

Energy Consumption and Greening: Strategic Directions for Pakistan

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Abstract

We compare Pakistan's energy consumption structures to selected East Asian economies with a view towards ensuring an adequate supply of power for economic catch-up and, at the same time, meeting the greening goals envisioned by the United Nations Framework Convention for Climate Change. The evidence shows that Pakistan relies significantly less on non-renewable energy to meet its energy demands compared to China, Japan, South Korea, Malaysia, and Thailand, while its dependence on fossil fuels has been rising rapidly. Using data for Pakistan from 1960 to 2015, we deployed panel co-integration and Granger causality tests to analyse selected East and Southeast Asian countries before exploring what it will take for Pakistan to develop its renewable energy (RE) sector. The evidence shows that catching up economically with these countries through rapid GDP per capita growth will exacerbate Pakistan's current energy imbalance, thereby aggravating greenhouse gas (GHG) and carbon dioxide (CO₂) emissions. We argue that Pakistan enjoys strong endowments to avert this problem, and hence, it should strategically focus on the development of RE resources, especially solar and wind energy, but only after taking account the relevant costs.

Keywords: Renewable energy, thermal energy, economic growth, hazardous emissions, Pakistan.

JEL classification: Q41, Q49.

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1. Introduction¹

Energy is a critical resource in production, distribution, and consumption. Until the early 1970s, it was sought with little recognition for conservation and the environment, which is why early examples of deforestation and environmental degradation largely occurred in Western Europe, the United States, and Japan. Efforts to lower energy use was initially driven by sharply rising oil prices in 1973-75 and 1979-80.² Consequently, oil usage intensity among the International Energy Agency (IEA) countries fell considerably over the period 1973-1980 (Birol and Keppler, 2000). Meanwhile, energy use in the consumption of the Organization for Economic Cooperation and Development (OECD) countries fell by around a third between 1973 and 1998, which was a result of technical change that drove cost-saving innovations (Goldemberg & Prado, 2011; Nordhaus, 2019; González-Álvarez et al., 2020). Additionally, net oil importers, such as most Western industrial European countries (e.g., France, Germany, Italy, Spain), along with Japan, Korea, and Taiwan also attempted to reduce their dependence on oil and gas.

The second major push to stimulate a reduction in the use of fossil fuels was driven by concerns over climate change and global warming. Since the beginning of the twentieth-century, global atmospheric temperatures has risen dramatically following a rise in greenhouse gas emissions (GHG) (Stern, 2006; Nordhaus, 2019), which has spurred governmental and multilateral initiatives to mitigate climate change. As countries became aware of the dangers of climate change and global warming since the launching of the annual Conference of Parties (COP) of the United Nations Framework Convention for Climate Change (UNFCCC), participating nations agreed to reduce GHG emissions over the period 2008-2012 to 1990 levels (UN, 1997). Subsequently, in 2015, almost all of the UN members pledged to contribute towards capping temperature rise to 1.5 degrees Celsius over a century from 2005 levels (Rasiah et al., 2016; Rasiah et al., 2018; Alsaleh and Abdul-Rahim, 2019; Hussain et al., 2020; Mubarik and Naghavi, 2020), although the United States withdrew from that pledge in 2017. Unlike previous efforts, the

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² Oil prices rose sharply in 1973-75, and in 1979-80 (Sachs, 1982).

COP meetings aim to mitigate climate change and global warming without compromising economic growth following the work of Stern (2006) and Nordhaus (2019). Carbon taxes and the development of renewable backstop technologies to substitute for fossil fuels and reduce the energy intensity of output, and inducements to promote sustainability transitions have been the prime channels through which these countries have targeted their energy transition roadmap (Biroi & Keppler, 2000; Nordhaus, 2019; Baležentis et al., 2011; Adom & Kwakwa, 2014; Kwakwa et al., 2020).

Natural resources offer Pakistan substantial endowments to shift towards renewable energy (RE), including biodegradable crop straws to replace nitrogen and phosphorus fertilizer (Zhuong et al., 2020). However, many of these resources have yet to be locally developed (Mubarik, 2015; Zafar et al., 2019). Hence, in 2015 most of the RE produced in Pakistan came from hydropower, accounting for 31 percent of electricity produced (Kamran, 2018). Wind, solar, and biomass resources have scarcely been developed, while oil, gas, and coal have remained the prime sources of fuels used in the country, which is not very different from the East Asian countries of China, Japan, South Korea, Malaysia, and Thailand. Thus, we have two objectives in this paper: First, we seek to examine energy sources trends and emissions of Pakistan in comparison with East Asian economies, and what likely consequences could face Pakistan if it managed to accelerate economic growth to catch up with the East Asian economies. Second, we attempt to test the relationship between GDP and RE on the emission of pollutants using greenhouse gas (GHG) and carbon dioxide (CO₂) emissions as the proxies. Its purpose is to see if drastic measures must be taken to develop green energy to reduce its dependence on non-renewable energy. Instead of comparing Pakistan with conventional peers like India and Bangladesh, we compare the country with the Asia-Pacific countries because the energy generation and consumption of the Asia-Pacific countries was similar to Pakistan before 2000 when the majority of these countries remained dependent on fossil fuel for energy production (Shi, 2016). However, since 2000, the Asia-Pacific countries have significantly shifted towards the use of renewable resources in their energy mix which has grown by 2.5 percent annually (APEC, 2016).

Furthermore, Malaysia's total installed capacity is expected to reach 6235 GW by 2040 with renewable energy's share accounting for 35 percent of energy consumption. Malaysia has become a leader, producing 256,830 KTOE energy from renewable energy resources like solar, wind etc. (Hosseini and Wahid, 2014; IEA 2020). According to Hosseini and Wahid (2014), "*the available RSE resources such as biomass, biogas, solar, and mini-hydro for energy generation contributed around 5% of the country's total electricity demand.*" Pakistan's similarity with these countries in their earlier years, in term of the energy generation, and their successful change in energy mix offer a strong case to compare Pakistan with these countries. We also attempt to assess Pakistan's capacity to follow the footsteps of these nations to shift its energy mix with a significant expansion in the use of renewable energy resources. We excluded Singapore as the country is an outlier as the country that uses over 85 percent of its energy from natural gas with renewable energy only contributing 0.7 percent of energy consumption in 2015 (Energy Market Authority, 2020).

2. Theoretical Considerations

Hydroelectric power and coal were the significant sources of energy countries harnessed until the advent of oil and gas. Concerns overdependence on non-renewable sources of energy (i.e., fossil fuels) were initially because of their scarcity, but subsequently those concerns have been largely over the harm they were causing to the environment.

The overcrowding of planet Earth through rapid population growth has been viewed as a demand-side problem facing the environment. Hence, the limits to growth argument advanced by the club of Rome resonated strongly among economists until the 1980s (Malthus, 1798; Ehrlich, 1968).

