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RESEARCH ARTICLE

On the asymmetric effects of premature deindustrialization on CO2 emissions: evidence from Pakistan

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Abstract
In this modern era, environmental pollution is the biggest problem attached to industrialization. This study tries to ensure the relationship between industrialization and CO2 emissions in Pakistan for the time period 1980–2018 by using nonlinear ARDL model while controlling for urbanization, GDP, and human capital variables as a likely factor of CO2 emissions. Our foremost study objective is to examine whether or not the outcome of industrialization on CO2 emissions is symmetric or asymmetric for Pakistan that is one of the core suppliers to CO2 in South Asia, as the emissions were 0.82 million tons in 2018. Our result approves the presence of an asymmetric effect of industrialization shocks on CO2 emissions both in the short run and long run. The results reveal that industrialization increases emissions and deindustrialization decrease emissions, in short as well as long run, in Pakistan. Moreover, our finding also advises that urbanization and GDP variables have exerted a positive impact on CO2 emissions. Based on the findings, some policy suggestions are proposed for Pakistan.

Keywords Industrialization · Urbanization · GDP · CO2 emissions · NARDL approach · Pakistan

Introduction

The manufacturing sector in Pakistan has been going through a crisis since the decade of 1990s. Pakistan is, in fact, suffering from what Rodrik (2016) has characterized as premature deindustrialization – a situation where manufacturing output and employment suffer at low-income levels before the industrial transformation has taken place. The term appears to have been first used by Dasgupta and Singh (2006). Traditional industries were destroyed, and millions of Pakistanis were thrown out of employment. Unfortunately, modern manufacturing industries were not sufficient to increase employment and output, leading to deindustrialization (Bagchi 1976). The share of manufacturing in GDP has stagnated and even shrinking in Pakistan. Therefore, it should be noted that deindustrialization effects environmental quality by lowing industrial activity (Lin et al. 2015). Such deindustrialization is considered as an indication of less emission of CO2.

In the decade of 1990s, Pakistan industries have grown well in the South Asian region. After this, deindustrialization began in Pakistan. As evident from Fig. 1, industrialization of Pakistan has been decreased from 15.45 in 1990 to 13.66% in 2000. Reindustrialization started in Pakistan for short period from 2000 to 2005; industrialization increased from 13.66 in 2000 to 17.48% in 2005. Again, Pakistan's deindustrialization began in 2006. After 2005, the share of industry value added is on the persistent decrease in Pakistan. Positive industrialization occurs as productivity grows in manufacturing, and negative industrialization happens because of stagnation in productivity in manufacturing sector in Pakistan. Therefore,

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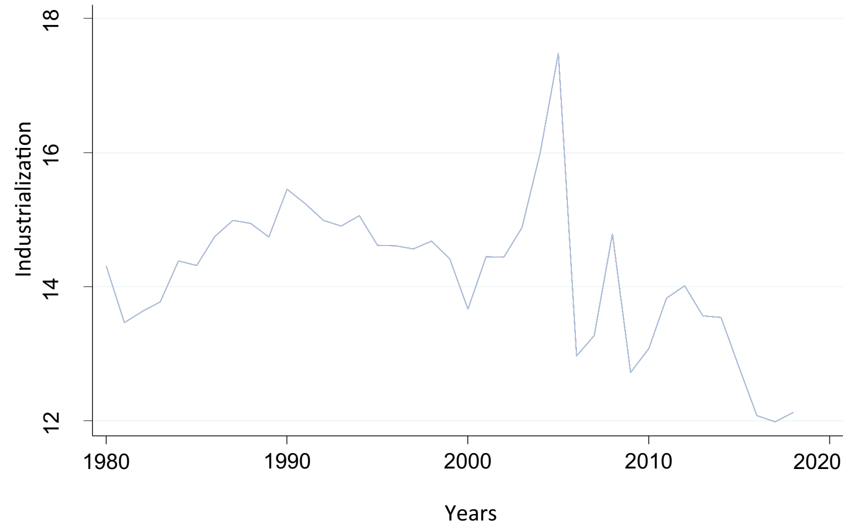

Fig. 1 Pattern of industrialization in Pakistan

findings revealed that deindustrialization is stronger in the case of Pakistan. The phenomenon of deindustrialization prominently existed in developing countries as well as in Pakistan (Rodrik 2016).

The industrialization report 2015 prepared by the United Nations Industrial Development Organization (UNIDO) has ranked nations in terms of its industrial performance. Pakistan has been ranked 80 out of 148 countries, above-bordering and non-bordering nations, for instance, China (no. 3), India (no. 39), Iran (no. 59), Sri Lanka (no. 75), and Bangladesh (no. 77) (UNIDO, 2015). Pakistan is the lowest in this rank. The worsening situation of industrialization in Pakistan reveals that industrial sector progress has mostly been unnoticed in the local policies. Pakistan has the potential for its industrial sector development as compared to other developing nations, considering the fast economic growth and enormous labor force. Climate change is industrial-induced, and progress is required on multiple fronts. Policies that ignore the industrial sector cannot provide a general approach to fight this challenge. This paper would be helpful for manufacturing regulation and making policies that can reduce CO2 emission in Pakistan. Currently, Pakistan is at the lowest level of industrialization in South Asia and has a small emission of CO2.

There are also numerous studies that emphasized on identifying the driving forces of Pakistan's CO2 emissions, such as the energy consumption and economic growth (Danish and Baloch 2017; Khan et al., 2019a Rehman et al. 2019); agriculture value added (Gokmenoglu and Taspinar 2018; Ali et al., 2019a); agricultural, industrial, and service sector (Akram et al. 2019); macroeconomic instability (Khan 2019); financial development and financial instability (Javid and Sharif 2016; Shujah-ur-Rahman et al., 2019); road transport (Rasool et al., 2019); income inequality and economic growth (Baloch et al. 2017); urbanization (Farhani and Ozturk 2015; Al-mulali and Ozturk 2015; Al-mulali et al. 2015; Shahbaz et al. 2017; Ali et al., 2019b; Khan et al., 2019b); and globalization (Khan et al., 2019a); none of these studies focuses on the implications of industrialization for the CO2 emissions in context of Pakistan. There is also a limited number of studies that found the linear industrialization impact on CO2 emissions in globe (Shahbaz et al. 2014; Li and Lin 2015; Xu and Lin 2015; Ahmad and Zhao 2018; Liu and Bae 2018; and Pata, 2017). The complete empirical literature is silent about the asymmetric relationship between industrialization and CO2 in the world.

