Integrated effect of energy consumption, economic development, and population growth on CO_2 based environmental degradation: a case of transport sector

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Abstract

The transportation sector consumes 25% of world energy with 23% of the world's total carbon emission. Therefore, it is necessary to investigate the integrated effect of fossil fuel source of energy consumption, economic development, and total population on CO_2 emission based on environmental degradation transportation sector. We employed the econometric method-ologies such as a hybrid error correction model, regression coefficients, platykurtic distribution, Dickey-Fuller test, and co-integration test in order to justify empirical analysis for Pakistan transport sector. Results reveal that an increase in economic growth, urbanization, and energy consumption increased transport-based environmental degradation urbanization. Moreover, very interestingly, during this period, energy consumption has increased by 13.5%, and it shows a high dependence of economic growth on energy consumption. Further, the CO_2 emission and energy consumption per capita has a positive relationship. Finally, this study has proposed some suggestion for policy and decision-makers to mitigate environmental degradation as well as make transport sector environmentally sustainable.

Keywords Energy consumption · Economic development · Transport-based CO_2 · Environmental degradation · Population growth

Introduction

The transportation sector contributes 23% to world total carbon emission, while it consumes 25% of world energy. Furthermore, transportation energy consumption is expected to increase up to 155 quadrillion B.T.U (British thermal units) in 2040 (World Energy Council 2016). Moreover, the world economy is growing at an average rate of 3.4% per year and population will increase from today's 7.4 billion to 9 billion in 2040. According to International Energy Agency (IEA) 2016, the megacities are expected to increase from 22 (today's megacities number) to 100 till 2050. Whereas, in developed countries, the transport sector energy consumption is continuously increasing and estimated more increase up to 30% due to improvement in living standards. Moreover, air pollution problems such as carbon monoxide (CO_2), nitrogen oxide

(NO_2), sulfur dioxide (SO_2), and particulate matters dangerously effecting health due to transport sector. However, carbon monoxide (CO_2) plays a significant role in deteriorating air quality and imposes serious diseases. Consequently, all these factors are making climate change more vulnerable and contributing to environmental degradation (Ratti and Vespignani 2016).

Pakistan is considered a climate-vulnerable country, and prone to environmental degradation due to CO_2 emission from the transport sector. Since the last decade, the adverse impacts of climate change has been visible due to increase of climate disasters such as floods and earthquakes in the region. However, the magnitude to which the 2010 flood afflicted Pakistan was unprecedented, and it became clear that the climate change events can occur on a bigger scale (Economic Survey of Pakistan 2017). Heat waves are another recurrent climate catastrophe in this region that killed 1250 people in 2 weeks being the prolonged heat wave in 2015 in Pakistan (Mohsin et al. 2018a). Moreover, other climate catastrophes in Pakistan are storms, avalanches, fog, smog, and shortage of clean water in the region (Mohsin et al. 2018b, 2019). According to Internal Displacement Monitoring Center (IMDC) 2017, transportation emission is a major hurdle to keep global warming below 2 °C in Pakistan, and it requires continuous efforts to ensure net-zero annual emissions. Pakistan encompasses transition economic activities, and the region is the epicenter of the world's dramatic trend such as the energy crisis, climate change, water security, and resource exploitation (Asbahi et al. 2019). The transport sector emission destroys social and economic benefits in Pakistan. Economic expansion, coupled with the world's highest rates of population outburst, exerts significant pressure on energy demand and the environment (Edenhofer and Kalkuhl 2011). Pakistan is believed to be the fastest growing region in the world having environmental problems. Development is the primary objective of this region in order to reduce poverty rate, but fossil fuel energy is a severe constraint for transport sector (Rasool et al. 2019; Seow et al. 2016).

Several studies (Brown 2017; Zhou et al. 2017; Geels et al. 2018) have been conducted to assess the anthropogenic emissions and concluded rapid economic development, improving living standards, caused increases in carbon emission. The higher amount of emissions due to increasing traffic caused great changes in regional climate, and environmental air quality produce fog, smog, and photochemical pollution. A proposed methodological framework has been developed to measure the dust pollution caused by transporting from the deserts in northwestern China and concluded its findings in winter and spring. Whereas, Cherp et al. (2018) conducted a study and observed that air pollution has a major impact on public health, climate model, and radioactive forces. Consequently, air pollution characteristics are required to show its compositions, sources, and chemical characteristics (Ru et al. 2010).

The objective of this study is to develop a framework to analyze the integrated impact of energy consumption, economic development, and population growth on CO_2-based environmental degradation through Environmental Kuznets Curve Hypothesis in transport sector. Furthermore, the study provides a set of policies to assist and originate key strategies which can perk up the environmental quality with population expansion and sustainable development (Ikram et al. 2019b). Further, the study investigated inter-temporal relationship of fossil fuel source of energy consumption, total population, and CO_2 emitted from the transportation sector. The way in which research was conducted was empirically sound and used practical, theoretical evidence which is mainly based on a quantitative framework of time series data estimation including error correction model, regression coefficients, platykurtic distribution, and Dickey-Fuller test and co-integration test. The relationship among the dependent and independent variables tried to investigate a unidirectional relationship, feedback relationship, and no causal relationships among population. Moreover, the analysis will help decision-makers to develop long-run policy. The study also offered a comprehensive policy framework to optimize the social benefits of economic development and environmental sustainability.

The rest of the paper is organized as follows: "Background of traffic trends in Pakistan" explains the methodology, "Methodology" describes data sources, "Results and discussion" explains results and discussion, and "Conclusion" contains the conclusion and policy implication.

Background of traffic trends in Pakistan

The growth rate of Pakistan's transport sector noted an increase of about 19% from 1990 to 2015 which is considered as an enormous rate, and this growth may be increased by inefficient public transport (Ahmad et al. 2016). Total motor vehicles registered in Pakistan were 17,715,428 in 2015 (Zahoor et al. 2016). Simultaneously, Pakistan railway decreased its delivery shipment while it was a significant mode of transport and it was at its peak in the 1950s, which was responsible for 73% of the freight traffic, and it was recently less than 5% in 2015. The transport sector is responsible for 90% of passengers and is currently operating up to about 95% of inland shipment (Qamar and Saeed 2016). The transport sector contributed to the national-level GDP more than 10% and 25–26% of Federal Public Programs. The quantity of vehicles on the road is greater than before from 2 million in 1990s to about 17 million in 2015 with a significant growth rate while more than 80% is made up of automobiles and motorcycles. Some two-stroke engines are 5.6 million to the total vehicles whereas trucks and diesel busses contributed more than 4 million in 2015. These types of transportation are a dramatic source of increasing rates of emissions through roadside transportation (Economic Survey of Pakistan 2017; Zhang et al. 2018). The transportation sector consumes 35% of Pakistan energy while it emits 29% of total carbon emission. Transportation energy consumption is expected to increase up to 52% by 2040.

