Environmental Science and Pollution Research (2020) 27:31211–31220
https://doi.org/10.1007/s11356-020-09240-y

RESEARCH ARTICLE

Examining the asymmetric effects of stock markets and exchange rate volatility on Pakistan's environmental pollution

Sana Ullah[1] · Ilhan Ozturk[2,3,4]

Received: 29 March 2020 / Accepted: 11 May 2020 / Published online: 1 June 2020

Abstract

The purpose of this study is to observe the effects of stock markets and exchange rate volatility on environmental pollution in Pakistan during the period 1985–2018. A nonlinear autoregressive distributed lag (ARDL) model is applied to get this objective. In general, the short-term results revealed that the positive and negative shocks in stock markets reducing the carbon emissions. In adverse, positive shocks in exchange rate volatility reduces the carbon emissions while negative shocks in exchange rate volatility have a positive significant effect on carbon emissions in Pakistan. Moreover, the positive and negative shocks in the stock market have a positive significant effect on Pakistan's carbon emissions but positive and negative shocks in exchange rate volatility negative influence on carbon emissions in the long run. The findings further show that positive and negative shocks of the stock markets and exchange rate volatility have the same effects in sign but different in magnitude in the long run. Based on these findings, some policy recommendations proposed in the context of Pakistan as well as for other developing countries.

Keywords Stock markets · Exchange rate volatility · Environmental pollution · Nonlinear ARDL · Pakistan

Introduction

It is a fact that stock markets are playing an important role in the modern economy. The stock markets and its significance to Pakistan's economy are rising largely as it shows a critical role in the nation's commerce and industry growth. Pakistan's Karachi Stock Market was listed among the 10 best stock exchanges in the world and it ranked one in terms of market capitalization in South Asia. Pakistan's finance capital markets are one of the most sustainable and emerging financial organizations in the economy. Therefore, it is indisputable that Pakistan's stock market shows an imperative role in its economic development. There are a huge number of registered companies in Pakistan's stock markets that are related to construction and industrial activities. These economic activities not only show a substantial rule to Pakistan's GDP but reports for its enormous influence on the country's environmental pollution emissions (World Bank 2019). Therefore, the stock market may be an influential driver of Pakistan's environmental pollution.

Fundamentally, environmental pollution is a continuing problem that is faced by Pakistan. There is no doubt that Pakistan is one of the leading carbon emitters in South Asia that is 0.82 million tons which signifies the second highest emitters after India (World Bank 2019). Recently, latest studies observed the effect of stock markets on environmental pollution in the perspective of G-20, emerging, and developed economies (Paramati et al. 2016, 2017, 2018) and their consequences in common exposed that the rise in stock market business activities has a positive effect on environmental pollution. The outcomes in common show that the effect of the stock market on environmental pollution is negative in the advanced economies while it has a positive effect in the developing and emerging economies (Paramati et al. 2016,

Responsible editor: Nicholas Apergis

✉ Ilhan Ozturk
ilhanozturk@cag.edu.tr

Sana Ullah
ana_ullah133@yahoo.com

1 School of Economics, Quaid-i-Azam University, Islamabad, Pakistan

2 Faculty of Economics and Administrative Sciences, Cag University, 33800 Mersin, Turkey

3 Department of Medical Research, China Medical University Hospital, China Medical University, Taichung, Taiwan

4 Department of Finance, Asia University, 500, Lioufeng Rd., Wufeng, Taichung 41354, Taiwan

2017, 2018). Moreover, it is recognized that stock markets are more responsive to clean environmental policy (Ramiah et al. 2013), main environmental events (He and Liu 2018), and pollution levels (Wu et al. 2018; Al-Mulali et al. 2019). Similarly, Zhang et al. (2011) did the same for China who noted that the stock market influences the carbon emission by expanding their business activities.

Since the 1970s, exchange rates became flexible; therefore, the response of exchange rates volatility on each macroeconomic variable has received renewed attention and environmental pollution is no exception. Since its introduction, many researchers have put their interests in it. This opened a new door for policymakers in the field of international finance to see how this volatility in exchange rate affected the environments in different countries. Bahmani-Oskooee and Mohammadian (2018) exposed that exchange rate volatility influences domestic production and they further infer that appreciations hurt domestic production in the Czech Republic. The fresh study by Bahmani-Oskooee and Gelan (2019) revealed that appreciation hurts domestic investment in Burkina Cote, Faso, Gabon, Ghana, and Mauritius in the short run, while depreciation also hurts investment in the long run in Cote and Gabon. Bahmani-Oskooee et al. (2019) and Bahmani-Oskooee and Gelan (2019) argue that exchange rate volatility reducing money demand in Asia and Africa, which also further affects the consumption, private and public investment, and energy consumption. While Bahmani-Oskooee and Harvey (2019) document that increased exchange rate volatility boosts the export of the USA economy. In this regard, exchange rate volatility may affect environmental pollution via money demand, investment, domestic production, price stability, and export.

In this process, a widespread part of the appropriate literature explores the influence of certain indicators on carbon emissions, containing economic growth (Narayan et al. 2016), energy consumption (Bloch et al. 2015; Usman et al. 2020), trade openness (Sbia et al. 2014), financial development (Zhang et al. 2011), industrialization (Ullah et al. 2020), and urbanization (Rafiq et al. 2016). However, the influence of the stock market and stock exchange volatility on pollution emissions has been irregularly explored in the past literature. A common feature of the previous literature (see Zhang et al. 2011; Li and Peng 2016; Paramati et al. 2016, 2017, 2018) is that they have supposed the impacts of stock markets on environmental pollution to be symmetric. In terms of the exchange rate volatility-environmental nexus, there are no research efforts that scrutinize the link between exchange rate volatility and environmental pollution.

