SPCRD GLOBAL PUBLISHING
Sustainable Solutions
READS Review of Economics and Development Studies
Journal homepage: http://reads.spcrd.org ISSN (Print): 2519-9692 ISSN (Online): 2519-9706

Path Dependence in Energy System and Ecological Footprint in Pakistan: Evidence from Time Series Data

Abre-Rehmat Qurat-ul-Ann [a], Sana Noreen [b]

[a] Lecturer, Department of Economics, University of Gujrat, Gujrat, Pakistan
Email: abre.rehmat@uog.edu.pk
[b] MPhil Economics, University of Gujrat, Pakistan

ARTICLE DETAILS

History:
Accepted 25 May 2022
Available Online June 2022

Keywords:
Path Dependence, Energy Systems, Ecological Footprint, Biocapacity, Fossil Fuels

JEL Classification:
O13

DOI: 10.47067/reads.v8i2.450

ABSTRACT

Path dependence refers to the consumption of fossil fuels in energy production system. This study empirically examines the effect of path dependence in energy systems on ecological footprint of Pakistan from 1981-2014. Unit root test determines the integrated order of variables, while Auto-Regressive Distributed Lag model investigates the existence of a long-run association between variables. The negative and significant speed of adjustment coefficient ensures the adjustment of the model used in long run after unexpected shocks. Fossil fuel consumption significantly increases ecological footprint in Pakistan. If fossil fuel consumption increases by 1 percent, ecological footprint rises by 2.07 percent. Increase in biocapacity increases ecological footprint by 1.1 percent. Urbanization and population density significantly decrease ecological footprint as 1 percent increase in population density decreases ecological footprint by 0.96 percent and one percent rise in urbanization reduces ecological footprint by 3.28 percent. Foreign direct investment does not show any significant association with the ecological footprint. Standard diagnostic tests support the empirical results of the study and confirm that no heteroscedasticity and serial correlation exists. The policy implication is to implement measures to diminish the usage of fossil fuels in energy systems and increased usage of alternative and renewable energy sources. This can abate the burden on environment and biocapacity of Pakistan making it feasible to reduce ecological footprint levels in Pakistan.

Corresponding author's email address: abre.rehmat@uog.edu.pk

1. Introduction

The significance of energy use for the economic development of any economy cannot be further emphasized (Barbir et al., 1990). But the energy production heavily relies on consumption of fossil fuels and other non-renewable sources of energy. Despite concerns raised and problems created by this heavy dependence of energy systems, majority of the world economies depend upon fossil fuels to fulfil their demand for energy. Path dependence reflects the fossil fuels consumption in the process of energy generation since former to the current eras. Although several renewable and environment-friendly resources for energy production are present, but proportion of renewable energy in overall energy mix is not adequate. Substantial use of non-renewable sources incurs costs equal to environmental damages and fossil fuels consumption for energy generation (Rafique & Rehman, 2017).

The energy system of most countries either developed or developing, depends upon the fossil fuels. Even in the presence of their positive indicators as these countries have good operational control on their thermal plants, the use of fossil fuels causes many problems that are analyzed and addressed in literature. Some of the problems are environmental effects, scarcity of natural resources, risk of supply, and instability of market prices. All of these problems suggest switching from consumption of fossil fuels to the renewable sources of energy (Martins et al., 2019).

Energy is an indispensable component for all human actions and developments. Increase in energy usage globally has detrimental effect and repercussion on the global dominion and ecosystem. Pakistan has encouraging future prospects of renewable energy with a total potential of renewable sources about 167.6 GW. Due to improper policies and infrastructure, this potential has not been used to satisfy the total electricity demand. Consuming fossil fuels and other conventional sources of energy for power generation is another paramount reason for the environmental degradation (Rafique & Rehman, 2017).

Most of the developed and developing countries hinge on conventional sources of energy for electricity generation, such as coal, natural gas, biomass, oil and renewable. Fossil fuel usage in energy production creates a significant component of the complete energy demand (Hidayatullah et al., 2011). Although fossil fuels are crucial for energy production in majority of developing and developed countries, their consumption causes some environmental problems in form of increased air pollution levels and global warming. Air pollution generates health problems for people and produces negative social and economic effects. The irregular sharing of fossil fuel consumption also gives rise to issues like energy security due to their significant role in energy systems (Martins et al., 2018).

Fossil fuels covered 82 percent of the total primary energy supply of the world in 2011. The main reason behind air pollution in most of the high-income and middle-income countries is usage of fossil fuels in energy systems. Combustion of fossil fuels in energy generation produces 85 percent of irrespirable particulate air pollution and most of the emissions in form of Sulphur dioxide and nitrogen oxide in the atmosphere (Perera, 2018).