The existing body of studies offers a significant gap in different ways. First, previous studies on CO2 emissions did not integrate industrialization in Pakistan (Shahbaz et al., 2014; Khan et al., 2019a). However, industrialization has been the core factor to explain the process of urbanization, energy consumption, and economic growth (see Danish and Baloch, 2017; Ali et al., 2019a). Second, previous studies employed linear ARDL for estimation that gives the biased results problem (Pata 2017; Liu and Bae 2018). This study has new empirics in environmental economics. None of the previous studies addressed the deindustrialization impact on CO2 and did not incorporate deindustrialization variables in their models. However, the current study provides the nonlinear ARDL results to check the positive as well as negative shocks of industrialization on CO2 emission along with urbanization, GDP, and human capital. However, a detailed and up-to-date analysis of Pakistan is still lacking. A study that can measure the influence of industrialization processes on CO2 emissions of Pakistan is also needed in a controversial situation.

The link between industrialization and carbon emissions was observed very regularly in globe, but there is specific and limited work on the nonlinear relationship between industrialization and CO2 in Pakistan. This paper fulfills this gap by inspecting the nonlinear association between industrialization and CO2 emission in Pakistan. This study is valuable for environmentalists, government, industrial researchers, policymakers, and civilians in evaluating and understanding how industrialization affects CO2 emission in both ways, i.e., positively and negatively. Additionally, this is the first study on Pakistan that considers asymmetric effects. Therefore, it implies that industrialization structural change affects CO2 in different ways. Previous studies, compared to this one, have parsimonious models.

This study is divided into four sections: Next section summarizes the literature review. Section 3 presents the methodology, model, and data. Section 4 discusses the empirical findings and discussion. Section 5 concludes the study with some policy implications.

Literature review

The industrialization has been considered as a crucial factor for nations to develop and grow. Therefore, it is assumed that manufacturing is an engine for economic growth. It has the potential for economic growth and development. Industrialization states to a procedure that manufacturing share started to increase at a certain phase of development in the economy. However, the previous couple of decades have seen a noteworthy decrease in the relative share of manufacturing in developing countries. This switch procedure of manufacturing has been described as deindustrialization. According to literature, deindustrialization means in the reduction of manufacturing share in total employment (Palma 2005). It has also been defined as a fall in the manufacturing share both in GDP and employment (Tregenna 2008).

The two aspects, degree of income per person and share of manufacturing in total output, are crucial points for defining the nature of deindustrialization. In view of these two points, we present the idea of premature deindustrialization, which is predominant in developing nations. The common concept of premature deindustrialization has been defined as deindustrialization that begins at a lower level of per capita income or low share of the industrial sector to GDP (Rodrik 2016). In developing countries, it is the general argument that economic growth and industrialization are the integrated part of each other and that it became a source of improvement in the economic agent, which occurred in Europe in the nineteenth century because of the industrial revolution (Fei and Ranis, 1999). However, numerous literature explained the negative effects of industrialization process on the air quality. Lopez (2007) described the cases of sub-Saharan Africa and Latin America where structural changes are due to the natural resource's degradation. Moreover, the researcher used the specific word "perverse structural change" to explain the structural variations of this kind, which are the following: (a) environmental erosion and (b) in both sectors, agriculture, and non-agriculture, wages are stationary or falling among unskilled labor force.

Similarly, the opportunity cost has been declining in non-agriculture sector due to environmental degradation. It can be considered as a fuel for the development process which is noticeable in literature. There are many other examples that explain the structural changes that occurred due to environmental degradation in many developed regions. In many countries like China and India, environmental problem becomes a hot issue and forced the public to change their environmental behavior to protect their environment against the industrialization process. During the current eras, a lot of work has been done at the overall industry level as well as on specific sector-wise to check the industrialization impact on the CO2 productions. The findings of some studies revealed that there is a positive relationship between industrialization and CO2 focusing on the overall relations at the industry level by ignoring its subdivisions (Shahbaz et al. 2014; Chandio et al. 2019). So, further studies focus on this issue and investigated the industrial sectors across various nations. According to Akbostancı et al. (2011), CO2 emissions is found to be a big determinant of the manufacturing industry in Turkey. The same results were found in the energy sector and in different countries of North America and Asia-Pacific (Sheinbaum-Pardo et al. 2012; and Moya and Pardo 2013).

Similarly, Shahbaz et al. (2014) used the ARDL model to examine the influence of industrialization on CO2 emission during the time period 1975 to 2010. They found environmental Kuznets curve (EKC) between industrial development and CO2 emission. Notwithstanding industrialization and urbanization has been thoroughly researched by researchers to capture the regional urban releases (Gurney et al. 2009). At the national level as well as city level, there are a lot of studies that exist on the relationship between industrialization and CO2 emission. Most of the studies worked on this relationship at the national level, and they found the positive link among the industrialization and CO2 discharge while ignoring the different phases of development (Sadorsky 2014). Further, the studies try to explore this environmental issue and find the impact of industrial sector development phase on CO2 emissions (Martinez-Zarzoso and Maruotti 2011). However, Zhu et al. (2012) inspected the link between urbanization and CO2 using the sample of twenty emerging nations during the time period 1992–2008; they found in their study that there exists a nonlinear relationship between them instead of inverted-U pattern. There are some studies that worked on the city level to handle these issues. Among them, Fragkias et al. (2013) revealed that smaller towns are more energy-efficient as compared to big towns. A similar finding is found by Yuelan et al. (2019) in China. However, Liu and Sweeney (2012) discovered opposite results which concluded that big cities are more energy-efficient and reduce energy consumption and that CO2 discharge from per household reduced.

In China, wide research is going on energy efficiency and on reducing the CO2 emission, and they are considering the industrialization as a tool. According to the general industry perspective, Zhu et al. (2012) determined that CO2 was the most central outcome which was received through the industrialization process. Moreover, there are many studies that worked on the link between industrialization and CO2 emission. Sun et al. (2011) determined a positive link between twin variables. They revealed that the share of heavy industries increases from 71.52 to 77.12% in 2012. In recent years, heavy industries (cement, iron and steel, and power industry) are responsible for CO2 emissions in China. However, Wen et al. (2015) displayed that the steel and iron industry development increases the CO2 emission in short run while reducing in the long run because of improving energy-efficient technology. By considering the connection between industrialization and CO2 emission, there are many similar studies that found a strong correlation between the two in China. At national level, some studies showed the positive link between the concerned variables (Sadorsky 2013). Due to this attribute, there is an increased in demand for private transport, public infrastructures like road network, sanitation, and drainage system and production of steel and cement for the construction in urban areas.