There is a small number of empirical studies that scrutinized the result of stock markets on environmental pollution in Pakistan, although the obvious rise in the stock market's economic activities has significance to Pakistan's environments. Moreover, dissimilar from the prior studies that scrutinized the symmetry association between the stock market and environmental pollution, our study will extend the literature by examining the asymmetric association between the stock market and environmental pollution. The asymmetric association can expose whether the positive or negative shocks of stock markets on environmental pollution have dissimilar effects. This study also provides rich thinking on the effect of the increase and the fall of exchange rate volatility on Pakistan's environmental pollution. This is the first study in the environmental economics literature that incorporates the exchange rate volatility as an independent variable. This study will help the policymakers to offer more precise policies to control environmental pollution levels that are generated from the stock market and exchange rate volatility. This study will provide new insights of policymakers in Pakistan as well as developing and emerging economies.

The rest of the study is outlined as follows: the "Literature review" section provides the empirical literature on existing studies; the "Model, methodology, and data" section discusses the data description, model, and methodology; the "Empirical results" section depicts the results and discussion; and the "Conclusion and policy implications" section provides concluding results with some policy implications.

Literature review

The growing economic activities of stock markets have affected environmental pollution in numerous ways. The furthermost way is stock market developments which are mainly engaging in commercial activities because they permit easy access to an extra source of finance capital. The important development of economic activities may consume more fossil fuel energy and contribute to carbon emissions around the globe (Sadorsky 2011). Furthermore, increased stock market business activities create a strong wealth effect, by spreading risks for producers and consumers that in turn disturb the environmental pollution (Mankiw and Scarth 2008). One school of thought, the stock market is frequently reflected as a main economic indicator of economic development in the literature that increased the consumers' and producer's confidence. In reflection, confidence increases the production of manufacturing activities that lead to increased environmental emissions (Sadorsky 2011).

Another school of thought, the stock markets support to lessen environmental pollution by imposing rules and regulations on the registered enterprises, so as they routine used cleaner technologies, which may reduce environmental pollution (Pardy and Mundial 1992; Lanoie et al. 1997). However, well-organized stock markets also compare and rank their registered companies to their environmental quality, which inspires emitters to decrease their pollution levels. Furthermore, stock market growths raise financial resources for clean and green energy ventures which may also shrink carbon emissions (Paramati et al. 2016; Al-mulali et al. (2019). A similar result is also found by Kutan et al. (2017) in major emerging market economies and Paramati et al. (2017) in developed economies, who reason that a stock market may provide finance capital to the clean and green energy sector. For possible reasons, stock market improvement may have an important influence on environments around the globe.

Extensive literature argues that stock market growths can considerably encourage economic development. Stock market growths may also influence economic development in two ways in the empirical literature. First, stock markets offer another channel for capital and savings formation and new resource allocations, which provide financial support to business activities. Undoubtedly, these large ventures spur economic growth in economies (Adjasi and Biekpe 2006). Second, an efficient stock market improves agent-principal problems that improve economic development in the long run. Empirically, pioneer studies (Spears 1991; Atje and Jovanovic 1993), who noted that stock market growths are significant positively linked with GDP per capita. Similar results have been found in the perspective of developed economies (Cooray 2010), emerging markets (Carp 2012), and Africa (Ngare et al. 2014). While Beck and Levine (2004) found the favorable result of stock markets on economic development by using panel data. Following channels of stock market activities have also a harmful impact on environmental quality.

In contrast, another bunch of empirical studies shows that stock markets have a significant negative effect on economic development. Therefore, Singh (1997) proposes that stock market instability could worsen macroeconomic instability, which may also disturb economic development in developing economies. While Devereux and Smith (1994) illustrate that stock market economic activities are central to risk sharing and, therefore, worse economic development. Considering 22 emerging economies, Sadorsky (2010) also found helpful evidence that stock markets have a significant positive influence on energy consumption that reverse environmental quality.

Limited empirical studies are available that scrutinize the effect of stock market activities on environmental pollution. In the earlier study, Lanoie et al. (1998) observe the Canada and USA stock markets and revealed that efficient capital markets affect the environmental quality by improving the enforcement rules to their firms. Therefore, stock markets give environmental incentives to develop air quality. Similarly, Dasgupta et al. (2001) show similar results for developing economies and the latter study emphases on Argentina, Mexico, Chile, and the Philippines economies. Their empirical finding explains that stock markets boost up the environmental quality of manufacturing firms. Similarly, Gupta and Goldar (2005) findings scrutinize that the stock market normally punishes the firms with an unfriendly behavior towards the environment quality, and hence, they show a significant role in environmental pollution controls. Tamazian et al. (2009) revealed that stock markets significantly decline the pollution emissions in Brazil, Russia, India, and China.

Zhang et al. (2011) illustrate the impact of stock markets on pollution releases in China along with whether financial indicators matter. The author's results show that the stock market has reasonably more influence on environments where stock market efficiency is weaker. The latest empirics by Paramati et al. (2017) realize the influence of stock market development on carbon discharges in G-20 economies. The authors present that stock markets have a significant negative impact on the carbon emissions in developed while positive effects on developing countries, respectively. Abbasi and Riaz (2016) document that stock markets have positively associated with carbon discharges in Pakistan. Al-mulali et al. (2019) inspect the asymmetric impacts of the stock market on environmental pollution in Malaysia by using a symmetric ARDL model. The results showed that positive shock in stock markets will increase carbon emissions in the short and long run. While a decline in the stock market has to decrease carbon emissions in the long run. Similarly, a group of studies found that exchange rate volatility can induce domestic production, domestic investment, money demand, trade balance, and economic growth (Bahmani-Oskooee and Mohammadian (2018) for the Czech Republic; Bahmani-Oskooee et al. (2019) for Asia; Bahmani-Oskooee and Gelan (2019) for Africa; and Bahmani-Oskooee and Harvey (2019) for the USA), which in turn hurts environments.