Nowadays, the energy consumption is a burning issue. Industrialization and economic progress continuously cause an increase in energy consumption (Staddon et al. 2016). The consumption of electricity has increased from 47 billion kWh in 2000 to 90 billion kWh in 2015–2016. Pakistan is significantly relying on imported oil to produce energy for consumption. Pakistan was using 216.69 K barrels of oil in 1990–1991 while this number almost doubled until 2017 by 588.62 K barrels (Sindhu et al. 2018). By contrast, in 2017, its daily oil production was just 62 barrels, against 440 barrels of consumption. Environmental problems caused by human interface with natural resources such as exhaling CO_2 and inhaling oxygen, trade liberalization, growing population, industrialization, and urbanization all can increase environmental degradation and pollution (Roege et al. 2014; Vesterberg 2018; Frondel et al. 2018). This environmental pollution poisons the food and drinking water and also pollutes the air inhaled (Fell 2017; Frondel et al. 2018).

In an effort to reduce the increasing level of CO_2 emissions and climate change, in 2015, the United Nations Framework Convention for Climate Change (UNFCCC) and the Conference of Parties (COP) agreed to decrease global temperature to 2 °C above pre-industrial levels by 2020 (Dogan 2016; Ikram et al. 2019a, b). Therefore, sustainable development and climate change become a hot issue at a national and international level in planning for renewable energy production and consumption (Solaymani et al. 2015; Steffen 2018). An economy may turn to a sustainable track if its energy consumption contains an optimal level of renewable and non-renewable energy mixture (Mills et al. 2012; Shahbaz et al. 2019a, b), so that policymakers must know the individual contributions of energy sources on economic growth and CO_2 emissions. Numerous other studies (Bölük and Mert 2014; Lanouar 2017; All et al. 2011) concerned with energy consumption, economic growth, and environmental degradation concluded that high levels of energy consumption are central to economic growth while at the same time, it has become a significant cause of environmental deterioration in developed and developing countries. Environmental pollution is considered an equivalent to the destruction of supplied food, fuel, sea animals, air, and shelter (Hillman et al. 2018). It is necessary to keep the air fresh because it ensures fresh lakes and sustains wildlife and landscape. It provides resources such as land, water, minerals, and forests which are the backbone of economic activity. Further, it helps to absorb the economic activity such as using harmful products and can counterbalance them which helps to preserve the ozone layer, genetic diversity, and climate change (Kaygusuz 2011; Cloke et al. 2017; Zafar et al. 2019). Lack of environmental markets, ecological assets, and services amenities have no fee in Pakistan, and ecological problems such as non-optimal pricing are rising due to lack of environmental markets. In developed economies, environment is considered as a scarce source and it is not possible to get every desired resource (Shahbaz et al. 2019b: Dickey and Fuller 1979).

Methodology

Data collection

This study used the data from 1975 to 2015 to examine the integrated effect of energy consumption, economic development, and population on CO2 emission. CO2 emission data for transport sector was collected from WDI. GDP per capita is used as a proxy variable for economic growth energy intensity computed as road transport energy consumption divided by based on constant 2010 US dollar and was collected from the World Bank (WB). Energy consumption data was gathered from International Energy Agency (IEA). Whereas, population data was collected from Federal Bureau of Statistics (FBS) Pakistan.

Augmented Dickey-Fuller unit root

Augmented Dickey-Fuller (ADF) unit-root test was introduced by Johansen 1988. The popularity of the ADF test is due to its extra lag terms on dependent variables in order to decrease the autocorrelation issue. Three different models have been used in this study:

$$\Delta Y_t = \beta_1 + KX_{t-1} + a_i + \epsilon_t \text{ (For intercept only)}$$

$$\Delta Y_t = \beta_1 + \beta_2 t + KX_{t-1} + a_i + \epsilon_t \text{ (For intercept and trend)}$$

$$\Delta Y_t = KX_{t-1} + a_i + \epsilon_t \text{ (No intercept, no trend)}$$

The null and alternative hypothesis has been defined, and these above models' satisfaction is a necessary consideration as a prerequisite of the unit-root test.

Null hypothesis: H_0: variable is non-stationary and has a unit root.

Alternative hypothesis: H_1: variable is stationary and has no unit root.

Let the variable Y to be tested whether these substances are crucial for evaluating whether the variable Y is stationary or not by using the unit-root test. It includes:

- Corresponding p values
- Critical values for the t-statistic according to the Dickey-Fuller distribution
- t-statistic on $Z = 0$

"t-statistic value is less than the critical value" which proves the stationary of the variable.

The unit root null hypothesis is rejected in this situation.

t − test value < critical value (stationary value).

"t-statistic value is greater than the critical value" which proves the non-stationarity of the variable.

The unit root null hypothesis is not rejected in this situation.

t − test value > critical value (unit-root value).

Such as, if the critical value is considered 5%, then the *p* value must be less than 0.05. If the coefficient Z value is positive, the null hypothesis will not be rejected in a one-sided test.

Johansen co-integration test

In multiple equations, to measure the co-integration, Serletis (1994) introduced a testing framework as a joint estimation to co-integrate the models. Variables having a unit root are definite with co-integration affiliation, and if these variables have a linear association, it means these are stationary. If the series has a co-integration relationship, then the long-run linear relationship exists among factors. Johansen developed alternative tests to verify this long-run relationship among variables. These alternative tests are the error correction model (ECM), maximum eigenvalues test, and trace test. Johansen's co-integration test followed certain assumptions such as factors that are assumed as non-stationary, but these variables become stationary after applying the first differences (Sabuhoro and Larue 1997). It implies that all the variables are integrated at the same level.

The Johansen's co-integration method runs for a system of n variables to test out co-integrating ranks $i = 0, 1, \ldots, n-1$ to n tests.

The component of tests follows a specific procedure.

1. Test out the null hypothesis to co-integrating rank which is being less or equal to I having a p value < 5%, then rejected the null hypothesis; it implies that more than I co-integrating vectors in the system exist.
2. Test out the null hypothesis to co-integrating rank, if p value > 5%, then accept the null hypothesis, which it implies that there are I co-integrating vectors.

This procedure is the same for the trace test and eigenvalues. There is no co-integration if the first test for $i = 0$ fails to reject while the system is stationary if the last test for $i = n - 1$ rejects which is a conflict with original assumptions. So, the error correction model has been used to test the chosen rank.

Hybrid error correction model

ECM has been employed for co-integrated systems to separate long-run and short-run dynamics (Johansen et al. 2000). ECM can be presented in first differences exclusive of error correction:

$$\Delta Y_t = Y_t - Y_{t-1}$$

ECM can be derived, and it is worth mentioning that autoregressive distributive lag model (ARDL) is the base of ECM.

The term is subtracted from both sides of ARDL by adding and subtracting the right-hand side of the equation. The forming equation is in order to satisfy the ECM condition; it is necessary that the coefficient should be similar to the minus's coefficient. The new equation is formed.