Using computer-simulated data Meadows et al. (1972) had argued that there are limits to economic growth, which did not resonate well with the governments of developing economies as it was viewed as an attempt to keep them underdeveloped. They questioned why developing countries should carry the burden of the global common when the developed countries had themselves grown through environmental destruction. This argument was then superseded by the inverted "U"

shaped relationship between pollution intensity and economic growth, which was adapted from the original work of Kuznets (1955) that identified a similar relationship between income distribution and the logarithm of per capita GDP using a longitudinal study of the developed countries. Grossman and Krueger (1991) and Panayotou (1994) advanced the Kuznets inverted "U" shaped relationship between pollution intensity and GDP per capita, which assumed that all countries would experience a rise first and subsequently a fall in pollution intensity once a threshold of per capita income is reached so that the utility of the environment will exceed that of the utility of material development. Uddin (2014, p.60) also discussed how "in the early stages of economic growth, environmental quality decreases with an increase in per capita income, but after a certain level environmental degradation starts decreasing with the increase in the level of per capita income, thus resulting in an inverted U-shaped curve (i.e., Environmental Kuznets Curve, EKC). While the assumptions used by this argument are static, its biggest shortcoming arises from the fact that the environment is a global common so that it is inevitable that the consequences of climate damage in one location will have disastrous consequences on the whole globe. But despite this shortcoming, the EKC provides the theoretical basis to model the relationship of GDP with environmental degradation, which is represented by greenhouse gases and carbon emissions.

Since the turn of the millennium, following new scientific insights economists became convinced that climate change and global warming were human-made problems (Stern, 2006; Nordhaus, 2019; Rasiah et al., 2018), which facilitated the deployment of computable general equilibrium models in climate projections to cap changes in temperature. Consequently, efforts to cap temperature rise through the United Nations Framework Convention for Climate Change (UNFCCC) gained currency as countries sought to substitute non-renewable sources of energy with renewable sources. The Paris Accord of 2015 provided its landmark agreement as over one hundred countries pledged to cap temperature rise to 1.5 degrees Celsius over the next hundred years.

Given the role played by energy in economic development, and the mixed experience of economies – both resource-rich and resource-poor – in stimulating rapid economic growth and structural change, we

review the above theories in light of empirical evidence from East Asia and Pakistan. In addition, unlike the advocates calling for limiting economic growth, it is pertinent to look at Stern (2006) and Nordhaus (2019) and their call to focus on shifting energy sources from fossil to non-fossil fuels through the introduction of a carbon-intensive tax, which should then be targeted at the development of the backstop technologies that will quicken this transition.

While the short-run consequences of imposing a carbon tax can be destabilizing to the economy, its long-term consequences may not only ensure the greening of the earth but also create a sustainable domestic source of energy supply. The large-scale development of green energy sources – *e.g., wind, solar, and biomass* – can also lessen Pakistan's sufficient deficit in energy trade, as well as offer firms in the country globally competitive prices in the long-run. In light of the latest evidence, it is important to examine the relationship between the RE share of overall energy utilization, GDP per capita and harmful emissions.

3. Methodology and Data

We carry out two exercises to examine the relationship between renewable energy GDP per capita, and harmful emissions. The first focuses on tracking the significance of green energy and trends in energy wastage. Simple two-way relationships are analysed graphically to establish changes in energy sources and usage. The emphasis is on comparing trends in the shift to RE, and trends in emission-intensity of two hazardous gases, *viz.*, GHG and CO₂. World Bank (2018) data was deployed to examine these trends. In doing so we avoided the use of energy prices and exchange rates because of the lack of consistent prices. Nonetheless, even though prices of renewable energy has fallen swiftly over the years, coal, oil and gas prices have remained significantly lower in the period 2018-2020 (Karberger, 2018; IEA, 2020). Exchange rates were also dropped because the members in the country panel obtain the entirety of their renewable energy from domestic sources.

The second exercise tests econometrically the relationships between RE and GDP on GHG and CO₂ using the following two models:

$$GHG = \beta_0 + \beta_1 GDP + \beta_2 RE + u_t \quad (a)$$

$$CO_2 = \phi_0 + \phi_1 GDP + \phi_2 RE + u_t \quad (b)$$

Modeling GHG with GDP and renewable energy is considered a simple yet robust approach to examine the associations between GDP, RE, and GHG, and has been previously used by many studies like Vasylieva et al., (2020), Baležentiset al., (2019), and Baloch et al., (2019). The models are also theoretically supported by the Environmental Kuznet Curve (EKC), which provides the theoretical foundations to link the GDP and renewable energy with CO₂ emission and GHG (Apergis & Ozturk, 2015). Rather than simply analyzing the above using Pakistan as an example, we compare Pakistan's experience with five East and Southeast Asian countries, that are: Malaysia, Thailand, Republic of Korea, Japan, and China. Using time series data from 1960 to 2016, data for the following variables were obtained from World Bank (2018):

- i. GHG emissions per capita (kt of CO₂ equivalent)
- ii. Fossil fuel energy consumption (% of total)
- iii. Renewable energy consumption (% of total final energy consumption)
- iv. CO₂ emissions in kilogram per USD GDP using 2010 prices.

Table 1 presents the abbreviations of the different variables used in the paper.

Table 1: Description of Variables

Variable	Abbreviation
GDP per capita	GDP
Greenhouse Gas emission per capita	GHG
Carbon Dioxide	CO ₂
Renewable energy as the proportion in total energy	RE

While modeling panel data, researchers have two options: pooled regression or panel regression. In the case of the former, researchers do not need to consider the variance across cross-sections or time series. However, when it is intended to check whether the model has a random effect or fixed effect, panel co-integration appears to be the most suitable approach for analysis (Chandran & Tang, 2013). We adopted the model specified by Chandran and Tang (2013), (which was developed from

Engle & Granger, 1987), to examine the effect of GDP and RE on GHG and CO₂ emissions. We deployed panel co-integration techniques to estimate the short- and long-term co-integration among the modeled variables. Before examining the existence of co-integration, we first checked the level of stationarity of each variable by applying a panel unit root test. After performing the unit root test, we applied the pooled mean-grouped (PMG) estimator, as demonstrated by Pesaran et al. (1999) to estimate the panel co-integration. In the PMG estimates, short-run coefficients and error variances can fluctuate by keeping the long-run coefficients to be identical. Since the mean-group estimator (MG) does not allow coefficients and variances to vary, Pesaran and Smith (1995) developed the PMG estimator by modifying the MG. Whether the MG or PMG should be used for analyzing the co-integration depends upon the Hausman test statistic. If the Hausman null hypothesis is rejected then the MG estimator is preferred. Otherwise, the PMG estimator is the most appropriate for the analysis. As demonstrated in equation 1, panel co-integration can be deployed for estimation regardless of the level of integration of individual variables. Panel ARDL provides short and long term results simultaneously by allowing the selection of a suitable number of lags according to the selection criteria (equation 2).

$$\gamma_{nt} = \alpha_{it} + \beta_{nt}X_{nt} + v_{nt}\dots\dots \quad (1)$$

$$\gamma_{nt} = \alpha_{nt} + \sum_{n=1}^j \lambda_{ik} \gamma_{k,t-n} + \sum_{n=0}^p \beta_{ik} X_{k,t-n} + v_{nt}\dots \quad (2)$$

In equation (1), $n = 1, \dots, n$ is the country index, $t = 1, \dots, T$ is the time index and v_{nt} a random disturbance term. Equation (2) lays out the assumptions about the parameters, the error terms and the exogeneity of the regressors.

The two fundamental equations we formulate to test in the second exercise are i) the relationship of GDP and the composition of RE in total energy consumption on GHG emissions; and ii) the relationship of GDP and the composition of RE in total energy consumption on CO₂ emissions.