Overall, the related empirical studies suggest that there are inadequate studies on the relationship between stock markets, exchange rate volatility, and environmental pollution. While limited literature is available on the relationship among stock markets and environments around the globe. Previous literature treats this nexus as a symmetric that give us biased results. Also, the previous empirical literature has not found any nexus on the exchange rate volatility-pollution emissions. Therefore, this new empirical study is deliberated to thin these research gaps and, by paying more attention to the empirical literature, to offer new insights for researchers and environmental policymakers.

Model, methodology, and data

In formulating the environmental pollution and explaining the approaches, we closely follow Al-mulali et al. (2019) and Ullah et al. (2020) who familiarized asymmetry analysis. As such, we begin with the following environmental pollution model:

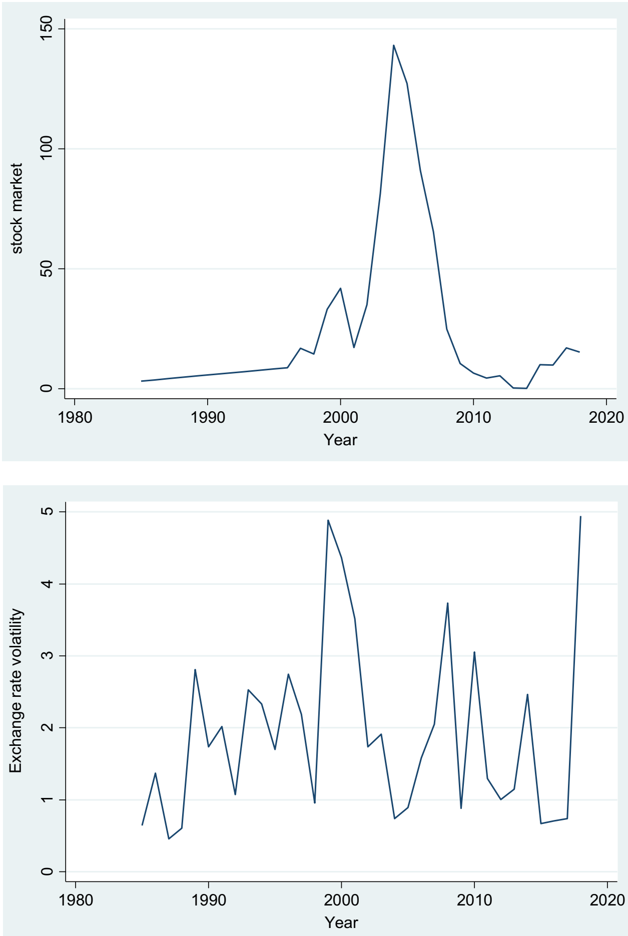

Fig. 1 Stock market and exchange rate volatility of Pakistan

$$CO_{2,t} = \alpha_0 + \alpha_1 SM_t + \alpha_2 VOL_t + \alpha_3 EG_t + \varepsilon_t \quad (1)$$

where carbon emissions ($CO_{2,\ t}$) is a dependent variable proxy of environmental pollution in Pakistan in time *t*. In Eq. (1), SM_i is the measure of the stock market development in Pakistan and VOLi is the measure of exchange rate volatility between Pakistan and the USA in period *t*. We expect as an estimate of α_1 to negative and that of α_2 to be positive or negative while economic growth (EG_t) would be positive.

However, Eq. (1) is a long-run model estimates that are given by OLS or any method only reproduces long-run effects. The next step is to formulate the short-run adjustment process into Eq. (1) followed by Pesaran et al.'s (2001) linear ARDL; therefore, extended error-correction model is:

$$\Delta CO_{2,t} = \alpha_0 + \sum_{i=1}^{n1} \pi_i \Delta CO_{2,t-i} + \sum_{i=0}^{n2} \eta_i \Delta SM_{t-i} + \sum_{i=0}^{n3} \theta_i \Delta VOL_{t-i} + \sum_{i=0}^{n4} \psi_i \Delta EG_{t-i} + \varphi_1 CO_{2,t-1} + \varphi_2 SM_{t-1} + \varphi_3 VOL_{t-1} + \varphi_4 EG_{t-1} + \varepsilon_t \quad (2)$$

Since the critical values are formed by assuming indicators which are either integrated of order zero *I*(0) or one *I*(1), there is no requirement for pre-unit root testing because almost model variables are a combination of either *I*(0) or *I*(1). One of the additional edges of this ARDL approach provides both short- and long-run effects in a single step by computing equation either (2) or (7). Once cointegration is established among model variables, we normalize φ_2–φ_4 by φ_1 to get long-run coefficients of all three variables on the carbon emissions. However, if the linear combination of lagged level variables is significant in the *F* test, this implies that cointegration established in the long run (Pesaran et al. 2001). However, the *F* statistics in this process uses new critical small sample values that they formulate. To this end, following the facts, we now introduce asymmetry adjustment of (SM) and (VOL) changes by decomposing such changes to positive shocks (SM^+_t, VOL^+_t) and negative shocks (SM^-_t, VOL^-_t). More precisely:

$$SM^+_t = \sum_{n=1}^{t} \Delta SM^+_t = \sum_{n=1}^{t} \max\left(\Delta SM^+_t, 0\right) \quad (3)$$

$$SM^-_t = \sum_{n=1}^{t} \Delta SM^-_t = \sum_{n=1}^{t} \min\left(\Delta SM^-_t, 0\right) \quad (4)$$

$$VOL^+_t = \sum_{n=1}^{t} \Delta VOL^+_t = \sum_{n=1}^{t} \max\left(\Delta VOL^+_t, 0\right) \quad (5)$$

$$VOL^-_t = \sum_{n=1}^{t} \Delta VOL^-_t = \sum_{n=1}^{t} \min\left(\Delta VOL^-_t, 0\right) \quad (6)$$

