Does Technological Innovation Advance Environmental Sustainability in ASEAN Countries?

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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.

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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 CO₂ 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,
& 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 fulfill 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 CO₂ 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 CO₂ emissions and energy consumption are also controversial. Few research studies concluded that carbon emission (CO₂) 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), CO₂ 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;

\[ \text{CO2} = f(\text{REC, TECH, POP, GDPPCG, TRADE}) \]  

Where \( \text{CO2} \) 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:

\[ Y_{it} = \alpha_{it} + \gamma_i Y_{it-1} + \beta_i X_{it} + \epsilon_{it} \]  
(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 \( i = 1,2,3,...,N \).

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.

\[ Y_{it} = \sum_{j=1}^{p-1} \gamma (Y)_{i,t-j} + \sum_{j=0}^{q-1} \beta (X)_{i,t-j} + \phi (Y)_{i,t-1} + \mu_i + \epsilon_{it} \]  
(3)

In the above equation, \( X_{i, t} \) represents the rank of the matrix is \((k \times 1)\), which is a set of descriptive variables of group \(i\), which represents cross-sections and \( \mu_i \) 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:

\[
\begin{align*}
CO2_{it} & = \gamma_0 + \sum_{j=1}^{p} \gamma_j C02_{it-1} + \sum_{j=0}^{q} \gamma_j REC_{it-1} + \sum_{j=0}^{p} \gamma_j TECH_{it-1} + \sum_{j=0}^{p} \gamma_j POP_{it-1} + \\
& \sum_{j=0}^{p} \gamma_j GDPPCG_{it-1} + \sum_{j=0}^{p} \gamma_j TRADE_{it-1} + \gamma_7 C02_{it-1} + \gamma_7 REC_{it-1} + \gamma_7 TECH_{it-1} + \gamma_7 POP_{it-1} + \\
& \gamma_7 GDPPCG_{it-1} + \gamma_7 TRADE_{it-1} + \epsilon_{it}
\end{align*}
\]  
(4)

3.4 Hausman Test

The Hausman test was used to verify that the estimates' results are better and consistent between the PMG and 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.

\[ H_0 = \text{There is no difference between the PMG and MG estimates and uses the PMG model} \]
\[ H_a = \text{difference between PMG and MG estimates and use the MG model} \]

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)

| Variables | Level Coef. | Level Prob. | First Diff. Coef. | First Diff. 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 fulfill 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.
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 | 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.