Some latest studies also discussed the effect of industrialization on CO2 emissions. A study by Mahmood et al. (2019) in Pakistan found robust long-run relationships between industrial production and carbon emissions. This study also revealed that earlier stages of development also matter in carbon emissions. Anwar et al. (2019) study the industrialization of partner countries of Belt and Road economies. The study noted the unidirectional causality running from industrialization to emission of CO2 and stressed to environment-friendly policies. Based on data from developed economies, Dong et al. (2019) elucidated that the highest carbon emissions are found in some developed economies due to industrialization. Therefore, this implies that industrialization has a similar effect on carbon emission in worldwide. Nasrollahi et al. (2018) found similar results in MENA countries who noted that the effect of industrialization on carbon emissions is generally significant, while Opoku and Boachie (2019) found insignificant results in African countries.

Furthermore, Liu and Bae (2018) described that CO2 emissions are due to urbanization in long run and have a causal positive link between the concerned variables in China. The same empirical results have been found in China when studies are conducted at city level (Hua et al. 2018). Since, in China, Shanghai showed expended urbanization and spatial features of carbon of soil organic which has boosted the CO2 emission. Though industrialization, as well as urbanization, has been empirically discussed extensively in China context, however, there are two core limitations. First point is that all the studies have been conducted at national level. There are few studies found which are at regional level. Therefore, provincial heterogeneity in CO2 emissions and its important determinants at inter-provincial level is ignored which needs attention. Second, to check the impact of industrialization and urbanization on CO2 emission, most of the studies used the linear model. This study is different from the previous researches. Therefore, this study examines the relationship between industrialization and carbon emissions by using the linear and nonlinear parametric regression approach in Pakistan.

Methodology

Variables and data description

For this study, we have employed the time series data over the period 1980–2018, and we have used industrialization (IND), urbanization (URB), GDP per capita (GDP), and human capital (HC) as independent variables, while carbon dioxide emissions (CO_2) is our dependent variable. The sources of the data are the Human Development Index (HDI) and World Development Indicators (WDI). For better results, GDP variable has been converted into a logarithm. Table 1 symbolizes a detailed description of the variables and data sources.

Descriptive statistics and correlation matrix are offered in Table 2. Descriptive statistics cover the period from 1980 to 2018 for Pakistan. The mean of CO_2, IND, URB, GDP per capita, and HC are 0.71mt, 14.19%, 32.57%, 848.87 $, and 5.41 years, respectively, while the standard deviation are 0.15mt, 1.09%, 2.55%, 167.02$, 2.13 years, respectively. Based on descriptive statistics, our results show that all the macro variables are normally distributed having mean zero and constant variance. The correlation matrix exposes a positive relationship between the fundamental variables. For example, industrialization is positively related to CO_2, and some other finding is also positive for urbanization and CO_2 emissions. A positive relationship is established for GDP with CO_2 emissions. An adverse effect is found with human capital and CO_2 emissions. Urbanization, GDP, and human capital are positively associated with industrialization. A positive association of GDP and human capital is established with urbanization. Lastly, there is also a positive association between human capital and GDP.

Specification of the model

The basic purpose of our effort is to examine the IND relationship with CO_2 in Pakistan. Further, the study of Shahbaz et al. (2014) and Du and Xie (2019) measured IND in their model. We continued their studies by taking IND as independent variable; moreover, we also consider URB in model that is one of the key causes of pollution commonly by following the appropriate theoretical background of the EKC hypothesis which is reliable with the Lin et al. (2015), Pata (2017), and

Table 1 Variables description

Variables	Symbol	Definition	Data source
Carbon dioxide emissions	CO_2	CO_2 emissions (metric tons per capita)	WDI
Industrialization	IND	Industrial value added (% of GDP)	WDI
Urbanization	URB	Share of urban residents in total population	WDI
GDP per capita	GDP	GDP per capita (constant 2010 US$)	WDI
Human capital	HC	Average total year of schooling	HDI

Liu and Bae (2018). The common associations between macro variables are offered in the following linear regression model:

$$CO_{2,t} = \beta_0 + \beta_1 IND_t + \beta_2.URB_t + \beta_3 GDP_t + \beta_4 HC + \mu_t \quad (1)$$

where $CO_{2,\ t}$ denotes the emission of carbon dioxide in time t, IND_t shows industrialization in time t, URB_t indicates urbanization in time t, GDP_t signifies GDP per capita in time t, and HC_t shows human capital in time t. Similarly, β_0 is a constant term; β_1, β_2, β_3, and β_4 are particular coefficients, while μ_t is the error term. The above Eq. (1) is a long-run model, and it only offers us long-run estimations. In order to get short-run estimates, we readjust the error correction system into Eq. (1). To that end, we have followed ARDL approach as suggested by Pesaran et al. (2001) given below in Eq. (2).

$$\Delta CO_{2,t} = \delta_0 + \sum_{n=0}^{p}\delta_1 \Delta CO_{2,t\text{-}k} + \sum_{n=0}^{p}\delta_2 \Delta IND_{t\text{-}k} + \sum_{n=0}^{p}\delta_3 \Delta URB_{t\text{-}k} + \sum_{n=0}^{p}\delta_4 \Delta GDP_{t\text{-}k} + \sum_{n=0}^{p}\delta_5 \Delta HC_{t\text{-}k} + \pi_1 CO_{2,t-1} + \pi_2 IND_{t-1} + \pi_3.URB_{t-1} + \pi_4 GDP_{t-1} + \pi_5 HC_{t-1} + v_t \quad (2)$$

The main advantage of Eq. (2) is that it can give short- and long-run estimates in a single equation. In specification (2), coefficients attached with Δ variables represent short-run estimates, whereas $\pi_2 \rightarrow \pi_5$ normalized π_1 represent the long-term coefficients, and v_t is the error term. However, for long-run estimates to be effective, we need to check whether there is the existence of cointegration among long-run variables. For this purpose, we need to check the joint significance of lagged level variables by applying F-test recommended by Pesaran et al. (2001). Nevertheless, the values of the F-test they suggested for long sample and for small samples like ours we relied upon the values of F-test proposed by Narayan (2005). If the calculated F-statistics of bounds testing approach is greater than their critical values, we can confirm the presence of cointegration among long-run variables, which validates our long-run estimates. In the opposite scenario, where critical values are not significant, we will perform another test of cointegration known as error correction modeling (ECM). In this test, we develop an error correction term ($ECM_{t\text{-}1}$) with the help of normalized long-run variables from Eq. (1). In the next step, we replace this $ECM_{t\text{-}1}$ with lagged level variables in Eq. (2). Depending upon the critical values proposed by Banerjee et al. (1998), if the values of $ECM_{t\text{-}1}$ are negative and significant, we can approve cointegration among long-run variables. Another advantage of ARDL approach is that the critical values we consider can account for the integrating properties of the variables. Hence, we can use the variables with order of integration either 0 or 1 or blend of both. As most of the macro variables are either I(0) or I(1), therefore, there is no need to perform pre-unit root testing. However, to endorse that no variable is I(2), we have performed the Augmented Dickey-Fuller (ADF) and Phillips-Perron (PP) unit root tests.