Table 1 Variables description and summary statistics

Variable	Symbol	Definition	Mean	SD
Carbon dioxide emissions	CO_2	Carbon dioxide emissions (kilotons)	115,272.8	41,899.53
Stock market	SM	Stocks traded, total value (% of GDP)	24.80	35.61
Exchange rate volatility	VOL	Volatility measure of the real exchange rate (REX) between the US dollar and Pakistani rupee	1.925	1.242
GDP growth	EG	GDP growth (annual %)	4.569	1.877

Table 2 Unit root tests

Variables	ADF test statistic			ERS test statistic			PP test statistic		
	Level	1st difference	Decision	Level	1st difference	Decision	Level	1st difference	Decision
CO_2	−3.43**	-	$I(0)$	6.33**	-	$I(0)$	−3.68**	-	$I(0)$
SM	−2.08	−5.26**	$I(1)$	4.61**	-	$I(0)$	−2.17	−5.23**	$I(1)$
VOL	−4.29**	-	$I(0)$	3.33**	-	$I(0)$	−4.18**	-	$I(0)$
EG	−3.55**	-	$I(0)$	3.83**	-	$I(0)$	−3.48**	-	$I(0)$

Note: ** and * denote significance levels at 5% and 10%, respectively

Since by way of construction, the partial sum of positive shock (SM^+_t, VOL^+_t) and the partial sum of negative shock (SM^-_t, VOL^-_t) variables introduce asymmetries into Eq. (7), Shin et al. (2014) call Eq. (7) as an asymmetric ARDL model, whereas Eq. (2) is called the symmetric ARDL equation. For other partial sum applications of asymmetric ARDL approach, see Bahmani-Oskooee et al. (2019), Ullah et al. (2020), and Usman et al. (2020). The new specification of the model is based on literature as follows:

$$\begin{aligned}\Delta CO_{2,t} = {} & \alpha_0 + \sum_{i=1}^{n1} \pi_i \Delta CO_{2,t-i} + \sum_{i=0}^{n2} \eta_i \Delta SM^+{}_{t-i} \\ & + \sum_{i=0}^{n3} \phi_i \Delta SM^-{}_{t-i} + \sum_{i=0}^{n4} \lambda_i \Delta VOL^+{}_{t-i} \\ & + \sum_{i=0}^{n5} \rho_i \Delta VOL^-{}_{t-i} + \sum_{i=0}^{n6} \psi_i \Delta EG_{t-i} \\ & + \varphi_1 CO_{2,t-1} + \varphi_2 SM^+{}_{t-1} + \varphi_3 SM^-{}_{t-1} \\ & + \varphi_4 VOL^+{}_{t-1} + \varphi_5 VOL^-{}_{t-1} + \varphi_6 EG_{t-1} + \varepsilon_t \quad (7)\end{aligned}$$

Once Eq. (7) is estimated, a few asymmetry propositions could be verified. Therefore, first, if $\Delta SM^+{}_{t-i}(\Delta VOL^+{}_{t-I})$ takes a different lag order than $\Delta SM^-{}_{t-i}(\Delta VOL^-{}_{t-I})$ that will be a sign of short-run dynamics asymmetries. Second, if the sign/magnitude of the partial sum of positive shocks is different than the partial sum of negative shocks, which shows the indication of short-run asymmetric effects. Third, by appalling the Wald test, if the estimate of positive shocks η_I (ϕ_i) is different than the estimate of negative shocks $\phi_i(\rho_i)$ at the same lags that will be a sign of short-run asymmetries effects. Lastly, long-run asymmetries will be documented through the Wald test, if the estimate is ${}^{\varphi_2{}^+}/_{\varphi_1} \neq {}^{\varphi_3{}^-}/_{\varphi_1}$ and ${}^{\varphi_4{}^+}/_{\varphi_1} \neq {}^{\varphi_5{}^-}/_{\varphi_1}$. In this process, symmetric and asymmetric models (2) and (7) are estimated in the next section.

The data on dependent, independent, and control variables have been gathered from the World Bank (2019). The annual carbon emissions are presented in kilotons (kt), stock market data is given as a total value (% of GDP) in the stock market, while exchange rate volatility data is constructed from the monthly data from the exchange rate of Pakistan and the USA, and economic growth is presented as GDP growth (annual %). The time series data range form 1985–2018. Carbon emissions variables have been transformed into algorithms in estimation. The mean of CO_2, SM, VOL, and EG are 115,272.8 kt, 24.80%, 1.925, and 4.569%, respectively, while the standard deviation (SD) is 41,899.53 kt, 35.61%, 1.242, and 1.877%, respectively. We plot the stock market and exchange rate volatility variables in Fig. 1. Based on data visualization, our descriptive results show that all the variables are well for estimation (Table 1).

Empirical results

Table 2 shows the findings of unit root tests of Elliott, Rothenberg, and Stock (ERS); augmented Dickey-Fuller (ADF); and Phillips-Perron (PP). In all tests, ADF, ERS, and ADF unit root tests revealed that CO_2, VOL, and EG are integrated of order zero, while SM has a mixed order of integration in three statistics such as $I(0)$ and $I(1)$; therefore, the ARDL estimation methodology is applicable.