We can apply ECM on the base of the condition if the sum of ARDL coefficient = 1, through the elimination of constant terms. In several studies such as Chang et al. (2001) and Dumitrescu and Hurlin (2012), the short-term ECM is indicated with τ. Therefore, the error correction term coefficient will be as follows. The long-run association can be obtained if the difference in the term grows at a constant rate, N, and it can be written as

$$Y_t = \beta_0 + \beta_1 Y_{t-1} + \beta_2 Z_t + \beta_3 Z_{t-1} + \vartheta_t$$

The term Y_{t-1} is subtracted from both sides of ARDL:

$$\begin{aligned} Y_t - Y_{t-1} &= \beta_0 + \beta_1 Y_{t-1} + \beta_2 Z_t + \beta_3 Z_{t-1} - Y_{t-1} + \vartheta_t \\ \Delta Y_t &= \beta_0 + \beta_1 Y_{t-1} + \beta_2 Z_t + \beta_3 Z_{t-1} - Y_{t-1} + \vartheta_t \end{aligned}$$

By adding and subtracting $\beta_2 Z_{t-1}$, the right-hand side of the equation. The forming equation is

$$\Delta Y_t = \beta_0 + \beta_1 Y_{t-1} + \beta_2 Z_t - \beta_2 Z_{t-1} + \beta_3 Z_{t-1} - Y_{t-1} + \beta_2 Z_{t-1} + \vartheta_t$$

or

$$\Delta Y_t = \beta_0 + (\beta_1 - 1) Y_{t-1} + \beta_2 Z_t + (\beta_2 + \beta_3) Z_{t-1} + \vartheta_t$$

In order to satisfy the ECM condition, it is necessary that the coefficient of Z_{t-1} should be similar to the minuses coefficient Y_{t-1}. The new equation form is

$$\begin{aligned} &\beta_1 - 1 = -(\beta_2 - \beta_3) \\ &\beta_1 + \beta_2 + \beta_3 = 1 \end{aligned}$$

Therefore, error correction term coefficient will be as follows:

$$\begin{aligned} \Delta Y_t &= \beta_0 + \beta_2 Z_t - \tau (Y_{t-1} - Z_{t-1}) + \mu_t \\ \tau &= -(\beta_1 - 1) = (\beta_2 + \beta_3) \end{aligned}$$

If the difference in term grow at a constant rate N for the long-run association and it can be written as

$$\begin{aligned} N &= \beta_0 + \beta_2 N - \tau (y^* - Z^*) \\ \tau (y^* - Z^*) &= \beta_0 + (\beta_2 - 1) N \\ y^* &= \beta_0 + \frac{(\beta_2 - 1) N}{\tau} + Z^* \end{aligned}$$

If the original sequence with and without the log is

$$y_t^{\ *} = KZ_t^{\ *}$$

After taking log on both sides,

$$Logy_t^{\ *} = LogK + logZ_t^{\ *}$$

By applying the anti-log of the above equation, the long-run expression is taken:

$$y^* = \exp\left[\frac{\beta_0 + (\beta_2 - 1)B}{\tau}\right]$$

where K symbolizes long-run association between Y and Z. ECM can be employed to evaluate the long-run relationship on the bases of short-run association. ECM represents the past disequilibrium in existing variable and the association among variables in both the short and long run:

$$\Delta N_t = \sum_{i=1}^{N} \tau_1 \Delta N_{t-1} + \tau_2\, \Delta N_{t-1} \beta_2 N + YZ_t + \mu_t$$

It is a vector of variables, exogenous variables, and vectors of parameters which show random disturbance term, and finally, the Granger Causality test has been run to evaluate the causality of proposed variables.

Granger causality test

The ARDL bound testing method is to incarcerate the long- and short-run dynamics at disaggregate levels. This ARDL technique has several advantages and can be used if the underlying factors are integrated at the level I(0) or first difference I(1). It offers the robustness in results despite the consequences of sample size being used in the model, and it easily regulates the lags and provides the unbiased estimates having valid t-statistics for the long-run model (Harris and Sollis 2003). Furthermore, by using the simple linear transformation, ARDL originates a dynamic unrestricted error correction model. The dynamic unrestricted error correction model joins short-run dynamics and long-run equilibrium whereas it is keeping long-run information intact. ARDL is an appropriate model in the existence of endogeneity and serial correlation in time series data (Pesaran et al. 2001). The following dynamic unrestricted error correction model was estimated to test the dynamic relationships among our variables of interest such as indicate power production and foreign direct investment in Nepal, and capital formation shows the capital formation yielded by a country's goods and services and ἐ shows the error term:

$$\begin{aligned}\Delta CO_{2t}^{TRNP} &= c_0 + \sum_{i=1}^{p_0} \beta_1 \Delta ECP + \sum_{i=0}^{p_1} \beta_2 \Delta GDP + \sum_{i=0}^{p_2} \beta_3 \Delta Popudensity \\ &\quad + \sum_{i=0}^{p_3} \beta_4 Popugrowth + \sum_{i=0}^{q1} \beta_5 \Delta Popuurbanagg + \lambda_1 ECP_{,t-1} \\ &\quad + \lambda_2 GDP_{t-1} + \lambda Popudensity_{3t-1} + \lambda_4 Popugrowth_{t-1} \\ &\quad + \lambda_5 Popuurbanagg_{t-1} + \varepsilon_t\end{aligned} \qquad (1)$$

where Δ is the first difference operator while P and q shows the lag lengths in the ARDL model, respectively. ECP is energy consumption, and GDP represents gross domestic product per capita, population density, population growth, and population in an urban agglomeration. The null hypothesis of no cointegration (H_0: $\beta_1 = \beta_2 = \beta_3 = \beta_4 = \beta_5 = 0$) is tested alongside its alternative hypothesis (H_1: $\beta_1 \neq \beta_2 \neq \beta_3 \neq \beta_4 \neq \beta_5 \neq 0$); the long-run relationship is explained by the coefficients c and β, and the coefficient λ explained the short-term relationship between the dependent and independent variables being tested for the proposed framework in the study. The capacity of factors to asses other factors is called causality. Econometrics measure causality by using various tests. Romano and Scandurra (2011) and Zaman and el Moemen (2017) proposed a more comprehensive test to asses two-way causality among variables. Granger causality determine (a) causes factors (b), then whether factor (a) is caused by (b), with the criteria of causality being that coefficients on lagged values of the other factor are non-zero. In large samples, non-zero lag coefficients mean the factor will improve the prediction of the caused factor.

System of variables

1. Carbon dioxide from the transport sector (ENDi)

The carbon emission intensity is the emissions of transport by consuming fossil fuel. It is a cost-type indicator, and it increases with increasing levels of energy consumption. Presently, the CO_2 emissions from the transport sector come from burning fossil fuels because the transportation in Pakistan operates solely on consuming fossil fuels. Carbon intensity is reduced by the improvement in economic growth and energy efficiency. Other factors like urbanization progress, population, technological advances, and consumption per capita also influence the carbon intensity. An average value of CO_2 emission intensifies the emission rate of pollution and from economic activity. CO_2 emission intensity represents the change in carbon emission caused by a change in other related factors. A recent study considered that an increase in CO_2 emission intensity shows an increase in environmental degradation level.

2. Energy consumption per capita (DEVe)

Energy consumption per capita is a cost-type indicator. Energy consumption is always influenced by other factors such as economic development, energy consumption structure, scientific innovation and technological progress, urbanization level, total population size, industrial structure, and industrialization level. In Pakistan, crude oil is being used to produce electricity, and it is considered a significant contributor to overall national energy consumption. Crude oil increases the environmental degradation and heat level. Electricity consumption per capita in kilowatts is taken as a measure. The studies on environmental Kuznets curve uses energy consumption per capita energy (kg of oil equivalent) which shows both economic development and environmental degradation. In developing countries, crude oil, coal, fossil fuels, and natural gas are major contributors to energy generation. Thus, energy consumption is used as a factor in environmental degradation.