Then, in this paper, we want to check whether the impact of industrialization on CO_2 emission is symmetric or asymmetric. To that end, we adopted nonlinear ARDL technique by Shin et al. (2014), for the reason that it documents asymmetric effects which are due to the positive and negative shocks on macroeconomic variables (Mensi et al. 2017). It is the extended version of a linear ARDL model. The method of NARDL has been used by numerous scholars in environmental economics so far like Munir and Riaz (2019) and Rahman and

Table 2 Descriptive statistics and correlation matrix

	CO_2	IND	URB	GDP	HC
Descriptive statistics					
Mean	0.716	14.19	32.57	848.87	5.41
Std. Dev.	0.156	1.099	2.556	167.02	2.13
Min	0.411	11.98	28.06	556.40	1.80
Max	0.947	17.48	36.66	1196.59	8.70
Correlation matrix					
CO_2	1				
IND	0.546	1			
URB	0.940*	0.424*	1		
GDP	0.903*	0.478*	0.879*	1	
HC	− 0.741*	0.403*	0.886*	0.983*	1

*, **, and ***show significance level at 1%, 5%, and 10%

Ahmad (2019). This technique is rare and near to reality in IND-carbon dioxide emission nexus in the context of Pakistan. Our key purpose is to check that IND has either asymmetric or symmetric effect on CO_2 emissions in Pakistan. In order to familiarize asymmetric effects, we follow Shin et al. (2014) and decompose the IND into two variables, one representing industrialization and one deindustrialization. Therefore, IND is separated into two parts where one has positive shocks (IND^+_t), while the other has negative shocks (IND^-_t): The model form is:

$$IND^+{}_t = \sum_{j=1}^{t} \Delta IND^+{}_t = \sum_{j=1}^{t} \max(\Delta IND^+{}_t, 0) \quad (3)$$

$$IND^-{}_t = \sum_{j=1}^{t} \Delta IND^-{}_t = \sum_{j=1}^{t} \max(\Delta IND^-{}_t, 0) \quad (4)$$

Eqs. (3) and (4) are two partial sum variables. Specification (5) is another error-correction model that is considered as the asymmetric or nonlinear ARDL. To get nonlinear ARDL equations, we replace two partial sum variables, IND^+_t and IND^-_t in Eq. (2):

$$\begin{aligned}\Delta CO_{2,t} = {} & \delta_0 + \textstyle\sum_{n=0}^{p}\delta_1 \Delta CO_{2,t-k} + \sum_{n=0}^{p}\delta_2 IND^+{}_{t-k} \\ & + \textstyle\sum_{n=0}^{p}\delta_3 IND^-{}_{t-k} + \sum_{n=0}^{p}\delta_4 URB_{t-k} \\ & + \textstyle\sum_{n=0}^{p}\delta_5 GDP_{t-k} + \sum_{n=0}^{p}\delta_6 HC_{t-k} \\ & + \pi_1 CO_{2,t-1} + \pi_2 IND^+{}_{t-1} + \pi_3 IND^-{}_{t-1} \\ & + \pi_4 URB_{t-1} + \pi_5 GDP_{t-1} + \pi_6 HC_{t-1} + v_t \quad (5)\end{aligned}$$

After estimating Eq. (5), we will perform Wald tests to confirm short-run joint asymmetry and long-run asymmetry. The null of the Wald test which confirms or rejects the short run combined asymmetry is $\sum \delta_{2k} = \sum \delta_{3k}$. If we can reject this null hypothesis, it means the effects of industrialization on CO_2 emission are asymmetric in short run. Similarly, the long-run asymmetric impacts of industrialization will be confirmed once we can reject the null hypothesis ($^{\pi_2^+}/_{\pi_1} = {}^{\pi_3^-}/_{\pi_1}$) of Wald test.

Results and discussion

The results of ADF and PP unit root tests are reported in Table 3. The results of ADF test statistic show that all the variables are nonstationary at the level and the null hypothesis of ADF shows the existence of unit root. This also implies that all the series are integrated at I(1). The PP test statistic shows that the series is unit root at level, but we found to be stationary at 1st difference, except urbanization variable, which implies the mix order of integration. However, in our model, none of the variables is integrated of order two. These results are also justified by the ARDL model. As per Akaike information criterion (AIC), the optimal lags of the ARDL model are (2, 2, 1, 3, 2, 0).

Our foremost objective of the study is to assess the symmetric and asymmetric impacts of IND on CO2 in Pakistan. The short-run and long-run estimates of linear and nonlinear ARDL models are offered in Table 4. In the linear ARDL model, the coefficient of IND is positively significant at 5% level in short run and long run, which suggests that IND releases the CO_2. Numerical estimates of IND confirm that 1% increase in industrialization will raise CO_2 by 0.676% in long run. This result is in favor of Shahbaz et al. (2014) and Pata (2017). This implies that old technologies and energy consumption in industries cause CO2 in Pakistan. Another possible reason is industrialization increases energy consumption that is one possible source of carbon emission. This finding is also dissimilar from Li and Lin (2015) who argue that industrialization has a negative and significant effect on environments in the low-, middle-, and high-income nations.

In short run, URB exerts a significant positive influence on carbon emissions at the 10% level of significance. In long run, coefficient of URB is significant at 10% level with an elasticity of 0.457, respectively. Our finding is similar to that of Liu and Bae (2018) for China and Pata (2017) for Turkey. This outcome favors the scholars who determine a positive impact of urbanization on CO_2 (Pata, 2017; Ali et al., 2019b; and Khan et al., 2019b). This result implies that Pakistan is the fastest urbanized country, and the common sources of energy are fossil fuels in cities. Urban people tend to use more household machines and transportation, thereby endorsing

Table 3 Results of the unit root test

	ADF test statistic			PP test statistic		
variables	Level	1st difference	Decision	Level	1st difference	Decision
CO_2	− 2.43	− 5.84**	I(1)	− 2.31	− 6.08**	I(1)
IND	− 2.71	− 7.32**	I(1)	− 2.68	− 7.87**	I(1)
URB	− 1.09	− 3.51**	I(1)	− 4.51**	− 3.71**	I(0)
GDP	− 0.33	− 3.76**	I(1)	− 0.95	− 3.77**	I(1)
HC	− 0.76	− 3.83**	I(1)	− 0.72	− 3.93**	I(1)