Energy policies are decisive towards achieving sustainable development and clean environment because two third of greenhouse gas (GHGs) emissions and 90 percent of CO_2 emissions are generated by energy sector (IEA, 2018). High energy use inevitably means higher GHG emissions. GHG emissions from energy supply sources are 47 percent of the total emissions (Rehman & Ali, 2016). Problems with fossil fuel consumption not only affect economy but it also harms environment in form of global warming, airborne pollution, and depletion of ozone layer, forest deterioration and emissions by radioactive substances (Dincer, 1999). These issues should be taken into account simultaneously if we want minimal environmental degradation and bright future of energy related systems. Literature suggests that continuous damage caused by human activities to natural environment negatively affects the future development (Dincer, 1999).

Fossil fuels combustion emits greenhouse gases which result in environmental damage (Haines et al., 2006). Outset of industrial revolution along with industrial expansion, has caused emission levels to increase to 76 percent of total greenhouse gas (GHG) emissions. 65 percent of these emissions are owed to fossil fuels and industrial processes, 11 percent is generated via forestry and further land use variations (Intergovernmental Panel on Climate Change [IPCC], 2014).

Pakistan is one of those countries who are facing a precarious climate change situation owing to rapid increase in GHG emissions. About 137 million metric tons of carbon dioxide emissions have been calculated on the base of per year consumption of fossil fuels in 2017. These GHGs emissions further result in bad environmental conditions and harm to the climate (Saleem et al., 2017).

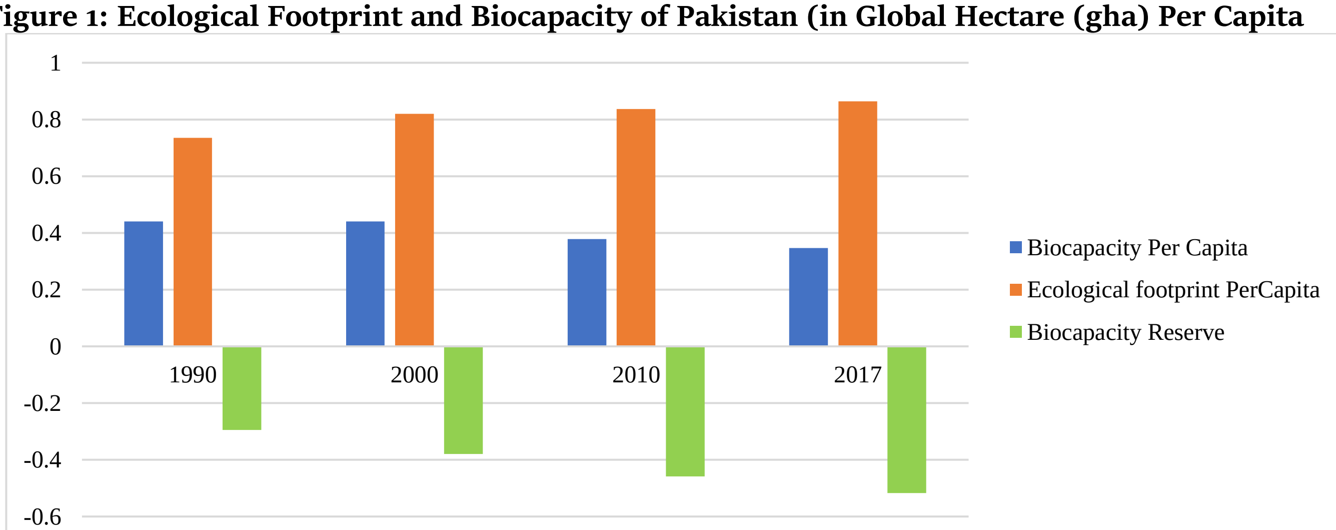
Table 1: Percentage of Energy Sources in Energy Mix of Pakistan- Fiscal Year 2018