3. Population density (URBd)

Population density is a major demographic factor which shows people per square kilometer of land area. Growing level of populace density shows an increasing population and urbanization as well.

4. Population in urban agglomerations (URB)

Urbanization shows more growth in big cities. Recently, the numbers in big cities are increasing day by day. This increase is causing a high population growth rate as well as a full environment in cities. Similar studies incorporated the cities having populations of more than one million residents as a percentage of the total national population. They argued that growth in urban agglomerations shows a negative impact on economic development and environment condition.

5. GDP per capita (DEV)

GDP per capita squared and GDP per capita are employed mainly in the environmental Kuznets curve (EKC) and related studies. Generally, both economic development and ecological performance has a twofold relationship. Such economic development causes an increase in environmental damages while environmental conditions begin to get better after a particular level of economic growth in the country.

6. Population growth rate (POP)

In the environmental analysis, the annual population growth is taken as major explanatory factors. Usually, studies such as these argue that population growth has a negative impact on environment and development.

Results and discussion

Descriptive statistics show that features like variability, central tendency, normality test, and skewness (lack of symmetry) can be used to show the accurate assessment of distribution's shape across the cases. All these features can be represented in a frequency distribution.

Table 1 shows that the statistical values of selected variables such as the third and last variable of environmental degradation are the transport sector CO_2 emission (END_t), which is the percentage of total fuel incineration. The mean value is 24.04, and the value of standard deviation is 2.86, and it is important to note that the transport sector CO_2 emission is negatively skewed, whereas the kurtosis value is 3.01 which implies that it is close to normal distribution.

Furthermore, the next statistical selected variable is population growth, and its mean value is 2.72 having standard deviation value of 0.55, and both show a negatively skewed value and platykurtic distributions. Similarly, the urban agglomeration (URB) mean value is 15.92 having standard deviation value of 1.06, but the positively skewed value with a platykurtic distribution and its kurtosis value is 2.77 which is less than 3. The log of GDP has a mean value of 5.13 with standard deviation 0.41, little positively skewed whereas platykurtic distribution value less than 3. Energy consumption per capita (DEV_{ep}) mean value is 380.21 and standard deviation of 70.26, and a positive skewness of 0.12 while platykurtic distribution is 1.72 showing value less than 3.

Table 2 shows the correlation matrix among all selected variables. Environmental degradation (END_t) has a positive relationship with energy consumption per capita (DEV_{ep}) and urbanization (URB), while GDP has a negative correlation with population growth (POP). Furthermore, END_t shows a weak relationship with GDP growth rate and POP. Consequently, URB and DEV_{ep} are expected to show a good explanatory power for the response, while LGDP and POP may be considered as a less crucial explanatory power response.

The cumulative sum (CUSUM) and CUSUM of squared recursive residual (CUSUMSQ) plots are executed to ratify that long-run and short-run links are stable. The results are shown in Fig. 1.

Trends of population growth rate, energy consumption (kg of oil equivalent), and GDP growth shows that the energy consumption per capita continued at a flat growth over this period as it started below 6% and ended at well over 6%. Population growth was 2.73% in 1972, accelerating after 1990; it was 1.83% in 2010 and about 2% in 2015. Numerous results of studies are consistent with our findings such as Bastola and Sapkota (2015) who have concluded that air pollution caused by the transport sector and respiratory diseases are close to each other; for example, it includes asthma attacks, acute bronchitis, and chronic bronchitis. The transport sector's air population also affected the nervous system,

Table 1 Statistical interpretation of variables

	Mean	Median	Maximum	Minimum	Std. Dev.	Skewness	Kurtosis
END_t	26.43	24.90	29.70	19.31	2.86	− 1.01	3.01
POP	2.61	2.78	3.36	2.04	0.50	− 0.46	1.96
DEVe	416.56	431.92	523.76	299.19	70.96	− 0.29	− 1.32
URB	32.10	31.83	38.75	26.341	3.48	0.211	− 0.962
LGDP	5.13	5.04	6.08	4.60	0.41	0.77	2.57
DEV_{ep}	603.58	382.50	1428.63	169.75	70.26	0.12	1.72

Source: Author's own calculation by using E-Views 5

cardiovascular system, and cell mutations, and it increases the chances of cancer. The transport sector mainly increases the GHG emissions and air pollutants due to the lack of environmental policies. Increasing population, GDP per capita, and industrialization also are supposed to be the major contributors to environmental degradation due to poor environmental policies such as a lack of renewable energy in households and traffic consumption (Mi et al. 2016). Also, it is proved that energy and the transport sector are mutually inter-reliant and go behind the electrification network to decrease the GHG emission and other social benefits such as travel costs, electricity price management system, and efficient battery management.

Table 3 shows the ADF test results. Usually, at the established level of time, the series is not stationary; however, all series are stationary at the first difference. When ADF test is conducted at the first difference, usually the null hypothesis can quickly be rejected at 1% or 5% significance level, so it is concluded that the data becomes stationary in the first difference. Further, the Johansen procedure is conducted to find out possible co-integration among selected variables. The test results have been shown in Tables 4, 5, and 6.

This model shows a relationship among population, energy consumption, environmental degradation, urbanization, and GDP per capita in Pakistan for the period of 1975 to 2015. The transport sector CO_2 emission (END_t) is presented as an indicator of dependent environmental degradation in Pakistan while urban agglomeration (URB), population growth rate (POP), energy consumption per capita (DEV_{ep}), and GDP per capita serve as independent variables. Detailed results signify that the energy consumption per capita and GDP per capita show a significant and positive relationship. Moreover, the accurate assessment shows that a single-unit increase in GDP resulted in an increase of 4.47% in CO_2 emission from the transport sector in Pakistan. It confirms the relationship that increasing trends of GDP is a major source of environmental degradation in Pakistan. Our study is consistent with the findings of Hao et al. (2016).

Table 2 Correlation matrix

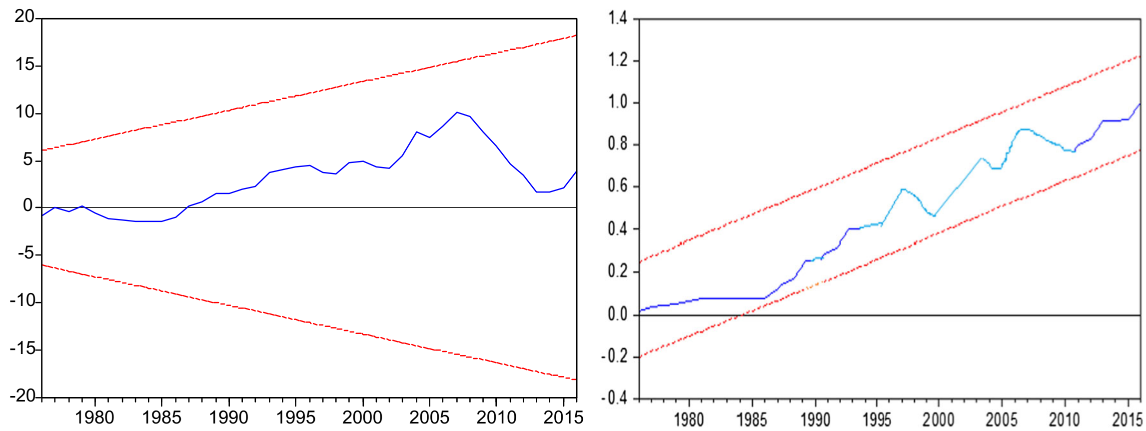
	END_t	DEV_{ep}	URB	POP	LGDP
END_t	1.00				
DEV_{ep}	0.59	1.00			
URB	0.57	0.68	1.00		
POP	− 0.15	−0.80	− 0.66	1.00	
LGDP	0.13	0.24	0.04	− 0.11	1.00

