chu)

	Level		First Diff.	
Variables	Coef.	Prob.	Coef.	Prob.
CO2	0.149	0.559	-4.512	0.000
REC	-0.284	0.388	-2.812	0.003
GDPPCG	-3.393	0.000		
TECH	0.504	0.693	-7.515	0.000
TRADE	-0.830	0.203	-5.098	0.000
POP	-1.460	0.072		

Technological innovation prevents the carbon emission level, which indicates the increase in the level of technology reduced the carbon emission level in ASEAN countries. However, its effects are minimal, almost zero, which further means that technological innovation has a minor effect on the carbon emission level. But according to the literature, it is a significant factor to diminish the carbon emission level by growing the energy level. Results to increase in growth and further, reduces the carbon production by replacing the renewable energy with fossil fuel Bento and Moutinho (2016); do Valle Costa et al. (2008) and results are also consisting with (do Valle Costa et al., 2008; Farhani & Rejeb, 2012; Jamil & Ahmad, 2011; Muhammad Atif Nawaz, Azam, & Bhatti, 2019; Sohag et al., 2015a; Tang & Tan, 2013; Zhou et al., 2010). They further explained that technological innovation plays a crucial role in tackling the increasing carbon emission level trend in those countries where a rise in carbon emission due to the high economic growing consumer wants to utilize more energy consumption to fulfil the production demand. Hence, they require technological innovation to cover the production level with current energy consumption, renewable energy. That results in a rise in energy use, leading to a boost in economic development and decreasing the carbon emission level.

Economic growth has a positive effect on carbon emission levels the results also verified the EKC hypothesis which means that rise in the economic development level rise in the emission level and these results are also similar to these studies (Chandran & Tang, 2013; Du et al., 2012; Jebli et al., 2016; Li, Wang, & Zhao, 2016; Pao & Tsai, 2011; Seker et al., 2015). It contradicts these, which found the inverse relationship between energy and growth

(Bakhtyar, Kacemi, & Nawaz, 2017; Bento & Moutinho, 2016). If the economy is developing phase, then the affiliation among growth and carbon release is less useful because it is in a contradiction phase among the environmental pollution and economic growth. Hence, they favoured high economic development with a high level of carbon emission, and after reaching a specific point, the governmental and environmental authorities need to improve the environmental level. So, in these countries, with an improvement in growth, carbon emission also steadily increased, resulting in decreased energy intensity. The impact of trade on carbon production is statistically significant and positive, which remains related to these studies (Chiu & Chang, 2009; Kasman & Duman, 2015; Shahbaz, Khraief, Uddin, & Ozturk, 2014). This further explains the increase in the level of trade in low-income countries, which boosts growth, which ultimately increases energy consumption and further boosts the carbon emission level.

Table 4: Results of PMG for ASEAN countries.

Dependent variable: CO2 Emission				
Variables	**Coef.**	**Std.**	**Z**	**Prob.**
Constant	0.900**	0.384	2.340	0.019
	Long-run estimates			
REC	0.070***	0.010	7.380	0.000
TECH	-0.000*	0.000	-1.790	0.074
POP	0.077	0.220	0.350	0.727
GDPPCG	0.094***	0.023	4.030	0.000
TRADE	0.290*	0.155	1.870	0.062
ECT	-0.314**	0.148	-2.120	0.034
	Short-run estimates			
D1.REC	0.051	0.038	1.340	0.181
D1.TECH	0.000	0.000	-1.140	0.252
D1. POP	0.459	2.575	0.180	0.858
D1. GDPPCG	-0.006	0.013	-0.500	0.616
D1.TRADE	-0.637	0.622	-1.020	0.306

Note: ***,** *and* * *show* 1%, 5% *and* 10% *level of significance respectively.*

According to the results, technological innovation is a detrimental factor in handling environmental degradation by reducing the carbon emission level with the use of nonrenewable energy, which ultimately increases energy use, boosts economic development, and improves the environment by reducing carbon emission levels.

5. Conclusion

This study used the panel ARDL (PMG) model to estimate the EKC hypothesis in the presence of technological innovation for 6 selected ASEAN countries from 2000 to 2018. This study also overcame the problem of omitted variable biases by taking the model's critical controlled variables. So, the EKC hypothesis within renewable energy and technological invention is estimated for selected ASEAN countries. Renewable energy, economic growth, and trade boost the carbon emission level while technological innovation creates hurdles in the carbon release level. There are two main reasons for economic growth positive impact on carbon emission levels. Firstly, to maintain an adequate development level, countries need to boost economic progress, which increases the carbon release level after attaining that development level, the environmental authorities also improved the environment. Secondly, technological innovation reduces the carbon emission level, and technological innovation is the crucial determinantal element to boost the energy level by introducing renewable energy consumption, which increases economic development and reduces the carbon emission level. Furthermore, trade boosts economic growth, which ultimately increases the carbon emission level.

Growth in the economic development level leads to a rise in energy use, so the demand for renewable energy increased that move to increase in the carbon release level. According to high carbon emission, countries try to diminish the carbon emission level by using technological change and using renewable energy instead of fossil fuel (nonrenewable) energy, resulting in an upsurge in energy while reducing the carbon discharge level. So, renewable

energy mitigates the carbon emission level, so the country tries to use more renewable energy than others to meet the desired environment. The other option is to handle the carbon emission level by increasing the technological sector's investment by importing new machinery and technologies. Furthermore, the transformation of the economic growth model is useful for transferring nonrenewable energy sources to renewable sources, reducing the carbon emission level. And the adoption of renewable energy technology also helps to keep the environment green and healthy.

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