In the "Empirical results" section, we also estimate both the symmetric and asymmetric ARDL models for the case of Pakistan in Table 3. In panel A, the short-run estimates of the symmetric ARDL model show that only the exchange rate volatility has effects on carbon emission 1 year ago in the short run. Similarly, economic growth has also a positive influence on carbon emissions in the short run in Pakistan.

Do these symmetric short-term responses last into the long term? Therefore, we return to long-run estimates in panel B; the stock market carries a positive significant impact on carbon emissions, which supports the environmentalist view. For example, a 1% positive development in the stock market upsurges carbon emissions by 20,288 kt. The findings show that the stock market intensifies carbon pollution confirms with Zhang et al. (2011) and Al-Mulali et al. (2019) and is not in line with Tamazian et al. (2009) and Paramati et al. (2017). The possible reason is stock market enhances the economic activities that generate more carbon pollution. Another economic justification is stock market business has a significant positive effect on the

Table 3 Short-run and long-run coefficient estimates

	ARDL			NARDL		
	Estimates	Std. error	*t* statistic	Estimates	Std. error	*t* statistic
Panel A: short-run estimates						
ΔSM_t	0.002	0.005	0.401			
ΔSM_{t-1}	− 0.007	0.005	1.450			
ΔSM_t^+				− 0.020	0.019	1.053
ΔSM_{t-1}^+				− 0.078**	0.025	3.115
ΔSM_t^-				0.021	0.018	1.166
ΔSM_{t-1}^-				− 0.078**	0.023	3.391
ΔSM_{t-2}^-				− 0.097**	0.030	3.228
ΔSM_{t-3}^-				− 0.092**	0.028	3.225
ΔVOL_t	0.001	0.002	0.502			
ΔVOL_{t-1}	− 0.006**	0.003	2.000			
ΔVOL_t^+				− 0.007**	0.003	2.333
ΔVOL_{t-1}^+				0.004	0.004	0.999
ΔVOL_{t-2}^+				− 0.005	0.004	1.250
ΔVOL_t^-				0.009	0.006	1.489
ΔVOL_{t-1}^-				0.045**	0.016	2.810
ΔVOL_{t-2}^-				0.041**	0.012	3.411
ΔVOL_{t-3}^-				0.015*	0.008	1.838
ΔEG_t	0.002**	0.001	2.005	− 0.005*	0.002	2.502
ΔEG_{t-1}	0.001	0.001	1.001	0.012**	0.004	2.993
ΔEG_{t-2}	0.004**	0.001	4.002	0.007**	0.002	3.418
Panel B: long-run estimates						
SM	0.176**	0.063	2.793			
SM^+				0.079**	0.032	2.466
SM^-				0.103**	0.005	20.60
VOL	− 0.048**	0.024	2.001			
VOL^+				− 0.015**	0.007	2.144
VOL^-				− 0.043**	0.008	4.994
EG	0.005	0.034	0.147	0.026**	0.006	4.225
C	5.198**	0.190	27.28	5.002**	0.055	90.65
Panel C: diagnostic tests						
F test	10.09**			6.785**		
ECM_{t-1}	− 0.540**	0.172	3.139	− 0.740**	0.192	3.854
LM test	1.065			0.785		
Ramsey RESET	0.297			0.524		
Adj-R^2	0.970			0.981		
CUSUM	S			S		
CUSUM squares	S			S		
WALD SR-SM				2.571**		
WALD LR-SM				2.712**		
WALD SR-VOL				2.077*		
WALD LR-VOL				4.603**		

Note: * and ** denote 10% and 5% level of significance, respectively. The critical values of RESET, LM, and Wald tests at the 10% level of significance is 2.70 and at 5% level 3.84

