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Asymmetric impact of renewable and non-renewable energy on economic growth in Pakistan: New evidence from a nonlinear analysis

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Abstract: This paper explores the asymmetric relationship between renewable energy consumption, non-renewable energy, and terrorism on economic growth of Pakistan. We applied a novel econometric cointegration method known as a nonlinear autoregressive distributed lag modeling (NARDL). Our empirical findings indicate that positive and negative changes have a significant long-run asymmetric relationship between renewable energy, and terrorism on economic growth. We also found a negative and significant effect of non-renewable energy consumption on economic growth. To keep our environment clean and free of emissions, the study specifies policies that rely on renewable energy sources to boost economic growth. However, reduces terrorism has a positive impact on economic growth in the long-run and shows as an influential tool to combat terrorism in Pakistan. These novel results will help policy-makers and government officials to understand better the role of renewable energy and economic growth in Pakistan's development.

Keywords: Renewable Energy, Non-renewable, Terrorism, Economic Growth, NARDL, Pakistan

1. Introduction

The heavy reliance of the world on non-renewable energy sources leads to serious worldwide concerns and problems, including potential depletion of non-renewable energy sources, energy security, and environmental issues. Because of these major issues and concerns throughout recent decades, governments have been paying attention to renewable energy sources and investments in renewable energy technologies that have enormously expanded since 2004 have resulted in a prompt decline in the cost of renewable energy technologies (Bulut and Inglesi-Lotz, 2019). Managing and planning energy resources is an essential component of economic growth that is now closely linked to sustainable development (Ur Rehman et al., 2019). As fossil fuel energy continued, the dominant contributor to the global energy consumption mix with 81% of total energy consumption. This statistic shows the world's fossil fuel consumption, such as coal, oil, and natural gas, even in recent times, given all the ecological consequences of their usage, as well as the efforts of countries to move to low-carbon energy supply mixes. This overreliance and its diligence over the years raises various concerns about the energy industry's future, but also about global socio-economic and environmental conditions, according to world bank (WDI, 2018). The average surface temperature of the planet has increased since the late 19th century, about 1.62 degrees Fahrenheit (0.9 degrees Celsius), a tendency driven mostly by rising carbon dioxide and other human-made environmental smog. Most of the climate change has taken place over the past 35 years, with the record five warmest years since 2010. According to the reports, 2016 was the hottest recorded year. However, eight of the twelve months that compensate the year — from January to September, except June — were the hottest months recorded in documents (NASA, 2018).

Energy instability can have severe economic effects, as economic output and maintaining suitable living standards in the population, that extremely dependent on energy use. Eventually, fossil energy combustion is the primary contributor to greenhouse gas emissions leading to climate change. Due to exposure to air pollution, seven million people died in 2012, as reported – one in eight of the world's total worldwide deaths (WHO, 2014). Worldwide economies face high-energy demand challenges to support sustainable growth and development. It comes with an awful assumption that fossil fuels are depleting the traditional energy sources. However, the environmental impacts of conventional energy sources are surprising (Mirza et al., 2012). The wide gap among demand and electricity supply, rising cost of imported fossil fuels, and increasing air pollution, require an urgent search for cost-effective, efficient, and environmentally friendly energy sources. As a result, there is much recent worldwide concern in developing renewable energy sources. Energy is seen as the foundation of economic prosperity and social well-being, while renewable energy is essential to the upcoming climate change. Energy's position always has a conventional output factor. Not only is development dependent on oil, but viable economic growth is also imperative, which can only be accomplished with adequate and sustained energy supply (Wang et al., 2018). Conversely, beyond the influence of energy on economic growth, it also distresses human well-being. For example, the presence of energy infrastructure directly linked to the provision of modern health facilities, education, and interaction. The shortage of energy resources is signs of inadequate health facilities, limited educational and employment opportunities, and the low population's capacity against poverty (Ouedraogo, 2013). As a consequence of economic changes and technological advances, the

international energy landscape is changing rapidly. "Game-changers" like the unconventional oil and gas revolutions or the rapid exit from nuclear power in some nations would drive this transition further (OECD, 2018).

Pakistan is located on the elevated belt of heating, giving it the cost advantage of solar energy in the creation. This power source is much cost-competitive than fossil fuels because it requires neither refining nor transport costs. That is the most desirable substitution for fossil fuels because it does not create environmental pollution. Pakistan, as a nation gifted with so many available energy sources that can minimize reliance on foreign assistance for oil imports if properly utilized. Such obtainable undiscovered energy resources in Pakistan have not only the potential to meet internal energy needs; nevertheless, they also can be exported to other countries with energy deficits. Unluckily, however, these resources were not adequately explored. Several countries across the world have recognized that ensuring pride and self-reliance in access to and eventual use of resources is the secret to achieving and sustaining stability and sovereignty. The energy system recently underwent a transition from fossil fuels to renewable energy and energy-efficient technology to address global challenges. Pakistan has enormous potential to tap renewable energy, and to achieving energy security, its share of the electricity mix needs to be increased. The main complications that need to be tackled in order to promote renewable energy on-grid through the private sector are security issues and circular debt in the country (Mirza et al., 2012). The power sector in Pakistan remains one of the foremost barriers to economic growth. Pakistan faces an acute energy deficit, like other emerging states in the region. It produces its energy from an energy mix that consists of oil, natural gas, and liquefied natural gas (LNG), coal, renewable energy (solar, wind, and hydro), nuclear and geothermal. Pakistan claims for 64% of its energy from electricity, i.e. fossil fuels, 27% from hydro, and 9% from renewable energy and nuclear energy. The country's current demand and supply gap is around 2000 MW at the highest period, with demand growing at a yearly utilization growth rate of less than 7% (Export.gov, 2018). Pakistan's new government plans to increase the share of renewable energy in total electricity production to 30% by 2030, referring to wind, solar, small hydro, and biomass capacity. There is also a target of 30% hydropower on a massive scale (more than 50 megawatts (MW)). Renewable energy presently accounts for a meager 4% share, which is relatively unimportant, given the fact that the country has enormous potential for renewable energy, mainly wind and solar. Big hydro presently supplies about one-fourth of the electricity supply in the country (Craig and Yakatan, 2010; Epstein and Gang, 2006; WWEA, 2019).

Interestingly, (Mohamed et al., 2019) first time investigated the causal relationship between renewable or fossil energies, trade openness, terrorism, and economic growth in France. Their results showed a bidirectional causality between renewable energy, terrorism, and economic growth. However, usually, studies concluded a strong relationship between the use of renewable energy and economic growth characterized as linear and symmetrical. Motivated by this, we have found related studies in the case of Pakistan such as, (Ashfaq and Ianakiev, 2018; Danish et al., 2017; Khan and Pervaiz, 2013; Malik et al., 2014; Maqbool and Sudong, 2018; Mirza et al., 2012; Rauf et al., 2015; Shakeel et al., 2016; Zeeshan Ashfaq, 2019). However, these studies focused on different aspects by factors, period, methodology and concluded that renewable energy has a significant impact on economic growth. Contrary, we have found the gap that none

of the studies concentrated on renewable energy, non-renewable energy, and terrorism effects on economic growth asymerically.