Source: Authors own calculation by using E-Views 5

The estimated model shows that the transport sector CO_2 emission (END_t) and energy consumption per capita (DEV_{ep}) have a direct and positive relationship. One unit increase in DEV_{ep} will increase by 0.19 units which will increase in END_t (transport sector CO_2 emission) in Pakistan. The positive relationship is an indication towards more consumption of energy which will escort to a rise in environmental degradation. GDP, CO_2 emissions, and energy consumption have enlarged 2.4, 3.8, and 1.8 times during the analysis time framework. The results of a current study show consistent behavior and are very relevant with previous studies done by Zhang et al. (2016), which concluded that energy consumption is an indispensable source of transport CO_2 emissions in developing and developed economies as well. In developing countries like Pakistan, the ecological problems are greatly interconnected with economic and social expansion.

The social context of this line of research is pragmatic and shows that the unintended and unhampered urbanization growth tends to create slums in the cities. As a result, it decreases air quality, creates urban congestion, and also worsens situations in cities, whereas the trade-off between economic growth and ecological predilection exists. For example, shifting from conventional agricultural practice to modern industrial tools proved to be environmentally harmful but economically helpful. Similarly, in developing countries like Pakistan, the manufacturing industries have a growing share in GDP and are economically feasible support, but at the same time, it is a dangerous source of CO_2 emission and other GHG gases. Continuous energy consumption in commercial and domestic and the transport sectors are major factors in causing the environmental degradation and poor air quality in Pakistan.

Since 1970s, empirical pieces of evidence show that an increase in GDP real growth rate (5.2% per year) is beginning to increase demand for energy to be and played a vital role in



CUSUM of Squares ….5% significance   CUSUM ……5% significance

Fig. 1 CUSUM and CUSUM of squares plots of recursive residuals

GDP. Very interestingly during this period, due to the high dependence of economic growth on energy consumption, energy consumption has increased by 13.5%. According to Economic Survey of Pakistan (2009), the coal supply grew by 13% annually from 1999 to 2008.

We also argued that a twofold relationship between industrialization and urbanization, because industrialization gives birth to urbanization, causes growth in industrialization (Lin and Ouyang 2014). This route also justifies the results as true for Pakistan as growth in urbanization where industrial production required transportation and sufficient amount of energy consumption. Pakistan's economy mostly relies on crude oil as imported energy and consume 45% crude oil as a major energy consumption source. The number of oil imports was 9.96 million tons in 1990, and it increased to 13.87 million tons in 2011–2012, and it was about 16 million tons in 2015. The transport sector's impact on environmental degradation can be proved by the fact that 8 million tons of oil contributed by the transport sector and is considered as more than half of total energy consumption Pakistan would typically emit CO_2 with the same ratio. Energy consumption per capita increased to 519 (kg of oil equivalent) in 2015 from 280 (kg of oil equivalent) in 1971.

Moreover, in Pakistan, the population grew from 163.93 million to 200 million in 2016; this growth rate is at 2.75% per year. The percentage of fossil fuel energy consumption in total energy consumption mix grew to 64% in 2015 while it was 35.60% in 1971 which caused a greater level of CO_2 emission. This ponderous rise in population and increasing energy demand for economic activity has enlarged the combustible waste at an intimidating level. It grew about 3000 (metric tons of oil equivalent) in 2015 from 10,628.916 (metric tons of oil equivalent) in 1971, and it is now 34% of total energy consumption. The uprising trend of CO_2 emission from the transport sector and population growth rate shows a significant and positive relationship.

Results reveal that a single unit increase in population growth rate will increase 51.39 unit CO_2 emission intensity from the transport sector. Our results concluded that an increase in the population growth yielded environmental degradation and transport emission in Pakistan. The findings concluded a negative impact on the environment. It reveals that population growth is a major source of economic development while it requires an appropriate plan to conserve sustainability. An astonishing level of population growth is responsible for over-utilization of renewable and non-renewable energy and other natural resources which caused ecological and environmental degradation.

Growing population utilize oxygen, food, and other necessities at an alarming rate. In Pakistan, the agricultural land is continuously increasing from 242,790 (sq. km) in 1971 to 265,500 (34%) (sq. km) in 2011, and currently is 47% in

Table 3 Results of augmented Dickey-Fuller test (ADF) for unit root

	Results of unit-root test with intercept			Results of unit-root test with trends and intercept		
Variable	Level	1st difference	Conclusion	Level	1st difference	Conclusion
POP	− 1.11	− 3.62	I(1)	− 2.54	− 3.74	I(1)
URB	− 1.56	− 2.47	I(1)	− 2.79	− 3.74	I(1)
LGDP	− 2.38	− 6.26	I(1)	− 2.41	− 6.17	I(1)
END_t	− 1.96	− 5.91	I(1)	− 1.4	− 6.35	I(1)
DEV_{ep}	− 0.22	− 5.56	I(1)	− 2.83	− 5.46	I(1)

Source: Authors own calculation by using E-Views 5

Table 4 Model 8.3 for unrestricted co-integration rank test (trace)

Hypothesized no. of CE(s)	Eigenvalue	Trace statistic	0.05 critical value	*p* value**
None*	0.72	95.47	69.81	0.0001
At most 1**	0.59	49.11	47.85	0.03
At most 2	0.26	16.79	29.79	0.65
At most 3	0.11	5.56	15.49	0.74
At most 4	0.03	1.37	3.84	0.24

Source: Author's estimation of E-Views 5. For 0 and one ranks, the trace statistics values are greater than the critical values at a 5% significance level, so we reject the null hypothesis, and two co-integrating vectors have been found. We focus on one vector. The results show the existence of a co-integration association. First co-integration vector at the dependent variable is required in order to measure the long-run association among selected variables normalization. The results show that the energy population growth (POP), urbanization (URB), and energy consumption per capita (DEV_{ep}) are significantly positively correlated with CO_2 emission (END_t) while LGDP the fourth variable is marginally significant

*Rejection at 5% significance level. L.R. test finds two co-integration equations at the 5% significance level

2015. While high growth population decreases the hectares per from 0.31 ha per person in 1971 to 0.10 ha per person in 2015. This huge demand for food has proved to be a major cause of deforestation and environmental degradation in Pakistan. The capability of the ecological system to absorb waste generated through economic activities is not balanced with population growth in Pakistan. Thus, population and continuous population acceleration are worsening the natural environment due to higher levels of energy consumption and having an increasing trend and unfavorable impact of population growth on environmental degradation.