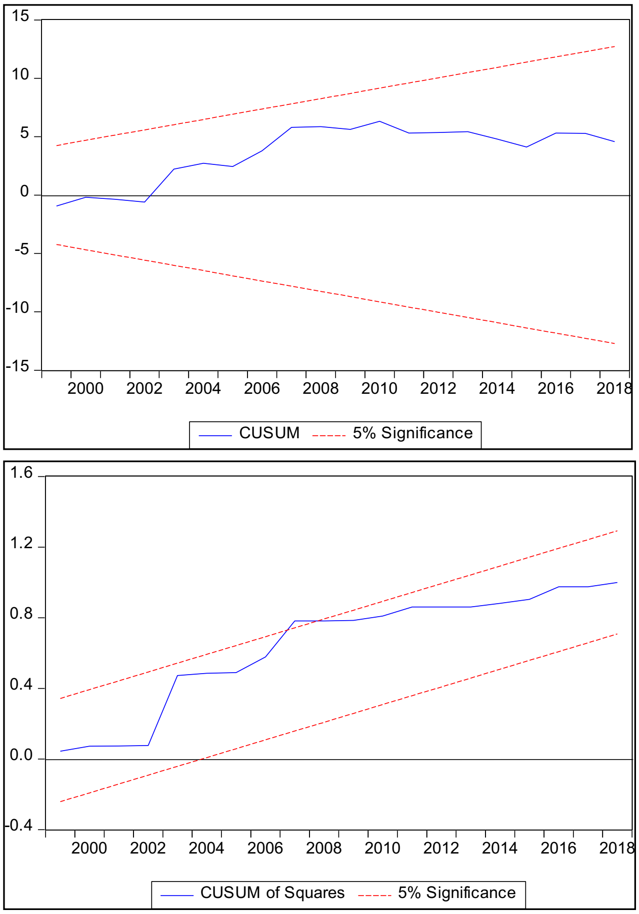

Fig. 2 CUSUM and CUSUM of squares of the ARDL model

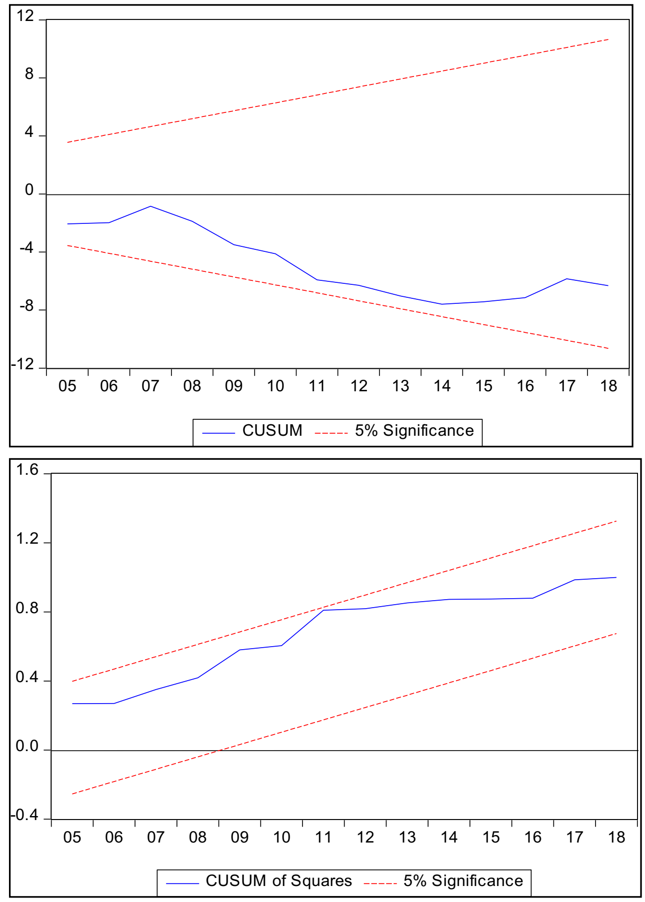

Fig. 3 CUSUM and CUSUM of squares of the NARDL model

environment via fossil fuel energy consumption. Moreover, the result implies that the stock market does not offer environmental quality incentives in developing countries than in developed countries. Furthermore, in the long run, exchange rate volatility affects carbon emissions positivity; this implies that a 1% increase in volatility enhances 5533 kt of carbon emissions. A possible reason is exchange rate volatility is boosting dirty domestic production due to fossil fuels; hence, environmental pollution enhances in Pakistan. Findings also suggest that exchange rate volatility significantly contributes to domestic unclean energy investment that is sources of environmental pollution. The result also indicates that exchange rate volatility influences the environments via trade openness. However, economic growth has an insignificant influence on Pakistan's CO_2 emission in the long run.

Is this long-run estimate valid? Therefore, our established F statistic is significant and indicating that cointegration has existed in the symmetric model. Alternative ECM_{t-1} statistics is also supported cointegration which implies that the speed of adjustment is 54% per year for Pakistan. Four extra statistics are described in panel C. LM and RESET test statistics are insignificant, supporting free autocorrelation residuals, and lack of misspecification. The stability of the short- and long-run coefficients estimated is established by employing famous CUSUM and CUSUM square tests to the residuals of the ARDL model in Fig. 2. We symbolized stable estimates by "S" and unstable ones by "US." The estimates of the linear ARDL is "S" in both statistics in Fig. 2. The last statistic described is the size of the adjusted R^2, which is employed to judge the goodness of fit.

Now we shift to the short-term and long-term estimates of the asymmetric ARDL. From the short-term outcomes in panel A, we indicated that the increase in stock market performance (SM^+) leads to enhances carbon emission while a fall in stock market performance (SM^-) has also decreased the carbon emission in the short run. The short-run impact of exchange rate volatility seems to be an asymmetric impact on carbon pollution in Pakistan since the estimate of (ΔVOL^+) is different than the estimate of (ΔVOL^-). The effect of economic growth on pollution emissions is also maintained in the short-run asymmetric model.

Do these short-term asymmetric impacts last into the long term? From the long-term estimates, it indicates that positive and negative shock of the stock market has significant positive effects on environmental pollution, while effects are significantly different in magnitude. This implies that a 1% rise (fall) in the stock market performance would lead to a 9106 kt

(11,873 kt) rise in carbon emissions. The previous results which infer that performance in stock market business activities enhances carbon emission that is reliable with the findings of Al-Mulali et al. (2019) who exposed that stock market business expansion will stimulate environmental pollution in Malaysia. One of the possible reasons is stock markets in the developing economies including the stock market of Pakistan focuses on the unclean economic growth raising the manufacturing, industrial, and construction activities while giving small attention towards the environmental quality. Another possible justification is still green financing is small in the stock market rather than dirty financing in Pakistan that is sources of environmental pollution. Therefore, the result indicates that Pakistan's stock market promotes unclean nonrenewable consumption of energy and, hence, stimulates carbon emissions. This result further implies that the development of the stock market in Pakistan is expected to enhance pollution emissions. Finding recommends that negative shock in the stock market could worsen macroeconomic instability, which may frustrate and change the patterns of economic growth that is not reasonable for environmental quality. This also implies that positive shock in the stock market has a smaller effect on carbon pollution than negative shock.

Similarly, if exchange rate volatility increases by 1%, carbon emissions would fall by 1729 kt, and if exchange rate volatility decreases by 1%, it would lead to a 4956-kt reduction in carbon emissions. This also implies that positive shock in volatility has a smaller effect on carbon pollution than negative shock. Furthermore, a fall in exchange rate volatility boosts export and domestic production that is also a source of environmental pollution in Pakistan. The result also indicates that increased exchange rate volatility slows the economic growth that helps lessen the carbon emissions in Pakistan as well as developing countries. The impact of economic growth is positive significant on pollution emissions, indicating that a 1% increase in economic growth enhances 2997 kt of carbon emissions.