To bridge the gap, this study explores the asymmetric effect of renewable energy, non-renewable energy, and terrorism on economic development in Pakistan using time series annual data from 1970 to 2018. Our study contributes to the energy literature in many ways. Firstly, to the best of the author's knowledge, it is Pakistan's first empirical study that considered renewable energy, non-renewable energy, and terrorism in production function. Secondly, this article differs methodologically from existing studies by using a nonlinear approach to the cointegration of the method NARDL developed by (Shin et al., 2014). Thirdly, as a conclusion to this analysis, our results indicate that preventing and controlling terrorism and investment in renewable energy can be improved Pakistan's economic growth significantly. Eventually, the study also provides new insights in a meaningful way by comparing other research findings to help the policy-makers for concrete and long-lasting decisions. This study, to the best of our knowledge, could be considered superior because none of the studies used these determinants by employing the NARDL model in the case of Pakistan.

The remainder of the study is ordered as follows: Section-II contains a literature review and points out the literature gap that this study seeks to fill. Section-III specifies the estimation approach and data. Section-IV describes the empirical analysis and discussion, and Section-V concludes the research with policy recommendations.

II. An overview of the literature

The causal relationship between energy consumption (renewable and non-renewable) and economic growth are of concern to many empirical studies. Most of the research included other factors, such as emissions of pollutants, or international trade (Ben Jebli and Ben Youssef, 2017; Fodha and Zaghdoud, 2010; Sadorsky, 2011). For instance, (Al-Mulali et al., 2014) documented the effect of renewable and non-renewable electricity consumption on production in Latin American countries. They found long-term causality between the consumption of electricity, renewable, and non-renewable energy resources, labor, and trade. Their empirical analysis indicated that renewable electricity is far more important than non-renewable electricity in supporting economic growth. (Lin and Moubarak, 2014) determined the relationship between China's renewable energy use and economic development by applying autoregressive distributed lag (ARDL) approach to cointegration, including irregular variables such as carbon dioxide emissions and labor. Their study shows that there is a long-term poly-directional causality between renewable energy use and economic growth. They also noted that China's booming economy is conducive to renewable energy sector production, which helps to improve economic growth.

In contrast, (Inglesi-Lotz, 2016) examined the impact of renewable energy consumption on the economic growth of four OECD countries and revealed that the consumption of renewable energy has a significant effect on economic development. (Ma et al., 2010) examined China's renewable energy economy from the analysis of the renewable energy production situation, evaluating the country's renewable energy capacity. According to (Pegels and Lütkenhorst,

2014), Germany is Europe's biggest economy as well as the leading consumer of renewable energy. They analyzed whether renewable energy factors have stabilized the country's prospects for economic growth concerning such improvements. They applied the detrended structural break test by ClementeMontanes-Reyes and combined the cointegration test by Bayer-Hack. Their causality analysis revealed the existence of a multiplicative effect between the consumption of renewable energy and economic growth. The relationship between the consumption of renewable energy and capital is observed to be bidirectional. On the other hand, (Magnani and Vaona, 2013) tried to establish the nature of any potential relationship between renewable energy and economic growth in Italy using data from 1997 to 2007. Their empirical results suggested that the production of renewable energy has significant effects on the current balance of payments constraints. Similarly, (Ocal and Aslan, 2013) inspected the intersection of renewable energy consumption–economic causality growth nexus in Turkey. Their empirical findings show that the consumption of renewable energy has an undesirable effect on economic growth, and economic growth causes renewable energy consumption.

Recently, (Eren et al., 2019) examined the effect on the use of renewable energy by India of financial progress and economic growth by considering economic development, renewable energy consumption, and economic progress as additional determinants. Their findings demonstrate that consumption of renewable energy and economic growth driven by long-term financial development, and bi-directional causality exist between consumption of renewable energy and economic growth in India. (Kocaarslan and Soytas, 2019) contributed to the existing literature by arguing for an asymmetric correlation between oil prices, interest rates, and stock prices of clean energy and technology firms. Using a newly developed approach, NARDL model, they found that the impact on clean energy stock prices of positive and negative shifts in oil prices, interest rates, and innovation stock prices vary considerably in the short-run and long run. They also pointed out that the increased investment in clean energy stocks tends to be due to speculative attacks along with a short-run rise in oil prices. However, the rising oil price has a negative impact on the prices of clean energy stocks in the long run, and this effect is asymmetric. (Fan and Hao, 2019) applied the dynamic generalized method of moments (GMM) panel model to examine the relationship between economic growth, carbon dioxide emissions, and the effect of imports and exports on renewable energy in different provinces in China. They stated that economic growth will certainly bring renewable energy consumption growth, and will play a major role in endorsing renewable energy consumption growth in China, amongst which the eastern part of China is utmost evident. According to (Bader and Schuster, 2015) noted the growing importance for international business, there has been scarcely any study of foreign assignments in countries at risk of terrorism. They examined the effect of features of expatriate social networks on psychological well-being in Afghanistan, India, and Pakistan, which is at risk of terrorism. Based on data surveying 175 expatriates, their empirical findings show that the psychological well-being of foreign expatriates is positively affected by large and diverse networks. They also found that a higher level of terrorism per se does not necessarily have a negative effect on the psychological well-being of expatriates.

In a recent study, (Shah et al., 2020) examined the role of renewable energy, economic growth and CO_2 emissions for the developing countries; their results find that renewable energy has a positive and important relationship with economic progress, whereas CO_2 emission had an

adverse effect, hereafter they supported using more renewable energy in the current infrastructure to improve economic development and for the safety of environment. (Sharif et al., 2019) explored the association between renewable, non-renewable energy consumption, and CO_2 emission by used panel data for 74 countries from 1990 – 2015. Their findings also show that the use of non-renewable energy has a positive effect on environmental degradation, while renewable energy has a negative impact on environmental degradation and helps to minimize pollutants. Likewise, economic growth also impacts negatively and substantially on ecological degradation. In another study, (Ike et al., 2020) analyzed the effects of renewable energy use, electricity prices, and carbon trading in the G7 nations. Their findings show that renewable energy and oil costs exert a negative effect on CO_2 emissions while the amount of trade exerts intense positive pressure on CO_2 emissions. The country-specific assessment findings provide evidence that energy prices have a detrimental impact on CO_2 emissions—the broad literature survey illustrated in Table - 1.