References
Al-Mulali, U., & Ozturk, I. (2016). The investigation of environmental Kuznets curve hypothesis in the advanced economies: the role of energy prices. Renewable Sustainable Energy Reviews, 54, 1622-1631. doi:10.1016/j.rser.2015.10.131
Al-Mulali, U., Saboori, B., & Ozturk, I. (2015). Investigating the environmental Kuznets curve hypothesis in Vietnam. Energy policy, 76, 123-131. doi:10.1016/j.enpol.2014.11.019
Al-Mulali, U., Solarin, S. A., & Ozturk, I. (2016). Investigating the presence of the environmental Kuznets curve (EKC) hypothesis in Kenya: an autoregressive distributed lag (ARDL) approach. Natural Hazards, 80(3), 1729-1747. doi:10.1007/s11069-015-2050-x
Apergis, N., & Payne, J. E. (2015). Renewable energy, output, carbon dioxide emissions, and oil prices: evidence from South America. Energy Sources, Part B: Economics, Planning, and Policy, 10(3), 281-287. doi:10.1080/15567249.2013.853713
Apergis, N., Payne, J. E., Menyah, K., & Wolde-Rufael, Y. (2010). On the causal dynamics between emissions, nuclear energy, renewable energy, and economic growth. Ecological Economics, 69(11), 2255-2260. doi:10.1016/j.ecolecon.2010.06.014
Bakhtyar, B., Kacemi, T., & Nawaz, M. A. (2017). A review on carbon emissions in Malaysian cement industry. International Journal of Energy Economics and Policy, 7(3), 282-286.
Bento, J. P. C., & Moutinho, V. (2016). CO2 emissions, non-renewable and renewable electricity production, economic growth, and international trade in Italy. Renewable Sustainable Energy Reviews, 55, 142-155. doi:10.1016/j.rser.2015.10.151
Bilgili, F., Koçak, E., & Bulut, Ü. (2016). The dynamic impact of renewable energy consumption on CO2 emissions: a revisited Environmental Kuznets Curve approach. Renewable and Sustainable Energy Reviews, 54, 838-845. doi:10.1016/j.rser.2015.10.080
Bölük, G., & Mert, M. (2014). Fossil & renewable energy consumption, GHGs (greenhouse gases) and economic growth: Evidence from a panel of EU (European Union) countries. Energy, 74, 439-446. doi:10.1016/j.energy.2014.07.008
Chandran, V., & Tang, C. F. (2013). The impacts of transport energy consumption, foreign direct investment and income on CO2 emissions in ASEAN-5 economies. Renewable Sustainable Energy Reviews, 24, 445-453. doi:10.1016/j.rser.2013.03.054
Chen, P.-Y., Chen, S.-T., Hsu, C.-S., & Chen, C.-C. (2016). Modeling the global relationships among economic growth, energy consumption and CO2 emissions. Renewable and Sustainable Energy Reviews, 65, 420-431. doi:10.1016/j.rser.2016.06.074
Chiu, C.-L., & Chang, T.-H. (2009). What proportion of renewable energy supplies is needed to initially mitigate CO2 emissions in OECD member countries? Renewable Sustainable Energy Reviews, 13(6-7), 1669-1674. doi:10.1016/j.rser.2008.09.026
Dinda, S., & Coondoo, D. (2006). Income and emission: a panel data-based cointegration analysis. Ecological Economics, 57(2), 167-181. doi:10.1016/j.ecolecon.2005.03.028
do Valle Costa, C., La Rovere, E., & Assmann, D. (2008). Technological innovation policies to promote renewable energies: Lessons from the European experience for the Brazilian case. Renewable Sustainable Energy Reviews, 12(1), 65-90. doi:10.1016/j.rser.2006.05.006
Dogan, E. (2016). Analyzing the linkage between renewable and non-renewable energy consumption and economic growth by considering structural break in time-series data. Renewable Energy, 99, 1126-1136. doi:10.1016/j.renene.2016.07.078
Dogan, E., & Seker, F. (2016). The influence of real output, renewable and non-renewable energy, trade and financial development on carbon emissions in the top renewable energy countries. Renewable Sustainable Energy Reviews, 60, 1074-1085. doi:10.1016/j.rser.2016.02.006
DOĞAN, E., & Seker, F. (2016). The influence of real output, renewable and non-renewable energy, trade and financial development on carbon emissions in the top renewable energy countries. doi:10.1016/j.rser.2016.02.006
Dogan, E., & Turkekul, B. (2016). CO2 emissions, real output, energy consumption, trade, urbanization and financial development: testing the EKC hypothesis for the USA. *Environmental Science and Pollution Research, 23*(2), 1203-1213. doi:10.1007/s11356-015-5323-8

Du, L., Wei, C., & Cai, S. (2012). Economic development and carbon dioxide emissions in China: Provincial panel data analysis. *China Economic Review, 23*(2), 371-384. doi:10.1016/j.chieco.2012.02.004

Fang, Y. (2011). Economic welfare impacts from renewable energy consumption: the China experience. *Renewable and Sustainable Energy Reviews, 15*(9), 5120-5128. doi:10.1016/j.rser.2011.07.044

Farhani, S., & Rejeb, J. B. (2012). Energy consumption, economic growth and CO2 emissions: Evidence from panel data for MENA region. *International Journal of Energy Economics Policy, 2*(2), 71-81.