4. Energy Transition Experiences

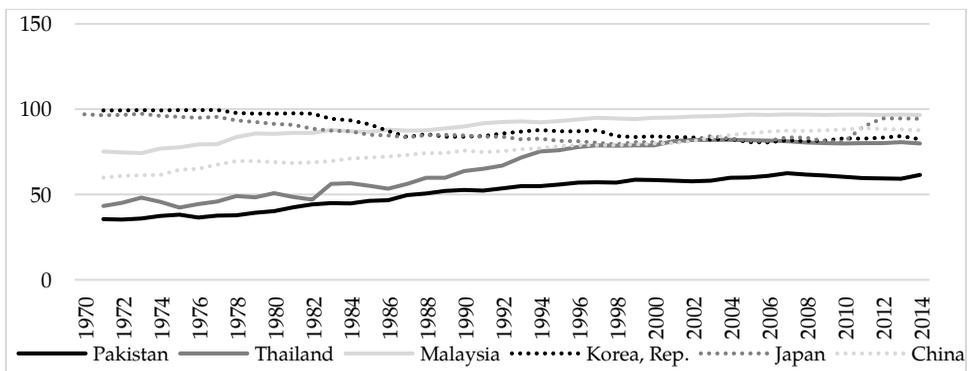
A major goal of the UNFCCC is to stimulate a shift from fossil fuels to renewable energy. The data available allows the comparative

assessment of fossil fuel composition of energy consumption, and GHG and CO₂ emissions, and the share of renewable energy consumption in total fuel consumption, and hydroelectric power consumption. Hence, we compare Pakistan's trends with selected East Asian economies with the purpose of assessing greening trends occurring in these economies.

Fossil Fuel Energy Consumption

Fossil fuels, drawn from oil, gas, and coal, are non-renewable resources are at the heart of the debate on dangerous carbon emissions. Also, it takes millions of years to form with these reserves, which are depleted drastically. Figure 1 shows Pakistan's dependence on hydrocarbons, which has grown immensely, resulting in a burgeoning import bill. According to the Economic Survey 2016-17, the domestic production of crude oil stood at 24.2 million barrels during nine months of fiscal year 2017. Due to the sudden increase in CNG usage, the current supply of natural gas is not meeting the energy demand in the gas sector. Pakistan is also suffering major shortages of oil, gas, and electricity. The reason behind is improper channelling of energy, insufficient exploration activities in the oil and gas sector, inappropriate distribution of resources, poor management, law and order situation, and bad governance. In this vein, Pakistan can learn a lesson from the Republic of Korea. The country has managed to not only reduce its fossil fuel energy consumption but has also kept it down despite a steep increase in overall energy generation. The country managed to also increase renewable energy resources.

Figure 1: Fossil fuel in Total Energy Consumption, Selected Nations, 1970-2014 (%)

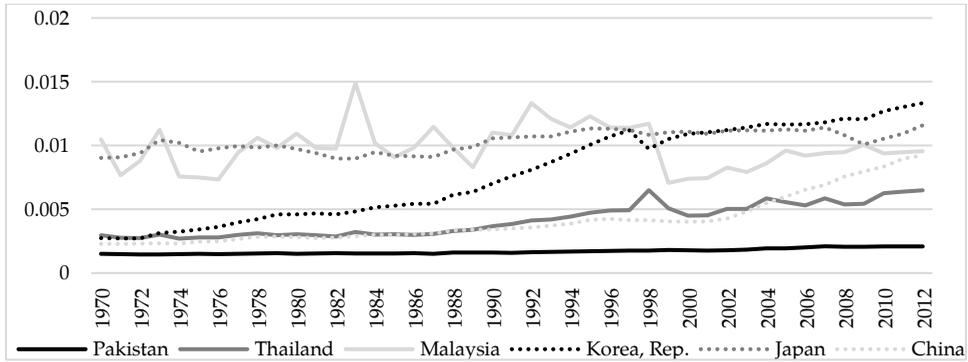


Source: Plotted from World Bank (2018).

Greenhouse gas emissions

Figure 2 compares Pakistan's greenhouse emissions with East Asian countries. Although Pakistan is not yet a significant contributor to global warming, its emissions derived from the energy sector (mainly from electricity generation, manufacturing, and transport) comes to be a main source of GHG emissions. In the energy sector of Pakistan, total fossil fuel consumption in 2012 was 47.96 Mtoe. Out of this, 14.19 Mtoe was consumed in the power sector for electricity generation, 13.26 Mtoe in the manufacturing sector, 10.06 Mtoe in the transport sector, 1.24 Mtoe in commercial/institutional sector, 6.46 Mtoe in the household sector and 2.75 Mtoe in the agriculture sector (HDIP 2013; Pak-IEM 2011). Pakistan emitted 361 million metric tons (MtCO_{2e}) in 2017, with the energy sector contributing 46 percent to overall emissions, followed by agriculture (41 percent), land-use change and forestry (6 percent), industrial processes (5 percent) and waste (2 percent). Greenhouse gas emissions increased by 87 percent from 1990 - 2012, primarily due to energy and agriculture sector emissions. According to a preliminary projection, the GHG emissions levels for Pakistan are expected to increase many times in the coming decades. Pakistan aims to reduce its 2030 projected GHG emissions by 20 percent, amounting to 1603 million ton of carbon dioxide equivalent subject to the availability of international grants to meet the total abatement cost for reduction which amounts to about US\$ 40 billion at current prices. According to government sources, Pakistan submitted its Intended Nationally Determined Contribution (Pak-INDC), under Article 2 of the Paris Agreement, to the United Nations Framework Convention on Climate Change (UNFCCC). Under the INDC, Pakistan's adaptation needs range between US \$7 to US \$14 billion per annum during this period. In this vein, Pakistan can learn from the experience of Malaysia and China. While there is upward trend of GHG emission in most countries, in Malaysia the trend has become relatively flat. This happened due to the Malaysian government's policies to adopt low-carbon development measures. Prominent among such measures was carbon capture and storage (CCS), which focuses on securing and storing carbon dioxide emissions before they are released into the atmosphere. Although this technology is still in its early stages, countries are committed to implementing variations of it with both bilateral and multilateral cooperation underway.

Figure 2: Total Greenhouse Gas Emissions Per Capita, Selected Nations, 1970-2012 (kt of CO₂equivalent)

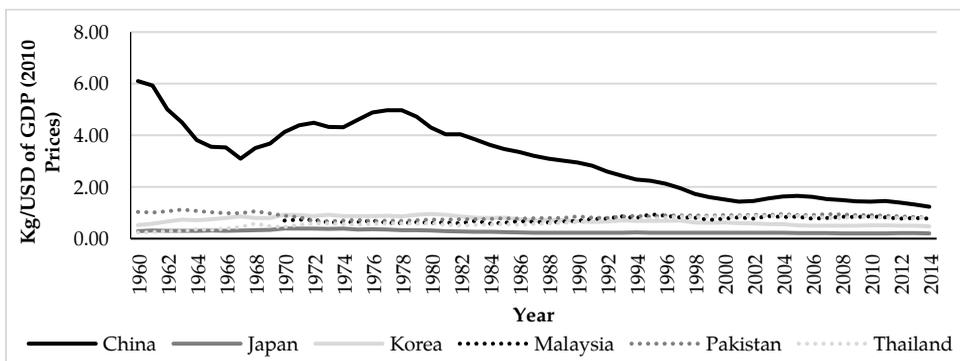


Source: Plotted from World Bank (2018).

Carbon Dioxide Emissions

We used CO₂ emissions in kilograms per unit of GDP as a proxy of CO₂-intensity of GDP deflated at 2010 prices in USD. China has been the largest emitter of CO₂ emissions among the countries compared (Figure 3). With its early focus to shift towards green energy, Japan has the lowest emissions of all the countries. South Korea has followed suit since the 1980s to show the second-lowest emissions per unit of GDP. Pakistan is bunched with Malaysia and Thailand with similar CO₂ intensities per unit of GDP. However, while the CO₂ intensities of GDP of Japan, South Korea and China show a trend fall, those of Malaysia, Pakistan, and Thailand have risen since the 1980s.