Table - 1: Summary of Literature Review

Author	Country	Timeframe	Methodology	Variables	Relationship
(Apergis and Payne, 2010)	Central America	1985 – 2005	Granger-causality	REC, EG	REC ↔ EG
(Malik and Zaman, 2013)	Pakistan	1975 – 2011	Cointegration	Terrorism, EG	Terrorism ↔ EG
(Raza and Jawaid, 2013)	Pakistan	1980 – 2010	DOLS	Terrorism, Tourism	Terrorism → Tourism
(Ismail and Amjad, 2014)	Pakistan	Survey	ECM	Terrorism, GDP	Terrorism → GDP
(Jaforullah and King, 2014)	US	1965 – 2012	VECM	CO_2, REC	REC ← CO_2
(Long et al., 2015)	China	1952 – 2012	Granger causality	RE, EG, CO_2	CO_2 → EG
(Shahbaz et al., 2015)	Pakistan	1972 – 2011	ARDL, RWA	REC, EG	REC → EG
(Estrada et al., 2015)	Pakistan	1989 – 2013	TAVE	Terrorism, EG	Terrorism → EG
(Alper and Oguz, 2016)	EU	1990 – 2009	ARDL	REC, EG	EC → EG
(Boontome et al., 2017)	Thailand	1971 – 2013	Cointegration	RE, EG, CO_2	RE, CO_2 → EG
(Narayan and Doytch, 2017)	Australia	1971 – 2011	GMM	REC, NRE, EG	REC → NRE → EG

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(Adewuyi and Awodumi, 2017)	Multi-country	2014 – 2016	Survey	REC, NRE, EG	REC → EG ← NRE
(Rafindadi and Ozturk, 2017)	Germany	1971 – 2013	ARDL	REC, EG	REC → EG
(Rehman and Vanin, 2017)	Pakistan	Survey 2009	OLS	Terrorism, Democracy	Terrorism → Democracy
(MengYun et al., 2018)	Pakistan	2001 – 2014	CAPM	Terrorism, Political Instability, Financial Crisis	Terrorism Political instability ↔ Financial Crisis
(Razmi et al., 2019)	Iran	1990 – 2014	ARDL	RE, SM, EG	RE, SM → EG
(Fan and Hao, 2019)	China	2000 – 2015	VECM	REC, FDI, EG	REC, FDI → EG
(Bildirici and Gokmenoglu, 2020)	Turkey	1975 – 2017	Trivariate Causality Test	Terrorism, FDI, EG	Terrorism, FDI ↔ EG

Note: ↔ is bidirectional, ←, → signifies unidirectional, whereas, ≠ presents no relationship.

After an enlightening the wide range of relevant literature, it becomes clear that renewable energy, non-renewable energy, and terrorism is a critical problem, and various studies examined the topic with multiple determinants. No prior studies have found investigating the relationship between energy consumption (renewable and non-renewable sources) and terrorism on economic growth in Pakistan. Several researches used the total energy use of renewable and non-renewable resources. Disaggregating energy for renewable and non-renewable sources may indicate the effect of each source of electricity on economic growth in Pakistan, which may have further policy implications. All of these evidences support to conduct a study for determining the effect between renewable energy consumption, non-renewable energy, and terrorism on economic growth in Pakistan.

III. Estimation Approach and Data

This study explores the asymmetric association among renewable energy, non-renewable energy, terrorism, and economic growth in Pakistan using the NARDL model, and the annual time series data for the period of 1970 – 2018. Renewable energy (in billion kWh), and non-renewable

energy/fossil fuel energy consumption (in % of total) (eia, 2018) while the total number of terrorist attacks used as a proxy for terrorism (GTD, 2018). The data for gross domestic product per capita extracted from the world development indicators (WDI, 2018), a global database prepared by the World Bank. Figure –1 delineates data and methodological workflow.
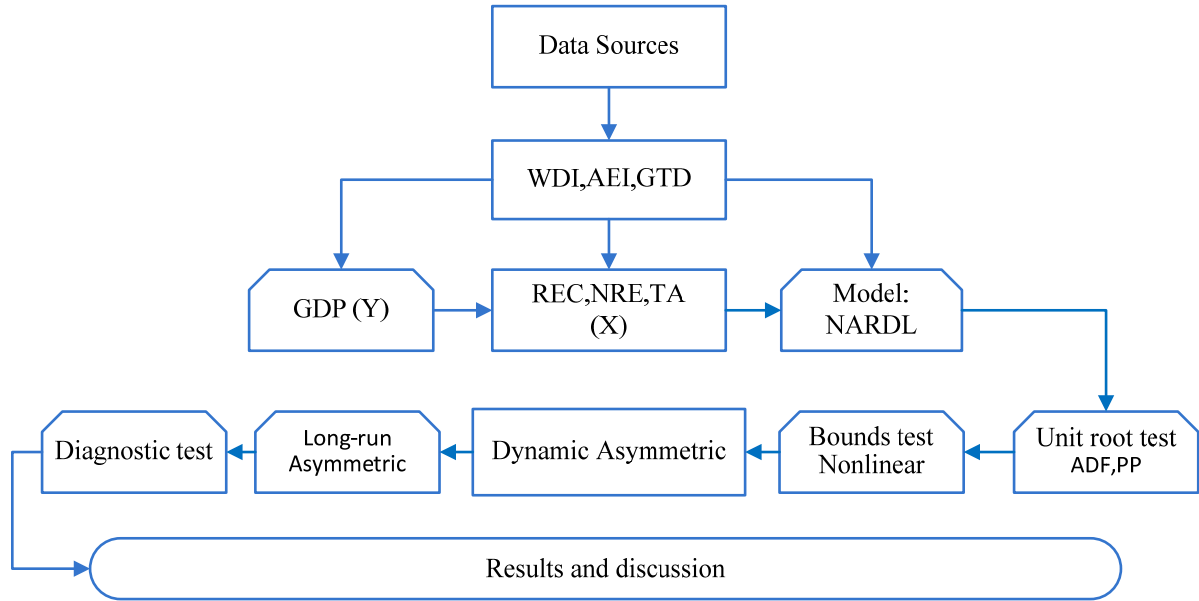

Figure - 1: Pictorial view of methodology workflow

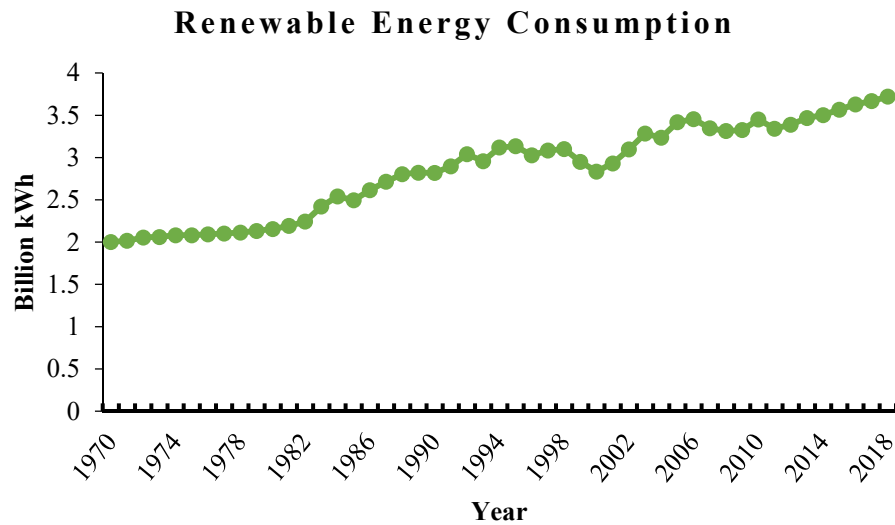Renewable energy consumption, non-renewable and economic growth historical trend shows in Figure - 2 to 4:

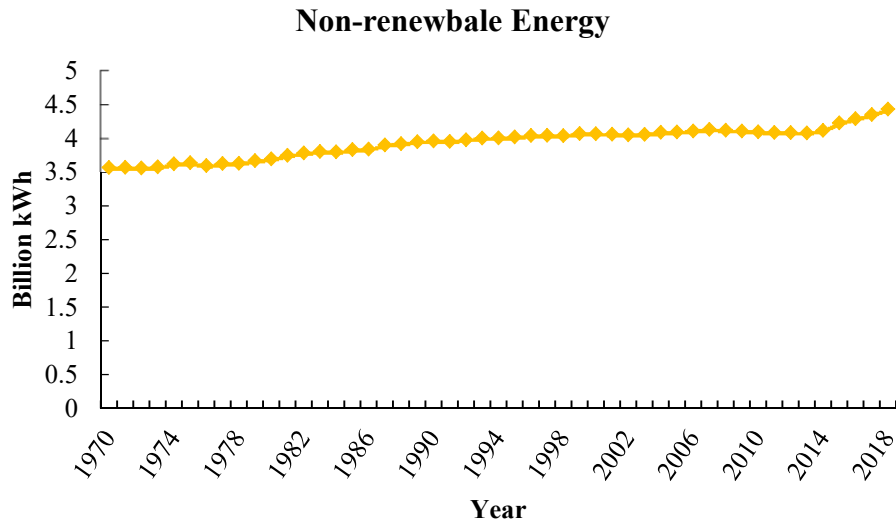Figure - 2: Renewable energy consumption Pakistan (eia, 2018)

Non-renewbale Energy

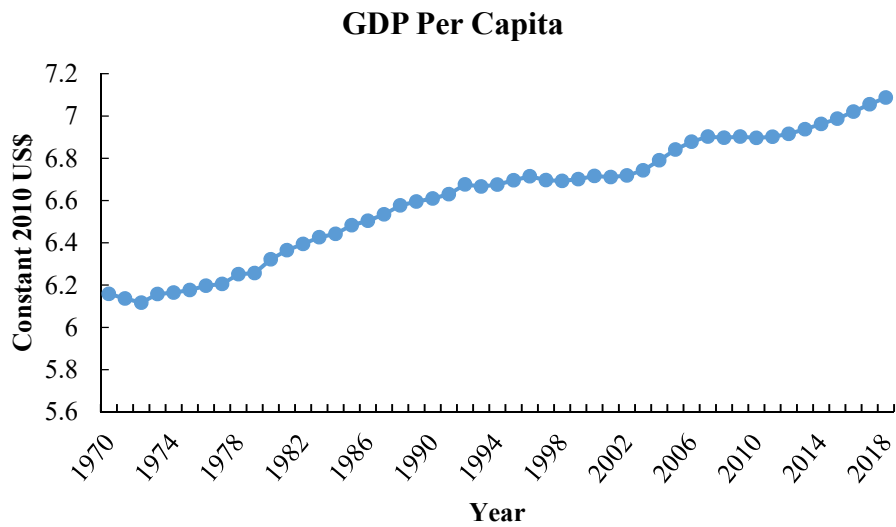Figure - 3: Non-renewable energy Pakistan (eia, 2018)

GDP Per Capita

Figure - 4: Gross domestic product per capita (WDI, 2018)

This study examines the asymmetric relationship between renewable energy (*Re*), non-renewable energy (*Nre*) consumption, and terrorism attacks (*Ta*) on the gross domestic product (*Gdp*) the empirical estimation; we proposed the following equation:

$$Gdp_t = f(Re_t, Nre_t, Ta_t) \tag{1}$$

A linear equation is shown below:

$$Gdp_t = \beta_0 + \beta_1 Re_t + \beta_2 Nre_t + \beta_3 Ta_t + \mu_t \tag{2}$$

Following equation 1 - 2 the empirical work followed by (Meo et al., 2018) where Gdp, Re, Nre, and Ta denotes gross domestic product, renewable energy, nonrenewable energy, and terrorism attacks, respectively. Depending on stationarity parameters, the long-run relationship between two or more variables calculated using the ARDL method, ECM, or Granger Causality. Such models do not take into account the asymmetric nature of the series. On the other hand, linear relationships between variables are calculated by linear regression models, which fail to account for the variables' nonlinear behavior. Considering the nonlinear nature of the variables lately (Shin et al., 2014) prolonged the ARDL framework of (Pesaran et al., 1999, 2001), to asymmetric ARDL cointegration method has employed. This method is proficient to capturing short-term instabilities and structural breaks (asymmetries). We explore the asymmetric effect of renewable, non-renewable, and terrorism on economic growth. (Fareed et al., 2018b) the specific long-term asymmetric equation - 3 of production function is as follows:

$$Gdp_t = \alpha_0 + \alpha_1 Re_t^+ + \alpha_2 Re_t^- + \alpha_3 Nre_t^+ + \alpha_4 Nre_t^- + \alpha_5 Ta_t^+ + \alpha_6 Ta_t^- + \varepsilon_t \tag{3}$$

Where Gdp refers to economic growth, Re is renewable energy, Nre for the non-renewable energy and Ta denotes terrorism, and $\alpha = \alpha_0, \alpha_1, \alpha_2, \alpha_3, \alpha_4, \alpha_5, \alpha_6$ is a cointegrating vector to be estimated while $Re^{+t}, Re^{-t}, Nre^{+t}, Nre^{-t}, Ta^{+t}, Ta^{-t}$ are partial sums of positive and negative changes in renewable energy, non-renewable energy, and terrorism, respectively, in economic growth.

$$Re_t^+ = \sum_{i=1}^{t} \Delta Re_t^+ = \sum_{i=1}^{t} \max \Delta Re_i, 0) \tag{4}$$

$$Re_t^- = \sum_{i=1}^{t} \Delta Re_t^- = \sum_{i=1}^{t} \min \Delta Re_i, 0) \tag{5}$$

$$Nre_t^+ = \sum_{i=1}^{t} \Delta Nre_t^+ = \sum_{i=1}^{t} \max \Delta Nre_i, 0) \tag{6}$$

$$Nre_t^- = \sum_{i=1}^{t} \Delta Nre_t^- = \sum_{i=1}^{t} \min \Delta Nre_i, 0) \tag{7}$$

$$Ta_t^+ = \sum_{i=1}^{t} \Delta Ta_t^+ = \sum_{i=1}^{t} \max \Delta Ta_i, 0) \tag{8}$$

$$Ta_t^- = \sum_{i=1}^{t} \Delta Ta_t^- = \sum_{i=1}^{t} \min \Delta Ta_i, 0) \qquad (9)$$