Urbanization (URB) and CO_2 emission from the transport sector signifies a direct relationship having the coefficient of urbanization yielded one unit would increase in urbanization 7.01. This relationship shows the increasing level of urbanization (URB) responsible for environmental degradation in Pakistan. It represents that the ecological problems in noise

Table 5 Normalize co-integration coefficients

Coefficient		St. error	t-statistics
DEVe	0.19***	(0.06)	[2.97]
URB	7.01***	(3.10)	[2.25]
POP	51.39***	(6.37)	[8.06]
LGDP	4.47*	(2.51)	[1.78]

Source: Author's estimation on E-Views 5. The results of the error correction model (VECM) which is the first equation of the full vector presented show the effects originating from the lagged disequilibrium on ΔEND

*denotes 10% significance level; **denotes 5%; ***denotes 1% significance level

Table 6 Vector of error correction model for short run dynamics-first equation

Variable	Δ (END_t)	St. error	t-statistics
$\Delta DEV_{ep}(-1)$	− 0.19	(0.06)	[− 2.97]
ΔURB(− 1)	− 7.01	(3.10)	[− 2.25]
ΔPOP(− 1)	− 51.39	(6.37)	[− 8.06]
ΔLGDP(− 1)	− 4.47	(2.89)	[− 1.54]
C	327.16	–	–
EC_{t-1}	− 0.11***	(0.04)	[− 2.75]

Source: Author's estimation in E-Views 5. The EC_{t-1} coefficient shows the short-run to long-run adjustment rate. The adjustment rate is 11%; it means that 11% disequilibrium is rectified/year per. The statistical significance of the coefficient confirms the long-run causality among explanatory variables and response variables. The Granger causality test outcomes are presented in Table 7

*denotes a 10% significance level; **denotes 5%; ***denotes 1% significance level

contamination, water pollution, and metropolitan air composition are connected with solid waste which is toxic or hazardous. Methods of urbanization, modernization, and industrialization are declining the ecological conditions and utilizing full resources including oxygen and fresh water at an enormous rate. Fossil fuel energy consumption in shipping production and for domestic purpose is causing severe pollution in water, air, soil, and climate. Predominantly, transport-based

Table 7 Pair-wise Granger causality tests

Null hypothesis:	Obs	F-Statistic	*p* value
DEV_{ep} does not Granger cause END_t	40	0.07	0.92
END_t does not Granger cause DEV_{ep}		1.07	0.35
URB does not Granger cause END_t	40	0.20	0.81
END_t does not Granger cause URB		0.01	0.99
POP does not Granger cause END_t	40	0.31	0.73
END_t does not Granger cause POP		2.53	0.09
LGDP does not Granger cause END_t	40	1.03	0.36
END_t does not Granger cause LGDP		0.05	0.94
URB does not Granger cause DEV_{ep}	40	0.06	0.93
DEV_{ep} does not Granger cause URB		5.33	0.01
POP does not Granger cause DEV_{ep}	40	0.55	0.57
DEV_{ep} does not Granger cause POP		13.77	0.85
LGDP does not Granger cause DEV_{ep}	40	0.61	0.54
DEV_{ep} does not Granger cause LGDP		1.04	0.36
POP does not Granger cause URB	40	11.76	0.00
URB does not Granger cause POP		5.42	0.01
LGDP does not Granger cause URB	40	0.28	0.75
URB does not Granger cause LGDP		0.20	0.81
LGDP does not Granger cause POP	40	2.46	0.10
POP does not Granger cause LGDP		0.15	0.85

Source: Author's estimation in E-Views 5 contaminated ingredients including CO_2, SO_2, and NO2 are increasing at an alarming rate in the air.

Conclusion

Even though the results show that the EKC is still heterogeneous but empirical, it justifies the inverted U-shape association between environmental degradation and GDP per capita. Finally, the results confirm the environmental Kuznets curve for Pakistan. Very interestingly, the turning point in income level where CO_2 emissions are maximum at US$789. Environmental degradation and economic development showed a positive relationship and concluded that an increasing trend of economic development is the major cause of the increase in environmental degradation. Moreover, results reveal that higher economic growth is the primary target whereas environmental degradation is a secondary priority. Efforts to increase GDP per capita and level of income are the cause of environmental degradation in Pakistan. The incidence of poverty plays a role in environmental degradation in Pakistan.

The targets of sustainable development policies and sustainable development achievement play a role in growth rate while it decreases the depletion of natural resources in the future. Environmental degradation and population growth continue to travel in a similar direction, but population growths put pressure on environmental conditions and natural resources and carbon dioxide emission (environmental degradation), and population density (population growth) represents a similar relationship in Pakistan. Results reveal that one unit increase in economic growth resulted in 4.47 units increase in transport-based environmental degradation whereas one unit increase of energy consumption causes 0.19 units of environmental degradation because of fossil energy consumption, sanitation, water, and air pollution. Moreover, one unit increase in population density increases by 0.02 units in environmental degradation whereas population growth by one unit would increase 0.88 units of environmental devastation. Urbanization (URB) and CO_2 emission from the transport sector shows that one unit increase in urbanization would cause a 7.01 while the single unit increase in population growth rate will increase 51.39 unit CO_2 emission intensity from the transport sector. Very interestingly during this period, energy consumption has increased by 13.5%, and it shows a high dependence of economic growth on energy consumption. The transport sector CO_2 emission (END_t) and energy consumption per capita (DEV_{ep}) has a positive relationship, and one unit increase in energy consumption per capita will increase 0.19 units increase in END_t (transport sector CO_2 emission) in Pakistan. Moreover, the accurate assessment shows that a single-unit increase in GDP resulted in an increase of 4.47% in CO_2 emission from the transport sector in Pakistan.

Policy implication

We put forward policy as follows:

1. Population growth, natural resources, and the ecological system should be balanced to decreases environmental degradation. Otherwise, environmental degradation would be affected by these resources.
2. Greenbelt and public parks should be developed, leaving a balanced ratio of land available to fight against environmental degradation.
3. Road temperature can be maintained through the development of tree-shaded footpaths or sidewalks for pedestrians, which will decrease the transport level in most inner areas of the city, which may prove to reduce temperatures.
4. Industrialization, economic development, and environmental degradation should be balanced especially using the green power supplies
5. District and provincial and national level road authorities should maintain a specific minimum level of green belt along the roadside. There should be a per-capita ratio between general public and number of forest area in the country.
6. Emission control policies should monitor coal-fired power generations, thermal power generations, and gas-fired power generations. The quality of coal and other fuel must be improved to decrease their negative consequences on the environment.
7. Sources of biomass energy should be encouraged to decrease the negative impacts of environmental degradations.
8. The institutional framework should be designed in a way that significant government institutions related to the energy sector should have well-defined roles and responsibilities and have mutual decision-making power. Institutional coherence is vital for effective renewable energy policy design. Coordination and information sharing between these essential organizations will enhance efficiency and can assist in making progress to renewable energy plans.
9. Capacity building programs should be initiated for ministries, regulatory agencies, financial institutes, and other utilities because of a wide range of skills and abilities that are required for policy-making, management, and regulatory design to project planning, financing, development, implementation, and evaluation. Increasing the skill base of the workforce through training is also crucial in swiftly moving towards a renewable energy market.
10. Availability of information related to renewable energy site-specific demand, exploitable level, potential availability, cost, and performance of renewable technologies is crucial in order for several potential stakeholders, i.e.,

policymakers, utilities, regulators, developers and suppliers of renewable technologies, other potential investors, researchers to play their part in development, and promotion of renewable energy resources.