Figure 3: Carbon Dioxide Emissions, Selected Asian Nations, 1960-2014

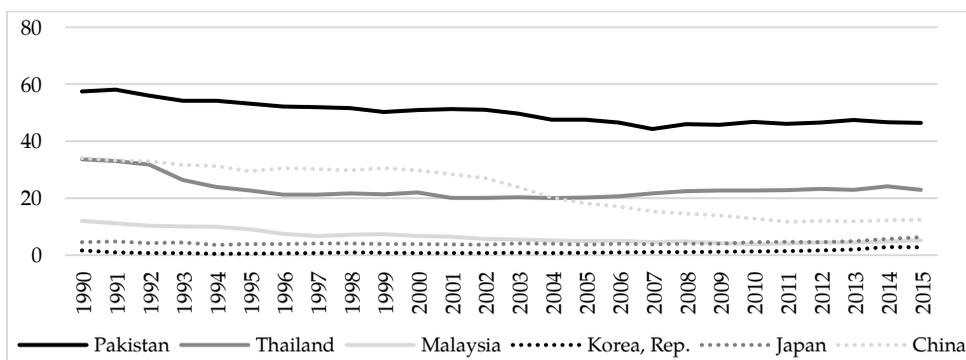


Source: Plotted from World Bank (2018).

Renewable Energy

Following the Paris Accord of 2015, most members of the United States submitted Intended Nationally Determined Contribution (INDC) to gradually replace fossil fuels with RE (UNFCCC, 2016). Pakistan and the East Asian countries were among the countries who pledged to increase the use of RE to 45 percent by 2030 with 10 percent coming from technology transfer from developed countries. Figure 4 shows the share of RE in total fuel consumption over the period 1990-2015. Pakistan (46 percent) shows the highest share of RE use followed by Thailand (23 percent) and China (12 percent) in 2015. Japan (6 percent) and South Korea (3 percent) showed low intensity of RE use in 2015.

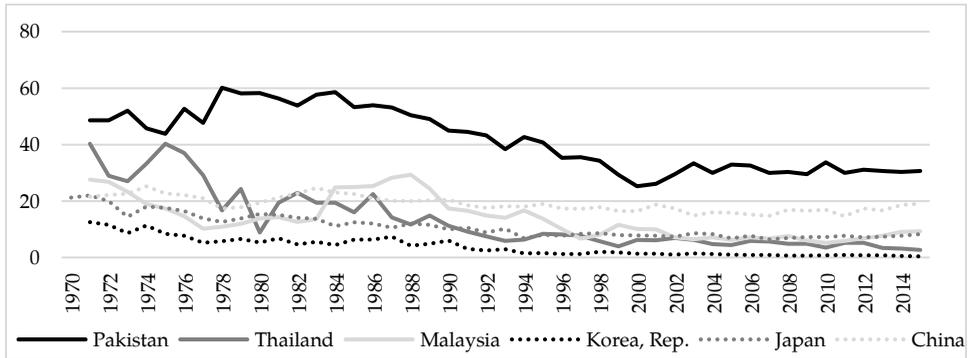
Figure 4: Renewable Energy in Total Energy Consumption, Selected Nations, 1990-2015 (%)



Source: Plotted from World Bank (2018).

Pakistan's vast RE resources largely comes from hydropower (Figure 5). Hydropower accounted for 31 percent of electricity produced in Pakistan followed by China (19 percent) and Malaysia (9 percent) in 2015. Japan (8 percent), Thailand (2 percent) and South Korea (almost zero) showed the least use of hydropower to produce electricity. The country's dependency on hydro can be attributed to the endowment of the rich Indus river and tributaries. Pakistan has constructed two major dams on its two prime rivers and the government plans to build two more dams.

Figure 5: Electricity production from hydropower, Selected Nations, 1970-2015

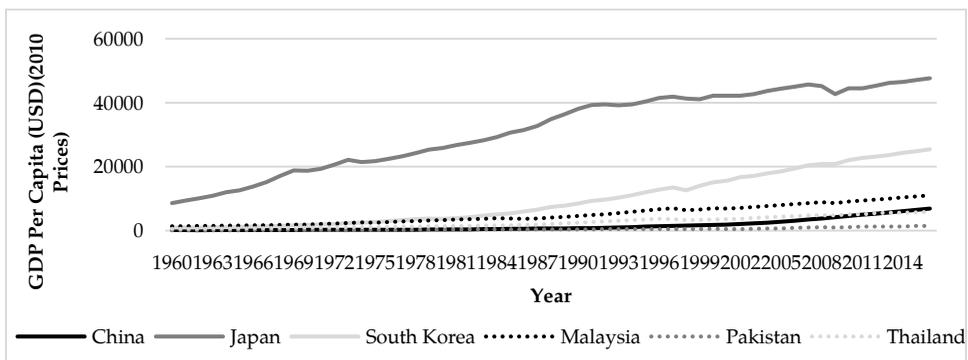


Source: Plotted from World Bank (2018).

Per Capita GDP

As shown in Figure 6, Pakistan has a lower GDP per capita as compared to China, Japan, South Korea, Malaysia, and Thailand.³ Even more serious is the rate of increase in Pakistani GDP per capita, which is the lowest among these selected countries. Its GDP per capita has grown significantly more slowly than the GDP per capital of the East Asian economies. Such a low annual average GDP per capita growth rate obviously means that the country will have to steeply increase energy sources for it to fuel an economic catch up with the East Asian economies.

Figure 6: GDP Per capita, Selected Nations, 1960-2016



Source: Plotted from World Bank (2018).

³ We preferred the constant prices in USD over local currencies to compare the GDP per capita of Pakistan with the East Asian economies.

While access to hydropower has allowed Pakistan higher RE shares, its total energy consumption is significantly lower than the East Asian economies, and rapid economic growth is likely to change the picture significantly. Its per capita GDP is still much lower than that of China, Malaysia, Korea, Thailand and Japan. Unless the country manages to further expand its RE supply, rapid economic growth may change the energy composition adversely to skew towards non-RE. In the next section, we examine if there exists a positive and causal relationship between GDP per capita growth and the share of RE in total energy emissions with two key hazardous gases as proxies of non-RE energy, i.e. GHG and CO₂.

5. Statistical Analysis

This section focuses on the impact of GDP per capita growth and the increasing share of RE on GHG and CO₂ emissions. The results will be important to examine the potential impact of accelerated Pakistan's GDP growth, which will be necessary if the country is to catch up with the East Asian economies.

Unit root tests

To examine the stationarity of the variables, we deployed two tests, namely Im, Pesaran and Shin test (Im et al., 2003) and Levin, Lin and Chu test (Levin et al., 2002). Both IPS and LLC tests have the assumption of common unit root processes across cross-sections. The results of the Panel Unit Root test at levels and first differences appear in Table 2. The results show that all variables are stationary at first difference. This in turn shows the suitability of a Panel-ARDL approach for estimating our models.

Table 2: Unit Root Tests

Variable	Level		1 st difference	
	LLC	IPS	LLC	IPS
GDPPC	0.014	0.024*	-4.58	-3.17*
GHG	3.481	2.45*	-3.94	-3.72*
RENE	0.406	2.12*	-2.62	-4.05*
CO2	0.373	0.521*	-4.21	-3.88*

Note: LLC stands for Levin, Lin & Chu test (LLC) & IPS for Im, Pesaran, and Shin W-stat test (IPS). Values in parentheses are p-values where *, **, *** represent 1%, 5%, and 10% respectively.