Following equation 4 - 9 in the asymmetric ARDL framework advanced by (Shin et al., 2014)

$$Gdp_t = \beta_0 + \beta_1 Gdp_{t-1} + \beta_2 Re_{t-1}^+ + \beta_3 Re_{t-1}^- + \beta_4 Nre_{t-1}^+ + \beta_5 Nre_{t-1}^- + \beta_6 Ta_{t-1}^+ + \beta_7 Ta_{t-1}^-$$

$$\sum_{i=0}^{m} \delta_{1i\Delta} Gdp_{t-i} + \sum_{i=0}^{n} \delta_{2i\Delta} Re_{t-i}^+ + \sum_{i=0}^{0} \delta_{3i\Delta} Re_{t-i}^- + \sum_{i=0}^{p} \delta_{4i\Delta} Nre_{t-i}^+ + \sum_{i=0}^{q} \delta_{5i\Delta} Nre_{t-i}^- + \sum_{i=0}^{r} \delta_{6i\Delta} Ta_{t-i}^+ \qquad (10)$$

$$+ \sum_{i=0}^{s} \delta_{7i\Delta} Ta_{t-i}^- + \mu_i$$

We presented *(m,n,o, p,q,r,s)* used as lags orders. However, $\beta_1, \beta_2, \beta_3, \beta_4, \beta_5, \beta_6, and \beta_7$ denote long-term positive and negative shock effects of renewable energy, non-renewable energy, and terrorism on economic growth. $\sum_{i=0}^{n} \delta_{2i}, \sum_{i=0}^{0} \delta_{3i}, \sum_{i=0}^{p} \delta_{4i}, \sum_{i=0}^{q} \delta_{5i}, \sum_{i=0}^{r} \delta_{6i}$ and $\sum_{i=0}^{s} \delta_{7i}$ measured the short-run impacts of positive and negative effects of renewable energy, non-renewable energy, and terrorism on economic growth, respectively. In this analysis, the nonlinear long-run relationship identified by applying the NARDL method. First, the stationarity of all variables is tested by using Phillips and Perron (1988) and Dickey and Fuller (1979) unit root tests. Stationary checking is not necessary for the ARDL method. We may apply the ARDL model when all variables are merely stationary at I(0), or I(1) or a mixture of I(1) and I(0). This model, however, has one limitation that the ARDL model will be unable to proceed with I(2) series (Fareed et al., 2018a). Hence, we checked the variables' stationarity to avoid inaccurate findings.

Equation - 10 is calculated by the ordinary least-square method in the second step. We also adopted the Schwarz Information Criterion (SIC) and the general-to-specific approach, as follows (Katrakilidis and Trachanas, 2012; Saeed Meo et al., 2018). In the third step, we used the bound test to check cointegration to confirm whether or not there is cointegration. After checking the existence of cointegration, we applied the asymmetric ARDL model. In this step, the asymmetric cumulative dynamic multiplier effects of a 1% change is derived as given below.

$$Re_{t-1}^+, Re_{t-1}^-, Nre_{t-1}^+, Nre_{t-1}^-, Ta_{t-1}^+, and \ Ta_{t-1}^-$$

respectively, as followed by (Fareed et al., 2018b).

$$S_h^+(Re) = \sum_{j=0}^{h} \frac{\partial Gdp_{t+i}}{\partial Re_{t-1}^+} \qquad (11)$$

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$$S_h^-(Re) = \sum_{j=0}^{h} \frac{\partial Gdp_{t+i}}{\partial Re_{t-1}^-} \qquad (12)$$

$$S_h^+(Nre) = \sum_{j=0}^{h} \frac{\partial Gdp_{t+i}}{\partial Nre_{t-1}^+} \qquad (13)$$

$$S_h^-(Nre) = \sum_{j=0}^{h} \frac{\partial Gdp_{t+i}}{\partial Nre_{t-1}^-} \qquad (14)$$

$$S_h^+(Ta) = \sum_{j=0}^{h} \frac{\partial Gdp_{t+i}}{\partial Ta_{t-1}^+} \qquad (15)$$

and

$$S_h^-(Ta) = \sum_{j=0}^{h} \frac{\partial Gdp_{t+i}}{\partial Ta_{t-1}^-} \qquad (16)$$

IV. Empirical Results

Following (Ajide and Lawanson, 2012) that the precondition of applying the ARDL bounds test is none of the variables stationary at I(2). The output of ARDL will be considered invalid if any I(2) variable involved in the model. Hence, the stationarity of all the variables is essential. Therefore, the most prominent test for unit root developed by (Phillips and Perron, 1988) and (Dickey and Fuller, 1979) applied, and results are shown in Table - 2. The all examined variables are nonstationary at level, while it turns at the I(1). Moreover, no evidence found I(2) among the variables. Now, it assured that we could proceed towards the ARDL bounds test.

Table - 2: Unit Root Analysis

Variables	Augmented Dickey-Fuller (ADF)		Phillip-Perron (P-P)		Order of integration
	Level	1st Difference	Level	1st Difference	
GDP	-0.67	-5.25*	-0.55	-5.24*	I(1)
REC	-0.47	-6.59*	-0.47	-6.59*	I(1)
NRE	0.33	-3.99**	0.28	-4.07**	I(1)
TA	-1.72	-7.58*	-1.65	-7.71*	I(1)

Note: *, **, and *** denotes to level of significance at 1%, 5%, and 10% respectively

The long-run relationship based on optimal lags and stock claimed by (Bahmani-Oskooee and Bohl, 2000) and, using too many lags or fewer can be lost the important information or may cause the inacceptable estimation by (Stock and Watson, 2012). For a reason, we consider the importance of optimal lags and used three lags as optimum following Akaike criteria. The

bounds test nonlinear results are shown in Table - 3. The F-statistic value 8.88, which is above the upper bounds critical value at 5% significance level, it is the confirmation of asymmetric cointegration. Hence, we should move forward to asymmetric ARDL specifications.

Table - 3: Bounds Test Analysis in Nonlinear Specification

Model	F- statistics	Upper bound	Lower bound
GDP/(REC^P, REC^N, NRE^P, NRE^N, TA^P, TA^N)	8.88		
Critical Values			
10%		2.12	3.23
5%		2.45	3.61
2.5%		2.75	3.99
1%		3.15	4.43

Note: The H_0 of no cointegration is $\rho = \theta^+ = \theta^- = 0$. The critical values are based on (Narayan and Doytch, 2017), a small sample size.