Table 4 Long- and short-run estimates

	ARDL			NARDL		
	Coefficients	S.E	T-stat	Coefficients	S.E	T-stat
Panel A: short-run estimates						
$\Delta CO2_{t-1}$	− 0.896**	0.216	− 4.149	− 1.006**	0.244	− 4.122
$\Delta CO2_{t-2}$	− 0.449*	0.231	− 1.949	− 0.531**	0.254	− 2.094
ΔIND_t	0.012**	0.005	2.585			
ΔIND_{t-1}	− 0.014**	0.004	− 3.812			
ΔIND_{t-2}	− 0.011**	0.005	− 2.431			
ΔIND_{t-3}	− 0.008	0.005	− 1.627			
ΔIND_t^+				0.029**	0.014	2.071
ΔIND_{t-1}^+				0.012	0.014	0.851
ΔIND_{t-2}^+				− 0.014	0.014	− 0.998
ΔIND_t^-				− 0.021*	0.012	− 1.750
ΔIND_{t-1}^-				− 0.014	0.009	− 1.537
ΔURB_t	0.836*	0.450	1.857	0.883*	0.504	1.751
ΔURB_{t-1}	− 0.923**	0.443	− 2.082	− 1.100	1.162	− 0.947
ΔURB_{t-2}				0.641	0.803	0.798
ΔURB_{t-3}				− 0.275	0.252	− 1.090
ΔGDP_t	0.617**	0.252	2.448	0.628*	0.355	1.770
ΔGDP_{t-1}	− 0.699*	0.362	− 1.933	− 0.653*	0.388	− 1.683
ΔGDP_{t-2}	0.562**	0.259	2.174	0.875**	0.344	2.545
ΔHC_t	− 0.021	0.020	− 1.020	− 0.012	0.023	− 0.522
Panel B: long-run estimates						
IND	0.676**	0.306	2.209			
IND^+				0.471*	0.281	1.676
IND^-				− 0.531*	0.292	− 1.818
URB	0.457**	0.208	2.197	0.398**	0.187	2.128
GDP	1.108*	0.657	1.686	1.286*	0.780	1.650
HC	− 0.443	0.565	− 0.783	0.052	0.123	0.420
C	− 28.932	31.248	− 0.926	0.320	9.417	0.034
Panel C: diagnostic tests						
F				6.621*		
ECM_{t-1}	− 0.179	0.132	− 1.356	− 0.233**	0.115	− 2.026
LM	1.310			1.668		
RESET	0.366			0.388		
CUSUM	S			S		
CUSUMSQ	S			S		
ADJ.R2	0.988			0.988		
WALD-short run				4.347**		
WALD-long run				3.444*		

a. The critical value of t-ratio is significance level at the 10% (5%) level is 1.64(1.96).

b. The critical values for LM, RESET, and Wald tests are significance at 5% (10%) level is 3.84 (2.71), and both statistics are distributed as $\chi 2$ with one degree of freedom.

increased CO2 in Pakistan. Another possible reason is industrialization, and urbanization growth jointly increases the consumption of energy-intensive goods and services like appliances, electricity, and transport; hence, they both are strong ingredients of carbon emission generally.

However, the coefficient of GDP is significant at 10% level, which suggests that high level of income increases the CO_2 in long run. A similar result is found in short run. The prior literature has also informed a positive connection between GDP and CO_2 (Lægreid and Povitkina, 2017; Hafeez et al.

2018). This finding is not surprising that when Pakistan is increasing the domestic production, it defiantly used more energy consumption. That is one of the basic sources of CO_2 in Pakistan. This study has nullified the conventional results of Lin et al. (2015) in the case of Nigeria that as the living standard of people gets better, they diffuse CO_2 emission. Finally, the results show a negative and insignificant effect of HC on CO_2 emission in short run as well as long run. It implies that HC is not a determinant of CO_2 in Pakistan. The reality of HC is not ignored in environmental quality in developed and developing countries. This negative relationship is due to the fact that HC raises society's income level which permits persons to install renewable energy sources. Education enhances environment-related information and stimulates pro-environmental practices (Wijaya and Tezuka 2013 and Ahmed and Wang 2019). All such practices have adversely impacted the CO_2. The linkage between HC and CO2 is positive and insignificant for Pakistan. This implies that education do not improve air quality in Pakistan. Overall, the results specified that all the coefficients are according to our expectations.

Panel C shows the outcomes of several diagnostic tests. Lagrange multiplier (LM) test is statistically insignificant in most models, supporting autocorrelation-free residuals. Another diagnostic is Ramsey's RESET test; all statistics are insignificant in almost all models that imply that models have a proper functional form. We select general to specific model form that does not hurt from any heteroskedasticity and serial correlation problem. From diagnostics tests, the stability of the model is verified through CUSUM and CUSUMSQ. We show stable estimates by "S" and unstable ones by "US". Almost all estimates are stable in ARDL, and model has experience of a good fit. Therefore, the favored ARDL model is more efficient and even reliable.

How do the results change if we apply the nonlinear ARDL model? Again, we report short- and long-run estimates and diagnostics of the nonlinear ARDL in Table 4. Due to high disparities in IND, we have used asymmetric ARDL model to capture the negative and positive shocks. The positive shock means industrialization, and negative shock means deindustrialization. The long-run outcomes tell that the estimates are negative and positive for decreased IND as well as increased IND. For instance, the elasticity of increased IND (decreased) signifying that CO_2 emissions is + 0.471 (− 0.531), implying that 1% increase (decrease) in IND is estimated to increase (decrease) CO2 by + 0.471% (− 0.531%), is also moderate significant in the model. This finding is also in line with the position of Du and Xie (2019) on China; they found that IND leads to environmental issues. Considering the different statistical direction of the expected elasticities, variation in IND appears to have an asymmetric or nonlinear effect on CO_2 in the long run. The coefficient of deindustrialization is greater than industrialization which shows that deindustrialization effect is higher on CO2 than industrialization in Pakistan, which implies that the country is not performing well in industrial sector in the last few years. Deindustrialization helps Pakistan to reduce CO_2 emissions. The similar results are also obtained in short run.