Source: Computed using World Bank (2018) data.

Panel Co-integration tests

In order to determine whether long-run relationships exist among variables or not, we applied a panel co-integration test using the Pedroni (2004) process. The results of panel co-integration of both models are exhibited in Table 3. The results show that among the seven-panel integration tests, six reject the null-hypothesis of no co-integration at the 1 percent level of significance. Likewise, in regards to the case of an intercept and a linear trend, five-panel co-integration tests reject the null hypothesis of no co-integration at the 1% significance level. Furthermore, the panel co-integration results exhibited in Table 3 also show the existence of co-integration among the modeled variables. A total of five out of six-panel co-integration tests reject the null hypothesis of no co-integration at the 1 percent level. On the basis of these results, we safely infer co-integration among variables in both models.

Table 3: Panel Co-integration Test

Dependent variable	Greenhouse Gas Emission (GHG)		CO2 Emission	
Variable	Statistics	Weighted	Statistics	Weighted
Pedroni Residual Co-integration Test				
Alternative hypothesis: common AR coefficients (within dimension):				
Panel v	-0.89	2.14	-0.78	2.31
Panel rho	2.10	1.15	1.95	1.39
Panel PP	-1.64**	3.84*	-1.83**	4.01*
Panel ADF	-1.72**	2.71*	-1.69**	2.44*
Alternative hypothesis: common AR coefficients. (between dimension):				
Group rho	2.34**		2.57**	
Group PP	-8.41*		6.53*	
Group ADF	-2.66**		3.01*	

Note: Values in parentheses are p-values where *, **, *** represent 1%, 5%, and 10% respectively.

Source: Computed using World Bank (2018) data.

Long Run and Short Run Estimates

In order to test the existence of short- and long-run relationships among the modeled variables, we deployed three tests, namely mean group (MG), pooled mean group (PMG), and dynamic or difference fixed effect (DFE) tests. For the PMG estimator, the long run coefficient must be homogenous by group for the PMG estimator to be consistent. On the other

hand, if the model is heterogeneous, the MG estimator would be consistent. In order to choose between the MG and PMG estimators, we used the Hausman test for long-run homogeneity (Table 4, Table 5). The test statistics value of the Model 1 Hausman test is 4.38, with a probability value of 0.251, which implies that the null hypothesis for cross sections are homogenous cannot be rejected. This means that PMG is the most efficient estimator in our analysis. The long run estimation results of PMG are presented in Table 3, which shows that GDP has a significant and positive relationship with GHG whereas RE has a significant and negative relationship with GHG at the 1 percent statistical level in the long run. Remarkably, GDP per capita's long-run elasticity coefficient is 1.03, indicating that a one percent rise in GDP will raise GHG per capita by 1.03 percent.

Further, RE consumption's coefficient value is 0.04, which demonstrates that a one percent increase in RE consumption will reduce GHG by 0.04percent. Further, in model 2, the long-run elasticity estimate of GDP per capita and RE portrays a similar picture. The GDP per capita value is just above the unity (1.01), implying a 1.01 percent increase in CO₂ per capita when GDP per capita increases by one percent. Likewise, the results of renewable energy show a one percent increase in renewable energy can decrease CO₂ emissions by .09 percent.

The values of ECT (error correction term) for both models are computed next. The ECT value of model 1 is -0.196, which is negative and significant (Table 4). It implies that a shock to the carbon emissions equations leads to an adjustment of almost 20 percent within the first year, and it takes approximately 5 years to converge to the long-run equilibrium level. Likewise, the ECT value of 0.16 for model 2 shows that in case of a shock to the GHG equation, there is a 16 percent adjustment towards the long run equilibrium in the first year.

Table 4: Hausman Test of Homogeneity

Variables	Model 1		Model 2	
	Panel PMG	MG	Panel PMG	MG
GDPPC	1.032	2.11	1.012	1.23
RE	0.022	0.31	0.09	0.18
Hausman MG Test	4.38 (0.251)		3.47 (0.217)	

Source: Computed using World Bank (2018) data.

The ECT of the countries, for both models, are presented in Table 5. In model 1, the ECT coefficient value shows that Thailand has the fastest speed of adjustment with an ECT coefficient value of 0.35 while Japan has the lowest. Our results support the pollution haloes hypothesis and are in line with the findings of Mazzanti and Zoboli (2005). However, our results contradict the findings of Tamazian et al. (2009) and Seker et al. (2015).

Table 5: Long Run and Short Run Results based on PMG Estimator

Variables	Model 1		Model 2	
	Coefficient	p-value	Coefficient	p-value
<i>Long Run</i>				
GDPPC	1.032	0.000	10.012	0.000
RENE	0.022	0.000	0.090	0.000
<i>Short Run</i>				
ECT	-0.196	0.000	0.160	0.000
$\Delta \ln \text{GDPPC}$	0.272	0.000	0.215	0.000
$\Delta \ln \text{REN}$	0.011	0.000	0.009	0.000
Constant				
<i>ECT for each country</i>				
Pakistan	-0.31	0.000	-0.27	0.000
Thailand	-0.35	0.000	-0.36	0.000
Malaysia	-0.29	0.000	-0.22	0.000
China	-0.22	0.000	-0.25	0.000
Japan	-0.16	0.000	-0.19	0.000
Korea	-0.27	0.000	-0.21	0.000

Source: Computed using World Bank, 2018 data.

A significant long-run relationship exists between GHG, GDP and RE, which indicates the existence of causality among these variables. In order to test this, we applied panel Granger causality tests. The results are shown in Table 6. Two important relationships can be noted from results. First, the significant short-run causality of CO₂ emission to renewable energy (RE) and, second, greenhouse gas emission to renewable energy. Further more, our results show that GDP has short-run causation with GHG and CO₂ emissions. Our results also show a short run significant bilateral causation between GDP- CO₂ emission, and GHG-GDP. From the causality results, it can be inferred that GDP growth needs fossil energy, which further emits CO₂. The interesting fact is that usage of fossil fuel

energy and CO₂ emissions encourage renewable energy consumption. These results concur with the studies of Ocal and Aslan, (2013), and Pao and Tsai, (2011). These studies found a bidirectional relationship between GDP and CO₂ emissions.

Table 6: Panel Causality Test

	F-statistics
$\ln\text{GDP} \rightarrow \text{GHG}$	3.05*
$\ln\text{GHG} \rightarrow \ln\text{GDP}$	1.25
$\ln\text{GDP} \rightarrow \ln\text{CO}_2$	2.98*
$\ln\text{CO}_2 \rightarrow \ln\text{GDP}$	3.41*
$\ln\text{RE} \rightarrow \ln\text{CO}_2$	2.05
$\ln\text{CO}_2 \rightarrow \ln\text{RE}$	5.37*
$\ln\text{RE} \rightarrow \text{GHG}$	1.50
$\ln\text{GHG} \rightarrow \ln\text{RE}$	4.62*

Source: Computed using World Bank (2018), data.

Overall, there is are strong short- and long-run causality relationships between GDP per capita and RE on GHG and CO₂ emissions. The key results from this exercise are that accelerating GDP growth will further exacerbate emissions of GHG and CO₂. Hence, even though Pakistan has relied more on RE in powering GDP growth than Japan, South Korea, Malaysia, China, and Thailand, efforts must be taken to develop RE further so as not to accelerate the use of non-renewable sources of energy in the future.