Hang, L., & Tu, M. (2007). The impacts of energy prices on energy intensity: evidence from China. *Energy policy, 35*(5), 2978-2988. doi:10.1016/j.enpol.2006.10.022

He, J., & Richard, P. (2010). Environmental Kuznets curve for CO2 in Canada. *Ecological Economics, 69*(5), 1083-1093. doi:10.1016/j.ecolecon.2009.11.030

Inglesi-Lotz, R. (2016). The impact of renewable energy consumption to economic growth: A panel data application. *Energy Economics, 53*, 58-63. doi:10.1016/j.eneco.2015.01.003

Jamil, F., & Ahmad, E. (2011). Income and price elasticities of electricity demand: Aggregate and sector-wise analyses. *Energy policy, 39*(9), 5519-5527. doi:10.1016/j.rser.2011.05.010

Jebli, M. B., Youssef, S. B., & Ozturk, I. (2016). Testing environmental Kuznets curve hypothesis: The role of renewable and non-renewable energy consumption and trade in OECD countries. *Ecological Indicators, 60*, 824-831. doi:10.1016/j.ecolind.2015.08.031

Jones, A. (2002). An environmental assessment of food supply chains: a case study on dessert apples. *Environmental management, 30*(4), 560-576. doi:10.1007/s00267-002-2383-6

Kasman, A., & Duman, Y. S. (2015). CO2 emissions, economic growth, energy consumption, trade and urbanization in new EU member and candidate countries: a panel data analysis. *Economic Modelling, 44*, 97-103. doi:10.1016/j.econmod.2014.10.022

Kula, F. (2014). The long-run relationship between renewable electricity consumption and GDP: evidence from panel data. *Energy Sources, Part B: Economics, Planning, and Policy, 9*(2), 156-160. doi:10.1080/15567249.2010.481655

Li, T., Wang, Y., & Zhao, D. (2016). Environmental Kuznets curve in China: new evidence from dynamic panel analysis. *Energy policy, 91*, 138-147. doi:10.1016/j.enpol.2016.01.002

Lin, B., & Moubarak, M. (2014). Renewable energy consumption–Economic Growth nexus for China. *Renewable and Sustainable Energy Reviews, 40*, 111-117. doi:10.1016/j.rser.2014.07.128

López-Menéndez, A. J., Pérez, R., & Moreno, B. (2014). Environmental costs and renewable energy: Re-visiting the Environmental Kuznets Curve. *Journal of Environmental Management, 145*, 368-373. doi:10.1016/j.jenvman.2014.07.017

Menyah, K., & Wolde-Rufael, Y. (2010). CO2 emissions, nuclear energy, renewable energy and economic growth in the US. *Energy policy, 38*(6), 2911-2915. doi:10.1016/j.enpol.2010.01.024

Narayan, P. K., & Smyth, R. (2009). Multivariate Granger causality between electricity consumption, exports and GDP: evidence from a panel of Middle Eastern countries. *Energy Policy, 37*(1), 229-236. doi:10.1016/j.enpol.2008.08.020

Nawaz, M. A., Azam, M. A., & Bhatti, M. A. (2019). Are Natural Resources, Mineral and Energy Depletions Damaging Economic Growth? Evidence from ASEAN Countries. *Pakistan Journal of Economic Studies, 2*(2).

Nawaz, M. A., & Hassan, S. (2016). Tourism in South Asia. *International Journal of Economic Perspectives, 10*(4).

Omri, A. (2013). CO2 emissions, energy consumption and economic growth nexus in MENA countries: Evidence from simultaneous equations models. *Energy Economics, 40*, 657-664. doi:10.1016/j.eneco.2013.09.003

Pao, H.-T., & Tsai, C.-M. (2011). Modeling and forecasting the CO2 emissions, energy consumption, and economic growth in Brazil. *Energy, 36*(5), 2450-2458. doi:10.1016/j.energy.2011.01.032

Pesaran, M. H., Shin, Y., & Smith, R. P. (1999). Pooled mean group estimation of dynamic heterogeneous panels. *Journal of the American Statistical Association, 94*(446), 621-634. doi:10.1080/01621459.1999.10474156
Pesaran, M. H., & Smith, R. (1995). Estimating long-run relationships from dynamic heterogeneous panels. *Journal of econometrics, 68*(1), 79-113. doi:10.1016/0304-4076(94)01644-F