Based on these findings some possible reasons are: First, the economy of Pakistan highly dependent on the agricultural sector and still lags behind in the industrial sector in the last decade that cannot lead to environmental problems. Therefore, deindustrialization produces less pollution that is one of the additional benefits in Pakistan. Second, our empirical finding reveals that deindustrialization improves the environment positively; low growth in industrial sector and contribution remained low in GDP last few years. Third reason is the energy crisis in Pakistan, particularly in gas, oil, and electricity sector; industries in Pakistan are focusing on use of substitute sources such as solar panels, batteries, inverters, etc., which are environment-friendly energy sources. Fourthly, the negative association between industrialization and CO_2 could be a consequence of deindustrialization in Pakistan. Fifth, over the previous few years, industrialization has suffered a significant setback in Pakistan due to financial, infrastructural, and structural problems. A number of industry owners have moved to other businesses, like education and real estate sectors, naming problems of regulatory bottlenecks, security and high risk, Chinese import penetration, overreliance on foreign technology, and energy crises. Mostly heavy industries were close down, and some remaining industries are not performing well in Pakistan. Therefore CO2 emission is on the decline in Pakistan. Pakistan has started numerous programs for environmental pollution, but industrialists are not willing to obey these standards due to weak law enforcement. Pakistan's government develops low-carbon society in which it banned plastic bags. Furthermore, the estimated long-run coefficients demonstrate that URB and GDP are also significant factors for CO2 emissions in the twin periods, while the results of ARDL model are also maintained in the NARDL model.

A few post-estimation diagnostics are also reported for the nonlinear model. From the Wald test, the null hypothesis of short- and long-run symmetry is rejected; this implies that it offers short- and long-run asymmetric effects of IND on CO2. The calculated short- and long-term estimates are very crucial and approved a cointegration relationship among the variables. While F-test of the nonlinear ARDL is statistically significant at 10% level, it indicates that cointegration holds among the variables. The error correction term (ECT) coefficient denotes the speed of adjustment of the short-term deviations to the long-term equilibrium. Moreover, the amount of ECT is (− 0.233) and significant at 10% levels. Thus, ECM test also supports cointegration in CO2 emission model. The ECM infers that CO2 readjust very rapidly to their long-run equilibrium, with a rate of 23% each year in the occurrence of other quantified variables. Similarly, nonlinear ARDL is a preferred model. The ARDL and NARDL models pass the main tests including R2, LM, and RESET. The results also show that short-run and long-run asymmetries are verified in the nonlinear model of the Pakistan, Wald statistic reported as Wald-short run, and Wald-long run in Panel C are significant.

Conclusion and policy implications

A considerable number of environmental economists usually blame that industrialization enhances CO2 emissions. But still, there is no known empirical study to check the role of IND on the environmental quality in Pakistan, and little attention is given in the past to check the negative and positive shocks of IND through asymmetric ARDL techniques in the globe. The key contribution of this effort is to check the effects of industrialization and deindustrialization on CO2 for Pakistan by applying a new asymmetric ARDL approach by covering the period of 1980–2018. It also examines the influence of URB, GDP, and HC on carbon emission in Pakistan. All the variables are stationary at first difference except one. The long-run results indicate that estimated coefficients of IND are negative and positive. For example, the elasticity of IND increases (declines) referring to CO2 emissions is $+0.471(-0.531)$ in the long-run and suggesting significant results in short and long run; hence, this asymmetric relationship is significant for policymakers. Our empirical consequences suggest that IND can lead to CO2 that is measured as one of the basic elements of environments in Pakistan in short run as well long run.

This study recommends that deindustrialization should decrease CO2 emissions in Pakistan. Deindustrialization in Pakistan is one of the unique cases. The deindustrialization effect is also supported in Pakistan where the growth rate of the industrial sector is low. Therefore, URB has also a critical role in CO2, so there is a need to have control of urbanization and using renewable and clean energies in industries as well as households. URB is connected with CO2 emissions due to its effect on energy consumption and overpopulation. Similarly, an increase in GDP, which shows improvement in living standards, enhances the problem of CO2 emission; however, this impact is modest in Pakistan. According to results, HC also has an insignificant positive effect on CO2 emission in Pakistan. Overall, we found that IND, URB, and GDP have significant positive effects on CO2 emission in Pakistan. Clearly, the results are Pakistan specific. Moreover, CUSUM and CUSUMSQ tests reveal the stability of the selected model.

Based on these outcomes, several important policy recommendations are suggested. First, there should be robust and forceful edges to promote industrialization; therefore, the government could enable environmental-friendly industrial practices in Pakistan. Furthermore, there are various types of industries in Pakistan, but no one is specifically focusing on CO_2 production controls. Furthermore, energy-efficient industries should be encouraged locally. There is a need to increase awareness among the manufacturers to address environmental problems in Pakistan. Also, in the industrial sector, use of atmosphere-friendly technology should be boosted. The government should focus on environmental rules and regulations. Second, environmental taxes should be levied to minimize the impact of industrialization on the environment and control unplanned industrialization in Pakistan. Industrial and urbanization sector reforms can play a significant role in reducing CO2 emission in Pakistan. The government should focus on clean and green energy consumption in industries by adding environmental rules for the unclean industries. On the other side, regulatory organization should offer financial incentives to the industries which are promoting the role of clean and green technology during their manufacturing process. Pakistan needs to redesign its environmental and industrial policies. The government should focus more on "*Billion Tree* Tsunami" that will help to absorb carbon emissions.

References

Ahmad M, Zhao Z (2018) Empirics on linkages among industrialization, urbanization, energy consumption, CO2 emissions and economic growth: a heterogeneous panel study of China. Environ Sci Pollut Res 25(30):30617–30632. https://doi.org/10.1007/s11356-018-3054-3

Ahmed Z, Wang Z (2019) Investigating the impact of human capital on the ecological footprint in India: an empirical analysis. Environ Sci Pollut Res 26(26):26782–26796. https://doi.org/10.1007/s11356-019-05911-7

Akbostancı E, Tunç Gİ, Türüt-Aşık S (2011) CO2 emissions of Turkish manufacturing industry: a decomposition analysis. Appl Energy 88(6):2273–2278. https://doi.org/10.1016/j.apenergy.2010.12.076

Akram Z, Engo J, Akram U, Zafar MW (2019) Identification and analysis of driving factors of CO2 emissions from economic growth in Pakistan. Environ Sci Pollut Res 26(19):19481–19489. https://doi.org/10.1007/s11356-019-05281-0

Ali R, Bakhsh K, Yasin MA (2019a) Impact of urbanization on CO2 emissions in emerging economy: evidence from Pakistan. Sustain Cities Soc 48:101553–101564. https://doi.org/10.1016/j.scs.2019.101553

Ali L, Shah T, Chandio A, Ali (2019b) Analysis of the Nexus of CO2 emissions, economic growth, land under cereal crops and agriculture value-added in Pakistan using an ARDL approach. Energies 12(23):4590–4602. https://doi.org/10.3390/en12234590

Al-Mulali U, Ozturk I (2015) The effect of energy consumption, urbanization, trade openness, industrial output, and the political stability on the environmental degradation in the MENA (Middle East and North African) region. Energy 84:382–389