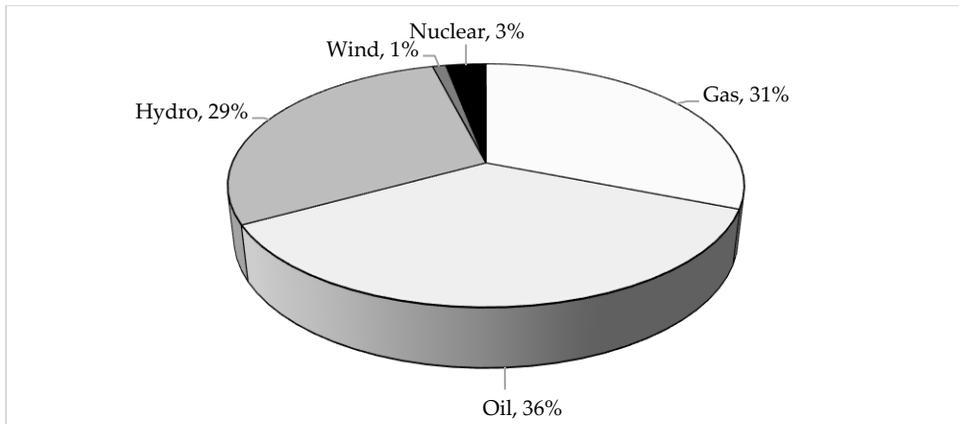
6. Implications for Pakistan

Having established a strong and positive link between GDP per capita and GHG and CO₂ emissions, we examine the policies Pakistan should adopt to avert the hazardous path that East Asian economies had taken to achieve rapid economic growth. Clearly, the government will have to develop its RE sources to ensure that its rapid economic growth will not exacerbate its current RE intensity in energy consumption. Pakistan primarily generates electricity from hydro and thermal resources (see Figure 7) and a small amount of energy is also produced through nuclear sources. The thermal resources are mainly drawn from non-renewable sources, such as coal, gas, and diesel, for producing electricity. Hydropower generation was second contributing about 30 percent in

2015. The Water and Power Development Authority (WAPDA) generates hydropower with an installed capacity of around 6556.4 MW. Nuclear power contributed 4.9 percent of the total energy supply in Pakistan. This source should only be expanded with caution given the potential for catastrophes like those that occurred in Chernobyl and Fukushima (Britannica, 2020; Sugiyama, 2019). Figure 1 shows that renewable energy production's global installed capacity has shown an increasing trend with 147GW in the year 2018.

While the provision of electricity to the masses in Pakistan has shown exponential growth, it is still significantly insufficient. With an acute power shortage of around 3-5 GW, the percentage of the population enjoying electricity is between 60 and 65 percent (Menanteau et al., 2003). Although Pakistan has an abundant supply of renewable energy, efforts to increase the use of these resources for energy generation have been insufficient. Hydropower is the major source of sustainable energy produced in Pakistan. Figure 7 shows that in Pakistan, 67 percent of energy production was estimated to come from oil and gas, hydro 29 percent, nuclear 3 percent, and wind 0.5 percent in 2017 (Kamran 2018).

Figure 7: Pakistan's Energy Mix, 2015



Source: Kamran (2018).

The first initiative to reform the energy sector of Pakistan can be traced to 1980 when the government took heed of widespread power shortages to devise a policy to attract the private sector to develop RE. In 1983-88, and in 1994-98, the government spent PRs14 million to promote

research and development in solar energy resources. The failure of these initiatives led to the government launching a power policy in 2002 to produce 500MW and 1000MW of alternative energy resources (with the exclusion of hydropower) by 2015 and 2020 respectively (Kaundinya et al.,2009). However, the policy initiative failed to attract private investment (Baily, 2003).During this period, the government also tried to develop renewable energy technologies. The government established the National Institute of Silicon Technology (NIST) and the Pakistan Council of Appropriate Technology (PCAT) in 1981 and 1985, respectively, which aimed to embolden, facilitate and develop RE technologies for producing hydro, solar, and wind energy. These institutions failed to perform and were merged into the Pakistan Council of Renewable Technology (PCRET) in 2002. The newly formed organization was formed to collaborate, manage, and grow research activities purely in the renewable sector. The government also formed the Alternative Energy Development Board (AEDB) in 2002 with the objective of developing new technologies for producing solar, hydro and wind power (Yazdani & Rutherford, 2010).

The failure of the earlier policies led to the launching of the Development of Renewable Energy for Power Generation Policy 2006. The policy aimed to support and develop renewable energy projects and technologies to meet at least 10 percent of Pakistan's energy demand by 2015. This policy specifically focused on micro- and meso-level projects of hydro, solar, and wind energy (Bhutta, 2008). However, this policy has only been marginally successful. The few projects that managed to generate power include the 100 MW Quaid-e-Azam solar park and the 50 MW wind energy production.

Pakistan's geographical landscape makes it an excellent location for the development and installation of solar energy projects. The country gets around 15.5×10^{14} kwh of solar irradiance annually, which has the capacity to produce 1600GW of power every year that could be the leading source of power production in Pakistan (Mendonça, 2009). Similarly, Pakistan receives heavy winds in the South with 6–8 m/s on average wind speed in the coastal provinces of Sindh and Baluchistan. These winds have the capacity to generate 122.7 GW power annually. Even though this capacity is much less than that of solar, its importance cannot be understated. Also, hydropower produced in the country

already accounts for around 29 percent of overall energy consumption in 2017 (Kamran, 2018).

The potential of wind energy for Pakistan can be assessed from developments in other countries. China is far ahead of other countries, having developed various sources of energy through clear policies to support rapid economic growth (see Table 7). Pakistan's neighbor, India, has also forged ahead to rank 4th in the world in wind energy. Existing studies on renewable energy sources do not provide detailed insight into the various dimensions of renewable projects in Pakistan. The case of wind potential can be put as an example. Recent statistics show that Pakistan has the potential to produce a huge amount of energy from its widely prevalent wind resources as compared to India. It is important that Pakistan's government install windmills in the South to generate wind power, which can be appropriated both during the day and in the night so long as the winds read a certain minimum force.

Table 7: Top ten countries producing energy from wind, 2010

Country	MW	%Share
PR China	145,362	33.6
USA	74,471	17.2
Germany	44,947	10.4
India	25,088	5.8
Spain	23,025	5.3
United Kingdom	13,603	3.1
Canada	11,205	2.6
France	10,358	2.4
Italy	8,958	2.1
Brazil	8,715	2.0
Rest of the World	67,151	15.5
Total Top 10	365,731	84.5
World Total	432,883	100

Source: World Bank (2010).

The Pakistani government will have to review existing RE policies using the example of countries like China and Malaysia to adapt rather than copy successful RE policies in order to move the green energy agenda forward. It will not only help to power GDP growth and catch up

with the East Asian economies but also ensure that the environment is not compromised.

7. Conclusions

For all the potential Pakistan has, its economic growth has been low compared to the East Asian economies. While the country has yet to provide an adequate supply of power to its population, concerns over climate change and global warming have opened up new alternatives that offer Pakistan the opportunity to develop RE from solar and wind. Although Pakistan's consumption of fossil fuels in total energy consumption – including natural gas - is low compared to East Asian economies, the intensity of fossil fuels consumed has risen steeply over the years. Our panel Granger causality tests using Pakistan, China, Japan, South Korea, Malaysia, and Thailand show that GHG and CO₂ emissions would rise rapidly if there is any acceleration in GDP growth. Yet, Pakistan has to step up GDP growth to catch up with the East Asian economies. Consequently, there is a need to develop the abundant solar and wind endowments Pakistan has to fuel rapid economic growth.