11. Energy conservation and energy efficiency measures should be considered laterally with a reduction in any transmission shortage. It is predicted that about 17% of electricity in the country can be preserved using energy conservation and efficiency. Use of energy-saving appliances should be endorsed as bungling electricity applications such as fans and lights add up to 67% of electricity expended in the local sector.
12. There should be a collective agreement among the provinces to manage with the matter of energy safety and environmental sustainability as well. Furthermore, the strategies of zero-level emissions from an energy infrastructure should be motivated by the government. If the government campaigns to fix renewable energy projects, it also might be able to attract foreign direct investment in the renewable energy divisions.
13. Consequently, government activities and plans have a central influence on global energy demand. Energy conservation activities should be accepted to decrease the operation of carbon-based fuels. There is a need to control the dramatic growth in demand. Governments should distribute a carbon emission quota, and it is essential to continue harmony among social, energy, economic, population size, and environmental developments.

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Abbreviations *BTU,* British thermal units; CO_2, carbon dioxide; NO_2, nitrogen oxide; SO_2, sulfur dioxide; *UNFCCC,* United Nations Framework Convention for Climate Change; *DEV*, GDP per capita; *URBd,* population density; *URB,* population in urban agglomerations; *FBS,* Federal Bureau of Statistics; *WB,* World Bank; *IMF,* International Monetary Fund; *ECM,* error correction model; *ARDL,* auto regressive distributive lag model; END_i, carbon dioxide from transport sector; *DEVe,* energy consumption per capita; *POP,* population growth rate; *GDP,* gross domestic product

References

Ahmad M, Ali A, Khiyal MSH (2016) Potential of volunteered geographic information for adaptation of climate change effects in Pakistan. In: 4th International Conference on Energy, Environment and Sustainable Development 2016 (EESD 2016)

All F, Corcoran SP, Ayres RU et al (2011) Sustainability economics: where do we stand? Ecol Econ 121:1–12. https://doi.org/10.1016/j.ecolecon.2007.12.009

Asbahi AAMHA, Gang FZ, Iqbal W et al (2019) Novel approach of principal component analysis method to assess the national energy performance via energy trilemma index. Energy Rep 5:704–713. https://doi.org/10.1016/j.egyr.2019.06.009

Bastola U, Sapkota P (2015) Relationships among energy consumption, pollution emission, and economic growth in Nepal. Energy 80:254–262. https://doi.org/10.1016/j.energy.2014.11.068

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. https://doi.org/10.1016/j.energy.2014.07.008

Brown P (2017) Narrative: an ontology, epistemology and methodology for pro-environmental psychology research. Energy Res Soc Sci 31:215–222. https://doi.org/10.1016/j.erss.2017.06.006

Chang T, Fang W, Wen LF (2001) Energy consumption, employment, output, and temporal causality: evidence from Taiwan based on cointegration and error-correction modelling techniques. Appl Econ 33:1045–1056. https://doi.org/10.1080/00036840122484

Cherp A, Vinichenko V, Jewell J, Brutschin E, Sovacool B (2018) Integrating techno-economic, socio-technical and political perspectives on national energy transitions: a meta-theoretical framework. Energy Res Soc Sci 37:175–190. https://doi.org/10.1016/j.erss.2017.09.015

Cloke J, Mohr A, Brown E (2017) Imagining renewable energy: towards a social energy systems approach to community renewable energy projects in the global south. Energy Res Soc Sci 31:263–272. https://doi.org/10.1016/j.erss.2017.06.023

Dickey AD, Fuller AW (1979) Dickey and fuller. J Am Stat Assoc 74:427–431

Dogan E (2016) Analyzing the linkage between renewable and non-renewable energy consumption and economic growth by considering structural break in time-series data. Renew Energy 99:1126–1136. https://doi.org/10.1016/j.renene.2016.07.078

Dumitrescu EI, Hurlin C (2012) Testing for Granger non-causality in heterogeneous panels. Econ Model 29:1450–1460. https://doi.org/10.1016/j.econmod.2012.02.014

Economic Survey of Pakistan 2016-17 (2017) Pakistan economic survey, 2016-17. Pakistan Econ Surv 2016–17:19–40. https://doi.org/10.1038/479299e

Edenhofer O, Kalkuhl M (2011) When do increasing carbon taxes accelerate global warming? A note on the green paradox. Energy Policy 39:2208–2212. https://doi.org/10.1016/j.enpol.2011.01.020

Fell MJ (2017) Energy services: a conceptual review. Energy Res Soc Sci 27:129–140. https://doi.org/10.1016/j.erss.2017.02.010

Frondel M, Krätschell K, Zwick L (2018) Environmental management systems: does certification pay? Econ Anal Policy 59:14–24. https://doi.org/10.1016/J.EAP.2018.02.006

Geels FW, Schwanen T, Sorrell S, Jenkins K, Sovacool BK (2018) Reducing energy demand through low carbon innovation: a sociotechnical transitions perspective and thirteen research debates. Energy Res Soc Sci 40:23–35

Hao Y, Chen H, Wei Y-M, Li Y-M (2016) The influence of climate change on CO2 (carbon dioxide) emissions: an empirical estimation based on Chinese provincial panel data. J Clean Prod 131:667–677. https://doi.org/10.1016/j.jclepro.2016.04.117

Harris R, Sollis R (2003) Applied time series modelling and forecasting

Hillman J, Axon S, Morrissey J (2018) Social enterprise as a potential niche innovation breakout for low carbon transition. Energy Policy 117:445–456. https://doi.org/10.1016/j.enpol.2018.03.038

Ikram M, Mahmoudi A, Shah SZA, Mohsin M (2019a) Forecasting number of ISO 14001 certifications of selected countries: application of even GM (1,1), DGM, and NDGM models. Environ Sci Pollut Res. https://doi.org/10.1007/s11356-019-04534-2

Ikram M, Zhou P, Shah SAA, Liu GQ (2019b) Do environmental management systems help improve corporate sustainable development? Evidence from manufacturing companies in Pakistan. J Clean Prod 226:628–641. https://doi.org/10.1016/j.jclepro.2019.03.265

IDMC. 2017. “Internal Displacement Monitoring Centre.” http://www.internal-displacement.org/global-report/grid2018/

International Energy Agency (2016) World Energy Outlook 2016. Int Energy Agency:1–8 http://www.iea.org/publications/freepublications/publication/WEB_WorldEnergyOutlook2015ExecutiveSummaryEnglishFinal.pdf. Acessed 06/03/2019

Johansen S (1988) Statistical analysis of cointegration vector. J Econ Dyn Control 12:231–254

Johansen S, Mosconi R, Nielsen B (2000) Cointegration analysis in the presence of structural breaks in the deterministic trend. Econ J 3: 216–249. https://doi.org/10.1111/1368-423X.00047