In equation–8, we estimate by using general to a specific approach. This approach has also been followed by the pioneering study of (Shin et al., 2014) to reach the final specification of the asymmetric ARDL model. According to the general-to-specific approach, we dropped all the insignificant lagged regressors because (Katrakilidis and Trachanas, 2012) suggested that it was necessary to remove insignificant lagged regressors because insignificant lagged regressors could create noise in dynamic multipliers. The results of the NARDL estimates are shown in Table - 4.

Table - 4: Dynamic Asymmetric Analysis

Variable	Coefficient	Std. Error	t-Statistic	Prob.
Constant	3.145	0.607	5.181	0.000
GDP (-1)	0.486	0.099	4.903	0.000
REC^P	0.048	0.040	1.186	0.246
REC^N	0.227	0.076	1.397	0.17
REC^P (-1)	0.031	0.047	0.653	0.519
REC^P (-2)	0.054	0.044	1.126	0.270
REC^P (-3)	0.054	0.042	1.126	0.205
REC^N (-1)	0.227	0.076	2.966	0.006
NRE^P	0.013	0.051	0.260	0.796
NRE^N	-0.059	0.300	-0.197	0.845
NRE^N (-1)	-0.195	0.355	-0.550	0.589
NRE^N (-2)	-0.703	0.352	-1.994	0.057
NRE^N (-3)	-0.584	0.303	-1.924	0.065

TA^P	-0.015	0.005	-2.930	0.007
TA^N	0.004	0.005	0.923	0.009
TA^P (-1)	0.012	0.006	2.041	0.051
TA^P (-2)	0.001	0.006	0.302	0.764
TA^P (-3)	-0.012	0.004	-2.797	0.009
TA^N (-1)	-0.004	0.006	-0.716	0.480
TA^N (-2)	-0.026	0.006	-3.825	0.000

Note: ^{P}: Positive & ^{N}: Negative denotes to partial sums of positive and negative variations

Table–5 presents the outcomes of the estimated factors of the long-term asymmetric relationship. It is noted that the long-term relationship between REC^P, REC^N and economic growth is asymmetric. It is found that GDP is growing by 0.36 due to the positive shock in REC^P, while the negative shock in REC^N is growing by 0.62. The sign of both coefficients, however, is the same but different in magnitude, which indicates REC has a significant asymmetric impact on economic growth. The major renewable energy sources include wind, solar, hydro (water), biomass, and geothermal. These sources are infinite in supply and can be exchanged naturally, while various studies suggest a positive association between renewable energy consumption on economic growth (Alper and Oguz, 2016; Ben Jebli and Ben Youssef, 2017).

Regarding non-renewable energy, a statistically significant long-run impact is detected only from the negative factor NRE^N. Diagnostically, the long-run coefficient on NRE^N indicates that a negative change in non-renewable energy results in a decrease of 3.00 in economic growth. Similarly, positive change in NRE^P leads to a 0.02 increase in economic growth. The negative change shows a more profound effect than a positive change. The output suggests that a decrease in non-renewable energy could be increased significantly in GDP. Pakistan, every year is paying a high cost to import oil, gas, and other resources of non-renewable energy, which causes economic loss. Non-renewable energy supply is limited and cannot be reprocessed or substituted; also, it cannot be used forever because they could not be replicated or regenerated with the same old power once consumed. Even, it takes years to complete the regeneration process. On the other hand, the overuse of fossil fuels, the amount of CO_2 pollution in the environment is rising, causing greenhouse gas emissions (Ali et al., 2017).

The projected long-run coefficients on TA^P and TA^N are -0.02 and 0.05, respectively. Consequently, we may conclude that a positive change increase in terrorist attacks results in a decrease of 0.02 in economic growth. Likewise, the decrease in terrorist attacks leads to a 0.05 increase in economic growth. Hence, our results indicate that law and order stability has a positive effect on economic growth. As a whole, empirical findings suggest that, due to the different coefficients, non-renewable and renewable energy consumption, and terrorism had asymmetric long-run effects on economic growth in Pakistan. However, our empirical results are in line with (Luqman et al., 2019; Mohamed et al., 2019; Shahbaz, 2013; Shahbaz et al., 2013, 2015), resulting consumption of renewable energy had a positive impact on economic growth. These studies have significant consequences for practitioners and policy-makers. First, non-renewable, renewable energy, and terrorism affect economic growth in Pakistan. Second, the

implications of energy consumption increase and decrease could vary from one another in terms of the magnitude of effects.

Table - 5: Long-run Asymmetric Analysis

Variables	Coefficient	Std. error	t-Statistic
REC^P	0.360	0.056	6.359
REC^N	0.621	0.092	6.751
NRE^P	0.026	0.098	2.635
NRE^N	-3.008	0.500	-6.010
TA^P	-0.024	0.009	-2.671
TA^N	0.050	0.009	5.253

Note: ^{P}: Positive & ^{N}: The long-run coefficients denote partial sums of positive and negative variations $= -\hat{\theta}+/\hat{\rho}$

In addition, we also tested other major regression issues, such as residual normality using the Jarque – Bera test, serial correlation using the LM serial correlation test Breusch – Godfrey, heteroscedasticity using the Breusch – Pagan – Godfrey test, and model stability using cumulative sum (CUSUM) and cumulative sum square ($CUSUM_{SQ}$). The empirical results are provided in Table - 6; we have checked that the model does not suffer from any of the above problems—some diagnostic tests conducted before the final implementation of the asymmetric ARDL model. The χ2 (p-value) of LM and Breusch–Pagan–Godfrey tests are 0.202 and 0.811, respectively, which means that our model is free from serial correlation and heteroscedasticity problems. The Jarque–Bera analysis also confirmed residual normality. The value 0.439 of Ramsey RESET is also statistically insignificant, which naturally explains that our model is correctly specified.

Table - 6: Diagnostic Analysis

Diagnostic Test	Serial Correlation	Heteroscedasticity	Normality	Model specification
	χ^2 (p-value)	χ^2 (p-value)	χ^2 (p-value)	χ^2 (p-value)
LM test	0.202			
Breusch-Pagan-Godfrey		0.811		
Jarque–Bera			0.231	
Ramsey RESET test				0.439

Moreover, (Brown et al., 1975), proposed checking for CUSUM and $CUSUM_{SQ}$ to verify the stability of the long-run coefficient. Figure **-** 5 represents that plots of CUSUM and $CUSUM_{SQ}$ results are within the critical bounds at the level of 5%. It indicates that all the coefficients measured are stable.
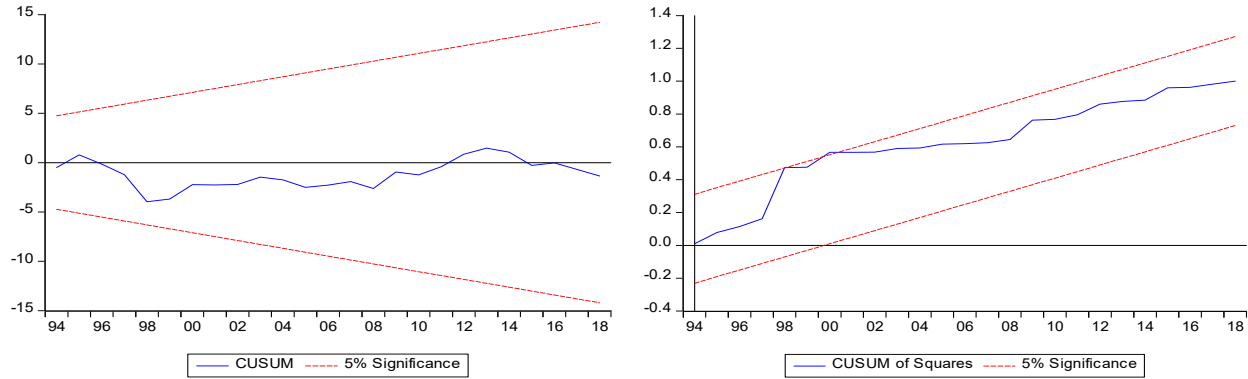