In addition, to step up the production of energy from solar and wind sources, Pakistan should attempt to regulate the energy sector to ensure that it is adequate to offer low prices, uninterrupted supply, and able to sustain the shift from fossil to non-fossil fuels. An energy master plan accompanied by five-year reviews would be helpful to achieve this cause. The master plan should push for a sharp expansion in energy supply if the government's plan to stimulate rapid economic growth is to be realized. The manufacturing sector is the most energy-intensive sector among the sectors that make up GDP. Since energy cannot be stored effectively, the plan should also lay out the rules for developing a demand-supply framework that on the one hand should be internationally competitive for industrial users and fair to the normal consumers, and on the other hand, be accessible to those whose needs cannot be translated into significantly higher demand owing to low incomes. Energy is a public utility that is excludable and rivalrous but yet needs to reach everyone.

Future studies should include the impact of prices of the different energy resources and exchange rates, especially for countries such as

Pakistan, which is often afflicted with Dutch Disease problems that raise fuel prices facing domestic consumers. Given that energy is an important component of inputs used by most industries and consumers, and because Pakistan is a net importer of oil and gas, an analysis of the impact of exchange rate appreciations (and the accompanying inflationary impacts) is an important avenue of research.

References

- Adom, P. K., and Kwakwa, P. A. (2014). Effects of changing trade structure and technical characteristics of the manufacturing sector on energy intensity in Ghana. *Renewable and Sustainable Energy Reviews, 35*, 475-483.
- Apergis, N., and Ozturk, I. (2015). Testing environmental Kuznets curve hypothesis in Asian countries. *Ecological Indicators, 52*, 16-22.
- Bailly H. (2003). Commercialization of wind power potential in Pakistan 2003. [Financial and Economic Evaluation Final Report].
- Baležentis, A., Baležentis, T., and Streimikiene, D. (2011). The energy intensity in Lithuania during 1995–2009: A LMDI approach. *Energy Policy, 39*(11), 7322-7334.
- Baležentis, T., Streimikiene, D., Zhang, T., and Liobikiene, G. (2019). The role of bioenergy in greenhouse gas emission reduction in EU countries: An Environmental Kuznets Curve modelling. *Resources, Conservation and Recycling, 142*, 225-231.
- Baloch, M. A., Mahmood, N., and Zhang, J. W. (2019). Effect of natural resources, renewable energy and economic development on CO₂ emissions in BRICS countries. *Science of the Total Environment, 678*, 632-638.
- Bank D. (2010). Global energy transfer feed-in tariffs for developing countries. Deutsche Bank Climate Change Advisors.
- Berry T, and Jaccard M. (2001) The renewable portfolio standard: Design considerations and an implementation survey. *Energy Policy, 29*(4), 263–77.
- Bhutta, N.(2008). Wind power projects and role of government. In World Wind Energy Conference. Islamabad, Pakistan: Energy Wing, Planning Commission.
- Birol, F., and Keppler, J. H. (2000). Prices, technology development and the rebound effect. *Energy Policy, 28*(6-7), 457-469.

- Brischke, L.-A., Lehmann, F., Leuser, L., Thomas, S., and Baedeker, C. (2015). Energy sufficiency in private households enabled by adequate appliances, In: ECEEE 2015 Summer Study proceedings, 1571–1582. Stockholm: ECEEE.
- Britannica (2020). Chernobyl Disaster, Britannica Encyclopedia, June 1, downloaded on June 30, 2020 from <https://www.britannica.com/event/Chernobyl-disaster>.
- Chandran, V. G. R., and Tang, C. F. (2013). The impacts of transport energy consumption, foreign direct investment and income on CO₂ emissions in ASEAN-5 economies. *Renewable and Sustainable Energy Reviews*, 24, 445-453.
- Ehrlich, P. (1968). *The Population Bomb*, Cutchogue (NY): Buccaneer Books.
- Department for International Development [DfID] (2013). Technical Report. UK.
- Energy Market Authority (2020). Singapore Energy Statistics. https://www.ema.gov.sg/Singapore_Energy_Statistics.aspx (Accesses on: June 28, 2020)
- Engle, R. F., and Granger, C. W. (1987). Co-integration and error correction: representation, estimation, and testing. *Econometrica: Journal of the Econometric Society*, 251-276.
- Fischer, C., Blanck, R., Brohmann, B.; Cludius, J., Förster, H., Heyen, D.A., Hünecke, K., Keimeyer, F., Kenkmann, T., Schleicher, T., Schumacher, K., Wolff, F., Beznoska, M. Steiner, V., Gruber, E., Holländer, E., Roser, A., and Schakib-Ekbatan, K. (2016). KonzeptzurabsolutenVerminderung des Energiebedarfs: Potenziale, Rahmenbedingungen und InstrumentezurErreichung der Energieverbrauchsziele des Energiekonzepts. Dessau-Roßlau, Freiburg, Berlin, Karlsruhe: Umweltbundesamt, Öko-Institute.V., Freie Universität Berlin, IREES GmbH – InstitutfürRessourceneffizienz und Energiestrategien
- Goldemberg, J., and Prado, L. T. S. (2011). The decline of the world's energy intensity. *Energy Policy*, 39(3), 1802-1805.

- Grossman, G.M. and Krueger, A.B. (1991). Environmental impacts of a North American free trade agreement. NBER Working Papers 3914, National Bureau of Economic Research.
- Haq R. (2008). Renewable energy to tackle Pakistan's energy crisis. [cited 2009 March 15]. Available from: (<http://www.riazhaq.com/2008/09/tackling-pakistans-electricity-crisis.html>).
- HDIP, (2013). Pakistan energy yearbook 2012. Hydrocarbon Development Institute of Pakistan (HDIP), Ministry of Petroleum and Natural Resources, Islamabad.
- Hosseini, S. E., and Abdul Wahid, M. (2014). The role of renewable and sustainable energy in the energy mix of Malaysia: A review. *International Journal of Energy Research*, 38(14), 1769-1792.
- IEA, (2020). Data and Statistics. Accessed from: [https://www.iea.org/data-and-statistics/?country=WORLD&fuel=Energy%20supply&indicator=Total%20primary%20energy%20supply%20\(TPES\)%20by%20source](https://www.iea.org/data-and-statistics/?country=WORLD&fuel=Energy%20supply&indicator=Total%20primary%20energy%20supply%20(TPES)%20by%20source) (Accessed on: June 28, 2020)
- Im, K. S., Pesaran, M. H., and Shin, Y. (2003). Testing for unit roots in heterogeneous panels. *Journal of Econometrics*, 115(1), 53-74.
- Intergovernmental Panel on Climate Change (IPCC) (2014). Climate change 2014 - synthesis report. https://www.ipcc.ch/pdf/assessment-report/ar5/syr/SYR_AR5_FINAL_full_wcover.pdf (accessed 23 April 2018).
- Kamran, M. (2018). Current status and future success of renewable energy in Pakistan. *Renewable and Sustainable Energy Reviews*, 82, 609-617.
- Karberger, T. (2018). Progress of renewable electricity replacing fossil fuels. *Global Energy Interconnection*, 1(1), 48-52.
- Kaundinya, DP., Balachandra, P., and Ravindranath, N. (2009). Grid-connected versus stand-alone energy systems for decentralized power—A review of literature. *Renewable and Sustainable Energy Review*, 13(8), 2041-50.