These long-run asymmetric effects are also meaningful since F statistic and ECM_{t-1} in the NARDL model are significant, supporting asymmetric cointegration. Other diagnostics, LM, and RESET statistics have a distribution with one degree of freedom. Again, it is insignificant in the NARDL model, which implies that there are no autocorrelation and misspecification problems in the model. Finally, adjusted R^2 is also well in the goodness of fit. Furthermore, short- and long-run asymmetric effects are further maintained by the Wald test that is significant and reported in panel C. CUSUM and CUSUM of squares of the NARDL model is also stable in Fig. 3. The dynamic multiplier graphs, based on the NARDL model, are explained in Fig. 4. The asymmetry curves show the nonlinear mixture of the dynamic multipliers due to positive and negative shocks of the stock market and exchange rate volatility variables (Fig. 4).

Conclusion and policy implications

The main purpose of this study is to scrutinize the asymmetric impacts of the stock market and exchange rate volatility on Pakistan's environmental pollution. To get this objective, we employed Shin et al.'s (2014) nonlinear ARDL approach for the period of 1985–2018 and carbon emissions have been used to proxy as environmental pollution. Moreover, in the short run, negative and positive shocks in the stock market have a negative influence on Pakistan's carbon emissions. In addition, in the short run, positive shock in exchange rate volatility has declined the carbon emissions while negative shock leads to carbon emission in Pakistan. Our empirical findings show that the stock market and exchange rate volatility exert an asymmetric long-run influence on carbon emissions. The findings show that, in the long run, negative and positive shocks in the stock market increase carbon emissions in Pakistan. Furthermore, in the long run, positive and negative shocks in exchange rate volatility decrease carbon emissions, but the positive shock is infinitesimally small compared with the negative shock. The effect of the stock market on pollution emissions is much stronger and harmful than

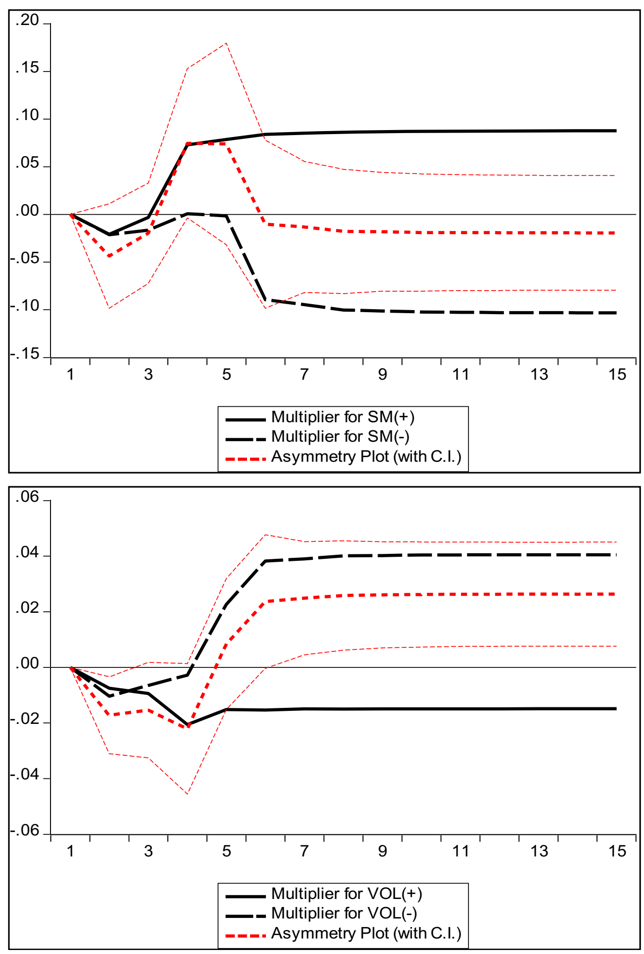

Fig. 4 Dynamic multiplier graphs

exchange rate volatility in Pakistan. The concept of asymmetries is supported in Pakistan.

Our findings have implications that improvement in stock market economic activities enhances Pakistan's pollution emissions which infer the stock traded in Pakistan regularly comes from enterprises that are fundamentally not environmentally friendly. Analysis suggests that the government could improve clean energy efficiency, and nourishing real-estate green infrastructure ventures for the registered enterprises is crucial to lessen Pakistan's environmental pollution. Furthermore, the government should offer economic incentives for the registered enterprises that are cleaner in their business activities. The government should focus on the green energy financing project in the shock market to registered companies. Furthermore, the government should also convert the foreign investment inflows into clean and green energy ventures by lowing the taxes. Mostly Pakistan's energy comes from conventional fossil fuels; therefore, policymakers should enhance private-public partnerships in clean and renewable energy projects. Governments should provide additional funding to stock markets for environmental quality. Stock market development enhances carbon emissions; therefore, governments should promote a strong institutional setup that provides the financial and non-financial incentives for healthy environments.