Figure - 5: Parameters Stability Analysis

The analysis also employs multiple dynamic adjustments. The results displayed in Figure – 6 and 7 demonstrate the trends in which economic growth adjusts to its new long-term equilibrium after a negative or positive shock in renewable energy, non-renewable, terrorism, and economic growth. The predicted dynamic multipliers are founded on the best-fit NARDL model chosen by the Akaike information criterion (AIC).
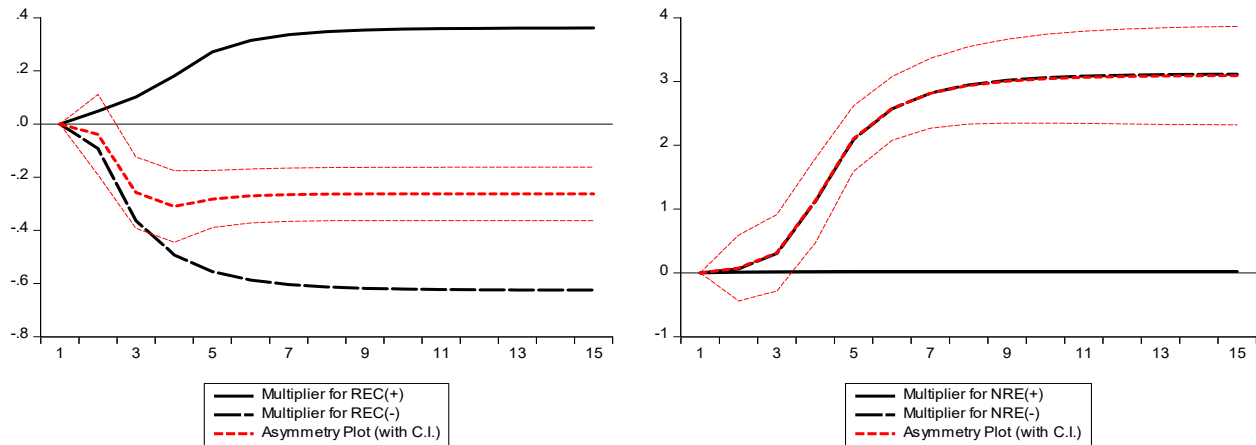

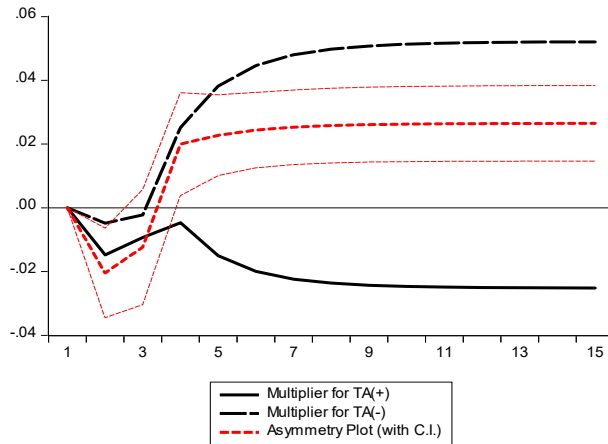Figure **- 6:** Asymmetric Dynamic Multipliers Effects $REC^P, REC^N, NRE^P, NRE^N$

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Figure - 7: Asymmetric Dynamic Multipliers Effects TA^P, TA^N

Note: The black line demonstrates the positive effect of REC^P, NRE^P, and TA^P while the dotted black line expresses the negative effect of REC^N, NRE^N, TA^N, and dotted red line shows asymmetry.

V. Conclusion and Policy Implications

This study explored the asymmetric relationship between renewable energy, non-renewable energy, and terrorism on economic growth in Pakistan. In doing so, we have used multivariate time series data from 1970 to 2018. We used a novel technique known as the asymmetric ARDL cointegration approach or NARDL cointegration approach to achieve the stated purpose of the research. The significant relative importance of this approach is that between predicted variables, it can simultaneously capture short-term and long-term dynamics. In the case of Pakistan's economy, the findings indicate a positive and negative change statistically significant asymmetric relationship between renewable energy and terrorism on economic growth, while a negative change in non-renewable energy also plays a significant role in economic growth.

Considering our econometric output, our policy recommendations for Pakistan as follows: based on the empirical results and benefits of renewable energy, this paper suggests that policy-makers should continue to encourage the generation and maintain the demand and supply of renewable energy in Pakistan. However, besides adding to economic growth, renewable energies have the benefit of being able to reduce environmental challenges. Whereas, controlling terrorism and maintaining law and order situation will be increased the confidence of investors that plays a vital role in economic growth. Hence, Pakistan's government should take into account economic growth's asymmetrical behavior. Considering the asymmetric results can be useful in better policymaking of Pakistan's economy.

Appendix A

Terrorism in Pakistan

Pakistan shares its international borders with China, India, Afghanistan, and Iran. The longest border of Pakistan connected with India and Pakistan-Indo associations have been noticeable by generations of severe hardship with three wars and repeated minor cross-border military incursions by both ends. Both countries' governments have accused their equivalents of backing and encouraging the actions of separatist/radical organizations in their lands (Shahbaz et al., 2013). Terrorism is a feasible plan of action to obtain the resources needed by the poor. Moreover, most poor-class people are going to sell their own lives to produce financial resources for their families, tempting them for terrorist acts. Many social scientists discussed the economic impact of terrorism in the economics of defense (Craig and Yakatan, 2010; Epstein and Gang, 2006).