Al-Mulali U, Ozturk I, Lean HH (2015) The influence of economic growth, urbanization, trade openness, financial development, and renewable energy on pollution in Europe. Nat Hazards 79(1):621–644

Anwar A, Ahmad N, Madni GR (2019) Industrialization, Freight Transport and Environmental Quality: Evidence from Belt and Road Initiative Economies. Environ Sci Pollut Res 1–18. https://doi.org/10.1007/s11356-019-07255-8

Bagchi AK (1976) De-industrialization in India in the nineteenth century: some theoretical implications. J Dev Stud 12(2):135–164

Baloch A, Shah SZ, Noor ZM, Magsi HB (2017) The nexus between income inequality, economic growth and environmental degradation in Pakistan. GeoJournal 83(2):207–222. https://doi.org/10.1007/s10708-016-9766-3

Banerjee A, Dolado J, Mestre R (1998) Error-correction mechanism tests for cointegration in a single-equation framework. J Time Ser Anal 19(3):267–283. https://doi.org/10.1111/1467-9892.00091

Chandio AA, Rauf A, Jiang Y, Ozturk I, Ahmad F (2019) Cointegration and causality analysis of dynamic linkage between industrial energy consumption and economic growth in Pakistan. Sustainability 11(17):4546–4556

Danish, Baloch MA (2017) Dynamic linkages between road transport energy consumption, economic growth, and environmental quality: evidence from Pakistan. Environ Sci Pollut Res 25(8):7541–7552. https://doi.org/10.1007/s11356-017-1072-1

Dasgupta, S., & Singh, A. (2006). Manufacturing, services and premature deindustrialization in developing countries: A Kaldorian analysis (No. 2006/49). Research paper, UNU-WIDER, United Nations University (UNU)

Dong F, Wang Y, Su B, Hua Y, Zhang Y (2019) The process of peak CO2 emissions in developed economies: a perspective of industrialization and urbanization. Resour Conserv Recycl 141:61–75. https://doi.org/10.1016/j.resconrec.2018.10.010

Du X, Xie Z (2019) Occurrence of turning point on environmental Kuznets curve in the process of (de)industrialization. Struct Change Econ. https://doi.org/10.1016/j.strueco.2019.06.003

Farhani S, Ozturk I (2015) Causal relationship between CO 2 emissions, real GDP, energy consumption, financial development, trade openness, and urbanization in Tunisia. Environ Sci Pollut Res 22(20): 15663–15676

Fei J, Ranis G (1999) Growth and development from an evolutionary perspective. Wiley-Blackwell

Fragkias M, Lobo J, Strumsky D, Seto KC (2013) Does size matter? Scaling of CO2 emissions and U.S. urban areas. PLoS One 8(6): 64727–64740. https://doi.org/10.1371/journal.pone.0064727

Gokmenoglu KK, Taspinar N (2018) Testing the agriculture-induced EKC hypothesis: the case of Pakistan. Environ Sci Pollut Res 25(23):22829–22841. https://doi.org/10.1007/s11356-018-2330-6

Gurney KR, Mendoza DL, Zhou Y, Fischer ML, Miller CC, Geethakumar S, De la Rue du Can S (2009) High resolution fossil fuel combustion CO2Emission fluxes for the United States. Environ Sci Technol 43(14):5535–5541. https://doi.org/10.1021/es900806c

Hafeez M, Chunhui Y, Strohmaier D, Ahmed M, Jie L (2018) Does finance affect environmental degradation: evidence from one belt and one road initiative region? Environ Sci Pollut Res 25(10): 9579–9592. https://doi.org/10.1007/s11356-018-1317-7

Hua Y, Xie R, Su Y (2018) Fiscal spending and air pollution in Chinese cities: identifying composition and technique effects. China Econ Rev 47:156–169. https://doi.org/10.1016/j.chieco.2017.09.007

Javid M, Sharif F (2016) Environmental Kuznets curve and financial development in Pakistan. Renew Sust Energ Rev 54:406–414. https://doi.org/10.1016/j.rser.2015.10.019

Jiang Z, Lin B (2012) China's energy demand and its characteristics in the industrialization and urbanization process. Energy Policy 49:608–615. https://doi.org/10.1016/j.enpol.2012.07.002

Khan D, Ullah A (2019) Testing the relationship between globalization and carbon dioxide emissions in Pakistan: does environmental Kuznets curve exist? Environ Sci Pollut Res 26(15):15194–15208. https://doi.org/10.1007/s11356-019-04913-9

Khan I, Khan N, Yaqub A, Sabir M (2019a) An empirical investigation of the determinants of CO2 emissions: evidence from Pakistan. Environ Sci Pollut Res 26(9):9099–9112. https://doi.org/10.1007/s11356-019-04342-8

Khan M (2019) Does macroeconomic instability cause environmental pollution? The case of Pakistan economy. Environ Sci Pollut Res 26(14):14649–14659. https://doi.org/10.1007/s11356-019-04804-z

Khan MK, Teng J, Khan MI (2019b) Effect of energy consumption and economic growth on carbon dioxide emissions in Pakistan with dynamic ARDL simulations approach. Environ Sci Pollut Res 26(23):23480–23490. https://doi.org/10.1007/s11356-019-05640-x

Li K, Lin B (2015) Impacts of urbanization and industrialization on energy consumption/CO 2 emissions: does the level of development matter? Renew Sust Energ Rev 52:1107–1122. https://doi.org/10.1016/j.rser.2015.07.185

Lin B, Omoju OE, Okonkwo JU (2015) Impact of industrialisation on CO 2 emissions in Nigeria. Renew Sust Energ Rev 52:1228–1239. https://doi.org/10.1016/j.rser.2015.07.164

Liu X, Bae J (2018) Urbanization and industrialization impact of CO2 emissions in China. J Clean Prod 172:178–186. https://doi.org/10.1016/j.jclepro.2017.10.156

Liu X, Sweeney J (2012) Modelling the impact of urban form on household energy demand and related CO2 emissions in the greater Dublin region. Energy Policy 46:359–369

Lægreid OM, Povitkina M (2017) Do political institutions moderate the GDP-CO2 relationship? Ecol Econ 45:441–450. https://doi.org/10.1016/j.ecolecon.2017.11.014

Lopez R (2007) Structural change, poverty and natural resource degradation. Handbook of sustainable development 220

Mahmood MT, Shahab S, Hafeez M (2019) Energy capacity, industrial production, and the environment: an empirical analysis from Pakistan. Environ Sci Pollut Res:1–10. https://doi.org/10.1007/s11356-019-07161-z

Martinez-Zarzoso I, Maruotti A (2011) The impact of urbanization on CO2 emissions: evidence from developing countries. Ecol Econ 70(7):1344–1353. https://doi.org/10.1016/j.ecolecon.2011.02.009