- Kuznets, S. (1955). Economic Growth and income inequality. *American Economic Review*, 45(1): 1-28.
- Levin, A., Lin, C. F., and Chu, C. S. J. (2002). Unit root tests in panel data: Asymptotic and finite-sample properties. *Journal of Econometrics*, 108(1), 1-24.
- Malthus T.R. (1798). *An essay on the principle of population*. Chapter V, 39–45, Oxford: Oxford World's Classics reprint.
- Mazzanti, M., and Zoboli, R. (2005). Delinking and environmental Kuznets curves for waste indicators in Europe. *Environmental Sciences*, 2(4), 409-425.
- Meadows, D. H., Meadows, D. H., Randers, J., and Behrens III, W. W. (1972). The limits to growth: A report to the club of Rome. *Google Scholar*.
- Menanteau, P., Finon, D., and Lamy, M-L. (2003). Prices versus quantities: Choosing policies for promoting the development of renewable energy. *Energy Policy*, 31(8), 799–812.
- Mendonça M. (2009). Feed-in tariffs: Accelerating the deployment of renewable energy. Routledge.
- Ministry of Finance, Government of Pakistan. Pakistan economic survey (2016-17)–[Online]. Available:(http://www.finance.gov.pk/survey_1617.html)[Accessed: 19.04.119].
- Model, P. I. (2011). Pakistan Integrated Energy Model(Pak-IEM): Final report (Volume I). *International Resources Group for Asian Development Bank (ADB) and Ministry of Planning and Development (MOPD), Government of Pakistan, Islamabad*.
- Moner-Girona M, et al. (2008). A new scheme for the promotion of renewable energies in developing countries: The renewable energy regulated purchase tariff. Office for Official Publications of the European Communities.

- Mubarik, M. S. (2015). *Human capital and performance of small and medium manufacturing enterprises: A study of Pakistan* (Doctoral dissertation, University of Malaya, Kuala Lumpur Malaysia). Retrieved from: http://studentsrepo.um.edu.my/6573/1/Shujaat_Mubarik_Thesis_Final_Submission_.pdf
- Mubarik, M. S., and Naghavi, N. (2020). Human capital, green energy, and technological innovations: Firm-level analysis. In *Econometrics of Green Energy Handbook*, 151-164. Springer, Cham.
- Nordhaus, William (2019). Climate change: The ultimate challenge of economics. *American Economic Review*, 109(6), 1991-2014.
- Ocal, O., and Aslan, A. (2013). Renewable energy consumption–economic growth nexus in Turkey. *Renewable and Sustainable Energy Reviews*, 28, 494-499.
- Pao, H. T., and Tsai, C. M. (2011). Modeling and forecasting the CO₂ emissions, energy consumption, and economic growth in Brazil. *Energy*, 36(5), 2450-2458.
- Pedroni, P. (2004). Panel co-integration: asymptotic and finite sample properties of pooled time series tests with an application to the PPP hypothesis. *Econometric theory*, 20(3), 597-625.
- Panayotou, T. 1994. Empirical tests and policy analysis of environmental degradation at different stages of economic development. *Pacific and Asian Journal of Energy*, 4(1), 23–42.
- Pesaran, M. H., Shin, Y., and Smith, R. P. (1999). Pooled mean group estimation of dynamic heterogeneous panels. *Journal of the American Statistical Association*, 94(446), 621-634.
- Pesaran, M. H., and Smith, R. (1995). Estimating long-run relationships from dynamic heterogeneous panels. *Journal of Econometrics*, 68(1), 79-113.
- Rickerson W, et al. (2012). Feed-in tariffs as a policy instrument for promoting renewable energies and green economies in developing countries. Washington, DC: United Nations

Environment Programme. [Technical Paper].
http://www.unep.org/pdf/UNEP_FIT_Report_2012F.pdf

- Rasiah, R., Al-Amin, A. Q., Ahmed, A., Leal Filho, W., and Calvo, E. (2016). Climate mitigation roadmap: Assessing low carbon scenarios for Malaysia. *Journal of Cleaner Production*, 133, 272-283.
- Rasiah, R., Fatimah, K., Sadoi, Y. and Mintz-Habib, N. (2018). Climate change and sustainable development issues: Arguments and policy initiatives. *Journal of the Asia Pacific Economy*, 23(2), 187-194.
- Rockström, J., Steffen, W., Noone, K., Persson, Å., Chapin, F. S., Lambin, E. F., Lenton, T. M., Scheffer, M., Folke, C., Schellnhuber, H. J., Nykvist, B., de Wit, C. A., Hughes, T., van der Leeuw, S., Rodhe, H., Sörlin, S., Snyder, P. K., Costanza, R., Svedin, U., Falkenmark, M., Karlberg, L., Corell, R. W., Fabry, V. J., Hansen, J., Walker, B., Liverman, D., Richardson, K., Crutzen, P., and Foley, J. A. (2009). A safe operating space for humanity. *Nature*, 461(7263), 472-475. <https://doi.org/10.1038/461472a>.
- Sachs, J. (1982). The oil shocks and macroeconomic adjustment in the United States. *European Economic Review*, 18(1), 243-248.
- Seker, F., Ertugrul, H. M., and Cetin, M. (2015). The impact of foreign direct investment on environmental quality: A bounds testing and causality analysis for Turkey. *Renewable and Sustainable Energy Reviews*, 52, 347-356.
- Shi, X. (2016). The future of ASEAN energy mix: A SWOT analysis. *Renewable and Sustainable Energy Reviews*, 53, 672-680.
- Shove, E. (2003). *Comfort, cleanliness and convenience: The social organization of normality*. Oxford: Berg.
- Stern, N. (2006). *The economics of climate change: The Stern review*. Cambridge University press.

- Sugiyama, S. (2019). In aftermath of Fukushima triple meltdown, Japan's nuclear industry faces fierce headwind, Japan Times, March 11, downloaded on June 30, 2020 from <https://www.japantimes.co.jp/news/2019/03/11/business/aftermath-fukushima-triple-meltdown-japans-nuclear-industry-faces-fierce-headwind/>
- Tamazian, A., Chousa, J. P., and Vadlamannati, K. C. (2009). Does higher economic and financial development lead to environmental degradation: Evidence from BRIC countries. *Energy Policy*, 37(1), 246-253.
- Tenenbaum B, et al. (2014). From the bottom up: How small power producers and minigrids can deliver electrification and renewable energy in Africa. World Bank Publications.
- Uddin, M. M. (2014). Causal relationship between education, carbon dioxide CO₂ emission and economic growth in Bangladesh. *IOSR Journal of Humanities and Social Science (IOSR-JHSS)*, 19, 60-67.
- UNFCCC (United Nations Framework Convention on Climate Change). 2016. Report of the Conference of the Parties on its twenty-first session, held in Paris from 30 November to 13 December 2015.FCCC/CP/2015/10/Add.1. Bonn: UNFCCC. <http://unfccc.int/resource/docs/2015/cop21/eng/10a01.pdf>. (accessed February 16, 2019)
- Vasylieva, T., Lyulyov, O., Bilan, Y., and Streimikiene, D. (2019). Sustainable economic development and greenhouse gas emissions: The dynamic impact of renewable energy consumption, GDP, and corruption. *Energies*, 12(17), 3289.
- Yazdanie, M., and Rutherford, P. D. (2010). Renewable energy in Pakistan: Policy strengths, challenges and the path forward. *ETH Zurich*, 2, 112-119.
- Zhuong, M.H., Zhang, J., Kong, Z.Y., Fleming, R.M, Zhang, C.Y. and Zhang Z.Y. (2020). Potential environmental benefits of substituting nitrogen and phosphorus fertilizer with usable crop straw in China during 2000–2017. *Journal of Cleaner Production*, 267(10), 122-125.