Kaygusuz K (2011) The paradigm of sustainability in Turkey's energy sector. Energy Sources, Part B Econ Plan Policy 6:83–95. https://doi.org/10.1080/15567240802458906

Lanouar C (2017) The impact of energy consumption and economic development on Ecological Footprint and {CO2} emissions: evidence from a Markov switching equilibrium correction model. Energy Econ 65. https://doi.org/10.1016/j.eneco.2017.05.009

Lin B, Ouyang X (2014) Analysis of energy-related CO<inf>2</inf> (carbon dioxide) emissions and reduction potential in the Chinese non-metallic mineral products industry. Energy 68. https://doi.org/10.1016/j.energy.2014.01.069

Mi Z, Zhang Y, Guan D, Shan Y, Liu Z, Cong R, Yuan XC, Wei YM (2016) Consumption-based emission accounting for Chinese cities. Appl Energy 184:1073–1081. https://doi.org/10.1016/j.apenergy.2016.06.094

Mills B, Schleich J, Volume EP (2012) Residential energy-efficient technology adoption, energy conservation, knowledge, and attitudes: an analysis of European countries Bradford Mills. Energy Policy 49: 616–628. https://doi.org/10.1016/j.enpol.2012.07.008

Ministry of Finance, Government of Pakistan (2009) Pakistan economic survey 10; n.d.Available: https://finance.gov.pk/survey0910.html

Mohsin M, Rasheed AK, Saidur R (2018a) Economic viability and production capacity of wind generated renewable hydrogen. Int J Hydrog Energy 43:2621–2630

Mohsin M, Zhang J, Saidur R, Sun H, Sait SM (2019) Economic assessment and ranking of wind power potential using fuzzy-TOPSIS approach. Environ Sci Pollut Res 26:22494–22511. https://doi.org/10.1007/s11356-019-05564-6

Mohsin M, Zhou P, Iqbal N, Shah SAA (2018b) Assessing oil supply security of South Asia. Energy 155:438–447. https://doi.org/10.1016/j.energy.2018.04.116

Pesaran MH, Shin Y, Smith RJ (2001) Bounds testing approaches to the analysis of level relationships. J Appl Econ 16:289–326. https://doi.org/10.1002/jae.616

Qamar U, Saeed A (2016) Contextualizing privatization in Pakistan: a case study of Pakistan railway. Pakistan Vis 17:259–291

Rasool Y, Zaidi SAH, Zafar MW (2019) Determinants of carbon emissions in Pakistan's transport sector. Environ Sci Pollut Res:1–15

Ratti RA, Vespignani JL (2016) Oil prices and global factor macroeconomic variables. Energy Econ 59:198–212. https://doi.org/10.1016/J.ENECO.2016.06.002

Roege PE, Collier ZA, Mancillas J, McDonagh JA, Linkov I (2014) Metrics for energy resilience. Energy Policy 72:249–256. https://doi.org/10.1016/j.enpol.2014.04.012

Romano AA, Scandurra G (2011) Dynamics of economic growth and electricity consumption at regional level: the Italian case. Energy Syst 2:143–150. https://doi.org/10.1007/s12667-011-0028-7

Ru G, Xiaojing C, Xinyu Y, Yankuan L, Dahe J, Fengting L (2010) The strategy of energy-related carbon emission reduction in Shanghai. Energy Policy 38:633–638. https://doi.org/10.1016/j.enpol.2009.06.074

Sabuhoro JB, Larue B (1997) The market efficiency hypothesis: the case of coffee and cocoa futures. Agric Econ 16:171–184. https://doi.org/10.1016/S0169-5150(97)00003-0

Seow Y, Goffin N, Rahimifard S, Woolley E (2016) A "design for energy minimization" approach to reduce energy consumption during the manufacturing phase. Energy 109:894–905. https://doi.org/10.1016/j.energy.2016.05.099

Serletis A (1994) A cointegration analysis of petroleum futures prices. Energy Econ 16:93–97. https://doi.org/10.1016/0140-9883(94)90002-7

Shahbaz M, Balsalobre-Lorente D, Sinha A (2019a) Foreign direct investment–CO 2 emissions nexus in Middle East and north African countries: importance of biomass energy consumption. J Clean Prod 217:603–614. https://doi.org/10.1016/j.jclepro.2019.01.282

Shahbaz M, Haouas I, Van Hoang TH (2019b) Economic growth and environmental degradation in Vietnam: is the environmental Kuznets curve a complete picture? Emerg Mark Rev 38:197–218. https://doi.org/10.1016/j.ememar.2018.12.006

Sindhu MA, Babar ZA, Abbas A (2018) Analyzing the relationship of energy consumption, consumer expenditures and economic growth: a case study of Pakistan*. J Res Soc Sci -JRSS January 6:2306–2112

Solaymani S, Kardooni R, Yusoff SB, Kari F (2015) The impacts of climate change policies on the transportation sector. Energy 81: 719–728. https://doi.org/10.1016/j.energy.2015.01.017

Staddon SC, Cycil C, Goulden M, Leygue C, Spence A (2016) Intervening to change behaviour and save energy in the workplace: a systematic review of available evidence. Energy Res Soc Sci 17: 30–51. https://doi.org/10.1016/j.erss.2016.03.027

Steffen B (2018) The importance of project finance for renewable energy projects. Energy Econ 69:280–294. https://doi.org/10.1016/J.ENECO.2017.11.006

Vesterberg M (2018) The effect of price on electricity contract choice. Energy Econ 69:59–70. https://doi.org/10.1016/J.ENECO.2017.10.039

World Energy Council (2016) World Energy Resources 2016. World Energy Resour 2016 4–37. http://www.worldenergy.org/wp-content/uploads/2013/09/Complete_WER_2013_Survey.pdf. Accessed 06/03/2019

Zafar MW, Shahbaz M, Hou F, Sinha A (2019) From nonrenewable to renewable energy and its impact on economic growth: the role of research & development expenditures in Asia-Pacific economic cooperation countries. J Clean Prod 212:1166–1178. https://doi.org/10.1016/j.jclepro.2018.12.081

Zahoor H, Chan APC, Masood R, Choudhry RM, Javed AA, Utama WP (2016) Occupational safety and health performance in the Pakistani construction industry: stakeholders' perspective. Int J Constr Manag 16:209–219. https://doi.org/10.1080/15623599.2015.1138027

Zaman K, el Moemen MA (2017) Energy consumption, carbon dioxide emissions and economic development: evaluating alternative and plausible environmental hypothesis for sustainable growth. Renew Sust Energ Rev 74:1119–1130

Zhang D, Shi M, Shi X (2018) Oil indexation, market fundamentals, and natural gas prices: an investigation of the Asian premium in natural gas trade. Energy Econ 69:33–41. https://doi.org/10.1016/J.ENECO.2017.11.001

Zhang S, Wu Y, Un P, Fu L, Hao J (2016) Modeling real-world fuel consumption and carbon dioxide emissions with high resolution for light-duty passenger vehicles in a traffic populated city. Energy 113:461–471. https://doi.org/10.1016/j.energy.2016.07.067

Zhou P, Delmas MA, Kohli A (2017) Constructing meaningful environmental indices: a nonparametric frontier approach. J Environ Econ Manag 85:21–34. https://doi.org/10.1016/j.jeem.2017.04.003

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