Mensi W, Hussain Shahzad SJ, Hammoudeh S, Al-Yahyaee KH (2017) Asymmetric impacts of public and private investments on the non-oil GDP of Saudi Arabia. Int Econ 156:15–30. https://doi.org/10.1016/j.inteco.2017.10.003

Moya JA, Pardo N (2013) The potential for improvements in energy efficiency and CO2 emissions in the EU27 iron and steel industry under different payback periods. J Clean Prod 52:71–83. https://doi.org/10.1016/j.jclepro.2013.02.028

Munir K, Riaz N (2019) Energy consumption and environmental quality in South Asia: evidence from panel non-linear ARDL. Environ Sci Pollut Res 26:1–8. https://doi.org/10.1007/s11356-019-06116-8

Nasrollahi Z, Hashemi M, Bameri S, Mohamad Taghvaee V (2018) Environmental pollution, economic growth, population, industrialization, and technology in weak and strong sustainability: using STIRPAT model. Environ Dev Sustain:1–18. https://doi.org/10.1007/s10668-018-0237-5

Narayan PK (2005) Fiji's tourism demand: the ARDL approach to cointegration. Tour Econ 10(2):193–206. https://doi.org/10.5367/000000004323142425

Opoku EE, Boachie MK (2019) The environmental impact of industrialization and foreign direct investment. Energy Policy:111178–111189. https://doi.org/10.1016/j.enpol.2019.111178

Pata UK (2017) The effect of urbanization and industrialization on carbon emissions in Turkey: evidence from ARDL bounds testing procedure. Environ Sci Pollut Res 25(8):7740–7747. https://doi.org/10.1007/s11356-017-1088-6

Palma G (2005) Four sources of de-industrialisation and a new concept of the Dutch disease. Beyond reforms: structural dynamics and macroeconomic vulnerability 3(5):71–116

Pesaran MH, Shin Y, Smith RJ (2001) Bounds testing approaches to the analysis of level relationships. J Appl Econ 16(3):289–326. https://doi.org/10.1002/jae.616

Rahman ZU, Ahmad M (2019) Modeling the relationship between gross capital formation and CO2 (a)symmetrically in the case of Pakistan: an empirical analysis through NARDL approach. Environ Sci Pollut Res 26(8):8111–8124. https://doi.org/10.1007/s11356-019-04254-7

Rasool Y, Zaidi SA, Zafar MW (2019) Determinants of carbon emissions in Pakistan's transport sector. Environ Sci Pollut Res 26(22):22907–22921. https://doi.org/10.1007/s11356-019-05504-4

Rehman A, Rauf A, Ahmad M, Chandio AA, Deyuan Z (2019) The effect of carbon dioxide emission and the consumption of electrical energy, fossil fuel energy, and renewable energy, on economic performance: evidence from Pakistan. Environ Sci Pollut Res 26(21):21760–21773. https://doi.org/10.1007/s11356-019-05550-y

Rodrik D (2016) Premature deindustrialization. J Econ Growth 21(1):1–33. https://doi.org/10.1007/s10887-015-9122-3

Sadorsky P (2013) Do urbanization and industrialization affect energy intensity in developing countries? Energy Econ 37:52–59. https://doi.org/10.1016/j.eneco.2013.01.009

Sadorsky P (2014) The effect of urbanization on CO2 emissions in emerging economies. Energy Econ 41:147–153. https://doi.org/10.1016/j.eneco.2013.11.007

Shahbaz M, Salah Uddin G, Ur Rehman I, Imran K (2014) Industrialization, electricity consumption and CO2 emissions in Bangladesh. Renew Sust Energ Rev 31:575–586. https://doi.org/10.1016/j.rser.2013.12.028

Shahbaz M, Solarin SA, Sbia R, Bibi S (2015) Does energy intensity contribute to CO2 emissions? A trivariate analysis in selected African countries. Ecol Indic 50:215–224. https://doi.org/10.1016/j.ecolind.2014.11.007

Shahbaz M, Chaudhary AR, Ozturk I (2017) Does urbanization cause increasing energy demand in Pakistan? Empirical evidence from STIRPAT model. Energy 122:83–93

Sheinbaum-Pardo C, Mora-Pérez S, Robles-Morales G (2012) Decomposition of energy consumption and CO2 emissions in Mexican manufacturing industries: trends between 1990 and 2008. Energy Sustain Dev 16(1):57–67. https://doi.org/10.1016/j.esd.2011.08.003

Shin Y, Yu B, Greenwood-Nimmo M (2014) Modelling asymmetric Cointegration and dynamic multipliers in a nonlinear ARDL framework. Festschrift in Honor of Peter Schmidt:281–314. https://doi.org/10.1007/978-1-4899-8008-3_9

Shujah-ur-Rahman, Chen S, Saleem N, Bari MW (2019) Financial development and its moderating role in environmental Kuznets curve: evidence from Pakistan. Environ Sci Pollut Res 26(19):19305–19319. https://doi.org/10.1007/s11356-019-05290-z

Sun Y, Wu Q, Shi G (2011) Graphene based new energy materials. Energy Environ Sci 4(4):1113–1126. https://doi.org/10.1039/c0ee00683a

Tregenna F (2008) Characterising deindustrialisation: an analysis of changes in manufacturing employment and output internationally. Camb J Econ 33(3):433–466. https://doi.org/10.1093/cje/ben032

UNIDO (2015) U (2015) international yearbook of industrial statistics. https://doi.org/10.4337/9781784715502

Wen S, Lan H, Fu Q, Yu DC, Zhang L (2015) Economic allocation for energy storage system considering wind power distribution. IEEE Trans Power Syst 30(2):644–652. https://doi.org/10.1109/tpwrs.2014.2337936

Wijaya ME, Tezuka T (2013) A comparative study of households' electricity consumption characteristics in Indonesia: a techno-socioeconomic analysis. Energy Sustain Dev 17(6):596–604. https://doi.org/10.1016/j.esd.2013.09.004

Xu B, Lin B (2015) How industrialization and urbanization process impacts on CO 2 emissions in China: evidence from nonparametric additive regression models. Energy Econ 48:188–202. https://doi.org/10.1016/j.eneco.2015.01.005

Yuelan P, Akbar MW, Hafeez M, Ahmad M, Zia Z, Ullah S (2019) The nexus of fiscal policy instruments and environmental degradation in China. Environ Sci Pollut Res 26(28):28919–28932. https://doi.org/10.1007/s11356-019-06071-4

Zhu H-M, You W-H, Zeng Z-f (2012) Urbanization and CO2 emissions: a semi-parametric panel data analysis. Econ Lett 117:848–850