Rafiq, S., Salim, R., & Nielsen, I. (2016). Urbanization, openness, emissions, and energy intensity: a study of increasingly urbanized emerging economies. *Energy Economics, 56*, 20-28. doi:10.1016/j.eneco.2016.02.007

Sadorsky, P. (2009). Renewable energy consumption, CO2 emissions and oil prices in the G7 countries. *Energy Economics, 31*(3), 456-462. doi:10.1016/j.eneco.2008.12.010

Saidi, K., & Mbarek, M. B. (2016). Nuclear energy, renewable energy, CO2 emissions, and economic growth for nine developed countries: Evidence from panel Granger causality tests. *Progress in Nuclear Energy, 88*, 364-374. doi:10.1016/j.pnucene.2016.01.018

Sebri, M., & Ben-Salha, O. (2014). On the causal dynamics between economic growth, renewable energy consumption, CO2 emissions and trade openness: Fresh evidence from BRICS countries. *Renewable and Sustainable Energy Reviews, 39*, 14-23. doi:10.1016/j.rser.2014.07.033

Seker, F., Ertugrul, H. M., & Cetin, M. (2015). The impact of foreign direct investment on environmental quality: a bounds testing and causality analysis for Turkey. *Renewable Sustainable Energy Reviews, 52*, 347-356. doi:10.1016/j.rser.2015.07.118

Shafiei, S., & Salim, R. A. (2014). Non-renewable and renewable energy consumption and CO2 emissions in OECD countries: A comparative analysis. *Energy policy, 66*, 547-556. doi:10.1016/j.enpol.2013.10.064

Shahbaz, M., Khraief, N., Uddin, G. S., & Ozturk, I. (2014). Environmental Kuznets curve in an open economy: A bounds testing and causality analysis for Tunisia. *Renewable Sustainable Energy Reviews, 34*, 325-336. doi:10.1016/j.rser.2014.03.022

Silva, S., Soares, I., & Afonso, O. (2013). Economic and environmental effects under resource scarcity and substitution between renewable and non-renewable resources. *Energy policy, 54*, 113-124. doi:10.1016/j.enpol.2012.10.069

Sohag, K., Begum, R. A., Abdullah, S. M. S., & Jaafar, M. (2015a). Dynamics of energy use, technological innovation, economic growth and trade openness in Malaysia. *Energy policy, 90*, 1497-1507. doi:10.1016/j.energy.2015.06.101

Sohag, K., Begum, R. A., Abdullah, S. M. S., & Jaafar, M. (2015b). Dynamics of energy use, technological innovation, economic growth and trade openness in Malaysia. *Energy, 90*, 1497-1507. doi:10.1016/j.energy.2015.06.101

Tang, C. F., & Tan, E. C. (2013). Exploring the nexus of electricity consumption, economic growth, energy prices and technology innovation in Malaysia. *Applied Energy, 104*, 297-305. doi:10.1016/j.apenergy.2012.10.061

Tugcu, C. T., & Tiwari, A. K. (2016). Does renewable and/or non-renewable energy consumption matter for total factor productivity (TFP) growth? Evidence from the BRICS. *Renewable and Sustainable Energy Reviews, 65*, 610-616. doi:10.1016/j.rser.2016.07.016

Wang, S., Li, Q., Fang, C., & Zhou, C. (2016). The relationship between economic growth, energy consumption, and CO2 emissions: Empirical evidence from China. *Science of the Total Environment, 542*, 360-371. doi:10.1016/j.scitotenv.2015.10.027

World Bank, W. (2020). The World Bank. Retrieved from [https://databank.worldbank.org/source/world-development-indicators](https://databank.worldbank.org/source/world-development-indicators)

Zhou, N., Levine, M. D., & Price, L. (2010). Overview of current energy-efficiency policies in China. *Energy policy, 38*(11), 6439-6452. doi:10.1016/j.enpol.2009.08.015

Zhu, H., Duan, L.,Guo, Y., & Yu, K. (2016). The effects of FDI, economic growth and energy consumption on carbon emissions in ASEAN-5: evidence from panel quantile regression. *Economic Modelling, 58*, 237-248. doi:10.1016/j.econmod.2016.05.003