Terrorism can be described as the use of force or the risk of violence in one or more individuals to induce mental and emotional fear. The sponsors are typically financial, political, ideological, nationalist, or separatist organizations that are illegal and hidden. As a short-term target, they aim to cause policy and economic uncertainty and thus accomplish certain medium- and long-term goals. Political, structural, and economic variables play a significant role in the acceleration of violence, resulting not only in the collateral damage but also in an economic and social interruption (Mohamed et al., 2019). Figure - A1 depicts affected cities by terrorist attacks.
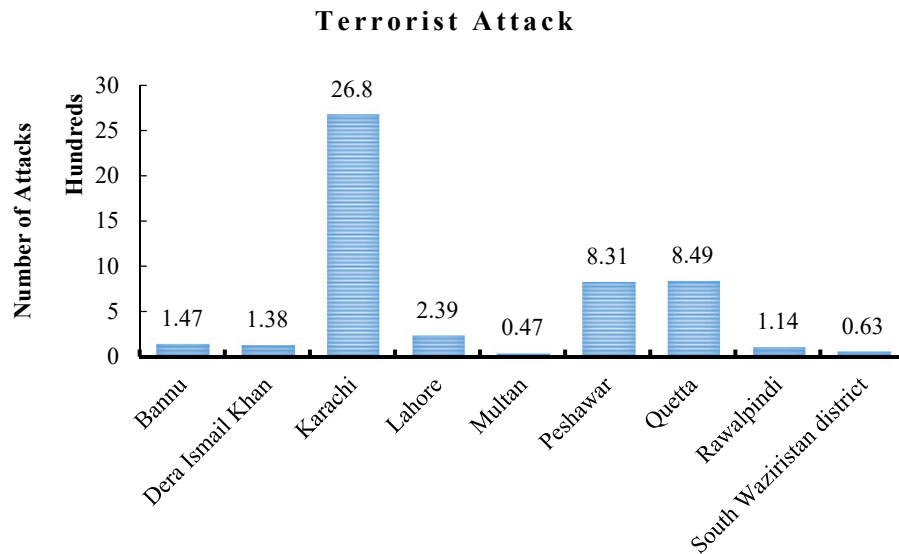
Terrorist Attack

Figure - **A1:** City-wise terrorist attacks (GTD 2018)

Terrorism is associated with political, cultural, and socio-economic circumstances such as injustice, literacy, freedom of women, and global political influences. In contrast, the term terrorism used in the following three meanings: (i) extortion, (ii) harassment, and (iii) trying to fight activity. The different definitions of terrorism highlight the need for a usually suitable description while, after 9/11, Pakistan faced the world's most horrific terrorist activity. While considering many facets of terrorism in the defense economy, in terms of inflation and economic

growth, the impact of terrorism in Pakistan has not been seen (Shahbaz, 2013). Figure – A2 displays provinces in percentage affected by terrorist attacks from 1970 to 2018.
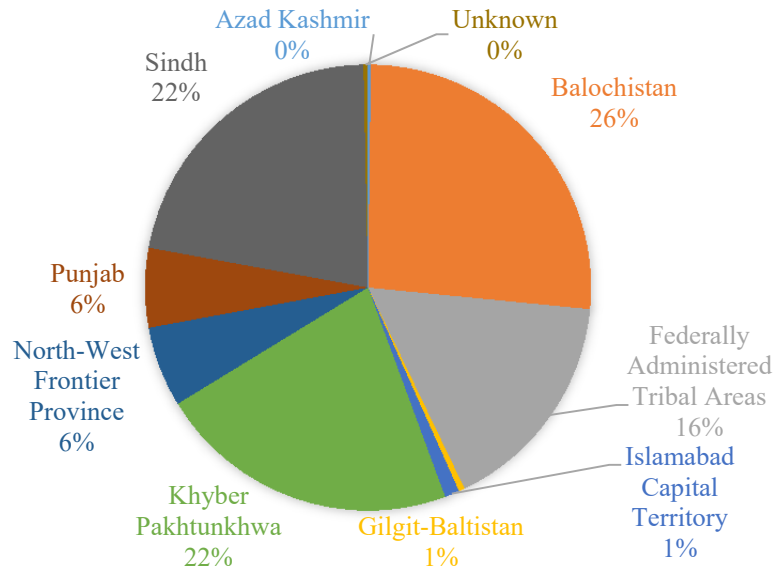

Figure - A2: Province wise terrorist attacks (GTD 2018)

The previous studies regarding Pakistan have revealed that renewable and non-renewable energies determinants have a significant impact on economic growth, for instance, (Mirza et al., 2012; Muhammad and Muhammad, 2012; Shaikh et al., 2015; Shakeel et al., 2016; Wang et al., 2018; Younas et al., 2016), and some studies also highlighted terrorism effect on economic instability, such as (Bashir et al., 2013; Ismail and Amjad, 2014; Malik et al., 2018; Malik and Zaman, 2013; MengYun et al., 2018; Shahbaz, 2013). Figure - A3 depicts the year-wise terrorist attacks in Pakistan.
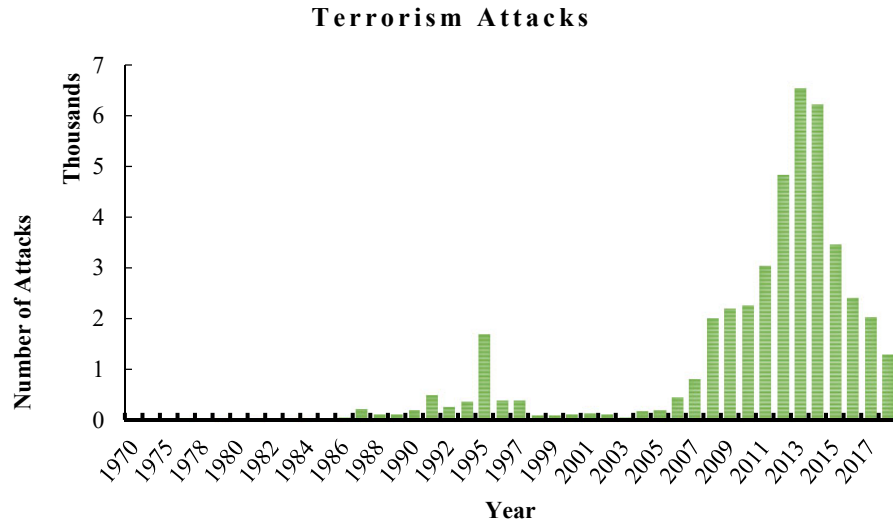
Terrorism Attacks

Figure - A3: Terrorist attacks in Pakistan (GTD 2018)

Table - A**1** shows the abbreviations and acronyms used in this study.

Table - A1. Abbreviations and Acronyms

Abbreviations and Acronyms	Full-Form
ADF	Augmented Dickey-Fuller
AIC	Akaike Information Criterion
ARDL	Autoregressive Distributed lag
DOLS	Dynamic Ordinary least Squares
ECM	Error Correction Model
EG	Economic Growth
FDI	Foreign Direct Investment
GDP	Gross Domestic Product
GMM	Generalized Method of Moments
MW	Megawatt
NARDL	Nonlinear Autoregressive Distributed lag
NRE	Non-renewable Energy
OECD	Organization for Economic Co-operation and Development
PP	Phillip-Perron
REC	Renewable Energy Consumption
SIC	Schwarz Information Criterion
TA	Terrorist Attacks
VECM	Vector Error Correction Model

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