References

Abbasi F, Riaz K (2016) Co 2 emissions and financial development in an emerging economy: an augmented var approach. Energy Policy 90: 102–114

Adjasi CK, Biekpe NB (2006) Stock market development and economic growth: the case of selected African countries. Afr Dev Rev 18(1): 144–161

Al-mulali U, Solarin SA, Ozturk I (2019) Examining the asymmetric effects of stock markets on Malaysia's air pollution: a nonlinear ARDL approach. Environ Sci Pollut Res 26(34):34977–34982

Atje R, Jovanovic B (1993) Stock markets and development. Eur Econ Rev 37(2):632–640

Bahmani-Oskooee M, Gelan A (2019) Asymmetric effects of exchange rate changes on the demand for money in Africa. App Econ 51(31): 3365–3375

Bahmani-Oskooee M, Harvey H (2019) Who is hurt by dollar-euro volatility in the euro zone? Int.Econ 159:36–47

Bahmani-Oskooee M, Mohammadian A (2018) Asymmetry effects of exchange rate changes on domestic production in emerging countries. J Emerg Mark Finance 54(6):1442–1459

Bahmani-Oskooee M, Xi D, Bahmani S (2019) More evidence on the asymmetric effects of exchange rate changes on the demand for money: evidence from Asian. App Econ Lett 26(6):485–495

Beck T, Levine R (2004) Stock markets, banks, and growth: Panel evidence. J Bank Financ 28(3):423–442

Bloch H, Rafiq S, Salim R (2015) Economic growth with coal, oil and renewable energy consumption in China: prospects for fuel substitution. Econ Model 44:104–115

Carp L (2012) Can stock market development boost economic growth? Empirical evidence from emerging markets in central and eastern europe. Procedia Economics and Finance 3:438–444

Cooray A (2010) Do stock markets lead to economic growth? J Policy Model 32(4):448–460

Dasgupta S, Laplante B, Mamingi N (2001) Pollution and capital markets in developing countries. J Environ Econ Manag 42(3):310–335

Devereux MB, Smith GW (1994) International risk sharing and economic growth. Int Econ Rev 35(3):535–550

He X, Liu Y (2018) The public environmental awareness and the air pollution effect in Chinese stock market. J Clean Prod 185:446–454

Gupta S, Goldar B (2005) Do stock markets penalize environment-unfriendly behaviour? Evidence from India. Ecol Econ 52(1):81–95

Kutan, A. M., Paramati, S. R., Ummalla, M., & Zakari, A (2017) Financing renewable energy projects in major emerging market economies: evidence in the perspective of sustainable economic development. Emerg Mark Financ Trade, (available online)

Lanoie P, Laplante B, Roy M (1997) Can capital markets create incentives for pollution control? World Bank Policy Research Working Paper 1753

Lanoie P, Laplante Bt, Roy M (1998) Can capital markets create incentives fo pollution control? Ecol Econ 26(1):31–41

Li Q, Peng CH (2016) The stock market effect of air pollution: evidence from China. App Econ 48(36):3442–3461

Mankiw, N. G., & Scarth, W (2008) Macroeconomics. 3rd Canadian Edition

Narayan PK, Saboori B, Soleymani A (2016) Economic growth and carbon emissions. Econ Model 53:388–397

Ngare E, Nyamongo EM, Misati RN (2014) Stock market development and economic growth in Africa. J Econ Bus 74:24–39

Paramati SR, Ummalla M, Apergis N (2016) The effect of foreign direct investment and stock market growth on clean energy use across a panel of emerging market economies. Energy Econ 56:29–41

Paramati SR, Mo D, Gupta R (2017) The effects of stock market growth and renewable energy use on CO2 emissions: evidence from G20 countries. Energy Econ 66:360–371

Paramati SR, Alam MS, Apergis N (2018) The role of stock markets on environmental degradation: a comparative study of developed and emerging market economies across the globe. Emerg Mark Rev 35: 19–30

Pardy, R., & Mundial, B (1992) Institutional reform in emerging securities markets (Vol. 907): Country Economics epartment, World Bank

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

Rafiq S, Salim R, Nielsen I (2016) Urbanization, openness, emissions, and energy intensity: a study of increasingly urbanized emerging economies. Energy Econ 56:20–28

Ramiah V, Martin B, Moosa I (2013) How does the stock market react to the announcement of green policies? J Bank Financ 37(5):1747–1758

Sadorsky P (2010) The impact of financial development on energy consumption in emerging economies. Energy Policy 38(5):2528–2535

Sadorsky P (2011) Financial development and energy consumption in central and eastern european frontier economies. Energy Policy 39(2):999–1006

Sbia R, Shahbaz M, Hamdi H (2014) A contribution of foreign direct investment, clean energy, trade openness, carbon emissions and economic growth to energy demand in UAE. Econ Model 36:191–197

Shin Y, Yu B, Greenwood-Nimmo M (2014) Modelling asymmetric cointegration and dynamic multipliers in a nonlinear ARDL framework. In: Festschrift in honor of Peter Schmidt. Springer, New York, pp 281–314

Singh A (1997) Financial liberalisation, stockmarkets and economic development. Econ J 107(442):771–782

Spears A (1991) Financial development and economic growth—causality tests. Atl Econ J 19(3):66–66

Tamazian A, Chousa JP, Vadlamannati KC (2009) Does higher economic and financial development lead to environmental degradation: evidence from bric countries. Energy Policy 37(1):246–253

Ullah S, Ozturk I, Usman A, Majeed MT, Akhtar P (2020) On the asymmetric effects of premature deindustrialization on CO2 emissions: evidence from Pakistan. Environ Sci Pollut Res:1–11

Usman A, Ullah S, Ozturk I, Chishti MZ (2020) Analysis of asymmetries in the nexus among clean energy and environmental quality in Pakistan. Environ Sci Pollut Res:1–12

World Bank (2019) World development indicators 2019. World Bank Publications

Wu X, Chen S, Guo J, Gao G (2018) Effect of air pollution on the stock yield of heavy pollution enterprises in China's key control cities. J Clean Prod 170:399–406

Zhang YJ, Fan JL, Chang HR (2011) Impact of China's stock market development on energy consumption: an empirical analysis. Energy Procedia 5:1927–1931