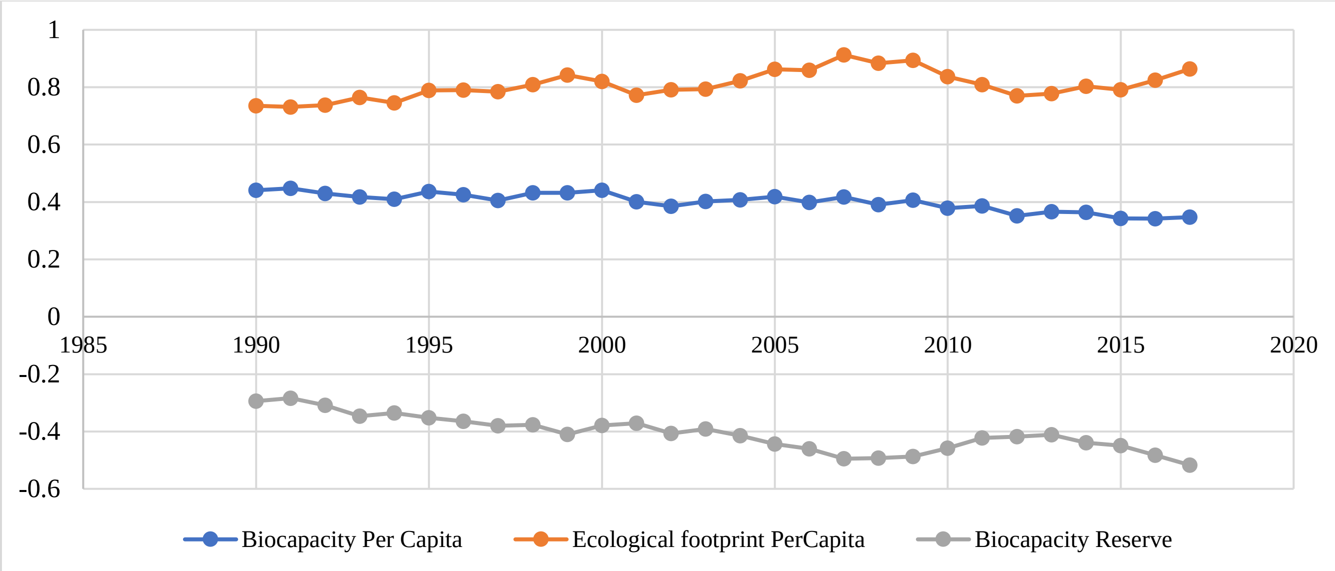
	Energy Source						
	Oil	**Hydro**	**Natural Gas**	**Imported LNG**	**Coal**	**Renewable sources**	**Nuclear energy**
Percentage Share in total energy mix	31.2	7.7	34.6	8.7	12.7	1.1	2.7

Source: HDIP, Government of Pakistan (2018-19)

Table 01 shows the contribution of fossil fuels in total energy mix of Pakistan depicting that Pakistan still depends on fossil fuels for functioning of energy system. Any change in the ecosystem is adverse for environmental health. As human undertakings are on the rise, the role of fossil fuels in manufacturing activities and energy utilization has also increased. This increased fossil fuel consumption has increased the overall temperature of the globe by putting high pressure on the natural resources of earth either directly or indirectly (Batool & Jamil, 2016). Ecological footprint of humans refers to the combined impact of all activities that take place by humans. It can be calculated in terms of naturally productive areas of land, the required water for production of goods that are needed to consume, and the absorption of generated waste. Simply, it can be defined as the environmental effect resulting from the human productive activities to acquire the required lifestyle (National Footprint Agency, 2017; Rashid et al., 2018).

Figure 1: Ecological Footprint and Biocapacity of Pakistan (in Global Hectare (gha) Per Capita





Authors' own work; Data Source: Global Footprint Network (2019)

Figure 1 shows the ecological footprint and bio-capacity levels of Pakistan in global hectare (gha) per capita (Monfreda et al., 2004; Galli et al., 2007). Its purpose is to observe the required biological regeneration ability of environment for human actions. These actions include both production as well as consumption of goods and services (Kitzes et al., 2008).

Ecological footprint is the pressure created on land by human activities (Destek et al., 2018). Majority of the recent literature used this variable as a measure and indicator for environmental degradation as it is more inclusive than CO_2 emissions (Aydin et al., 2019; Charfeddine, 2017; Mrabet & Alsamara, 2016; Mrabet et al., 2017; Destek & Sarkodie, 2019; Sarkodie & Strezov, 2018; Wang & Dong, 2019; Ozturk et al., 2016; Wang et al., 2013). It encompasses the direct and indirect environmental ramifications of human consumption and production activities (Ulucak & Bilgili, 2018). The world has been living in a situation of ecological overrun since 1970s as per ecological footprint chart (Ewing et al., 2010), which indicates that, the human demands are more than the Earth's biocapacity (WWF, 2014).

Literature suggests that consumption of fossil fuels; coal, oil, and natural gas harms earth's climate by rising atmospheric concentration of carbon dioxide gas. Global climate damage is expected to harm the ecological footprint. Burning fossil fuels is one of the paramount reasons that are responsible for decreasing ecological footprint of Pakistan (Perera, 2018).

Ecological footprint of Pakistan was 6.7 gha in 2012 which was 14 times smaller compared to ecological footprint of Australia (WWF, 2006, 2012). According to the estimations of Global Environmental Statistics, Pakistan is at 104^{th} rank out of 140 countries on the basis of ecological footprint (EF). Moreover, according to the Happy Planet Index (HPI) in 2011 the EF value of Pakistan had been 0.8.

There are multiple significant advantages of using ecological footprint for measuring environmental damage. It assists in highlighting the environmental influences of consumption and production actions (McDonald & Patterson, 2004). Most influential aspect of the ecological footprint is that it captures an extensive variety of ecological data combined as only one indicator (Costanza, 2000).

This study is significant as Pakistan has to attain SDG climate change, renewable energy and alternate energy use.

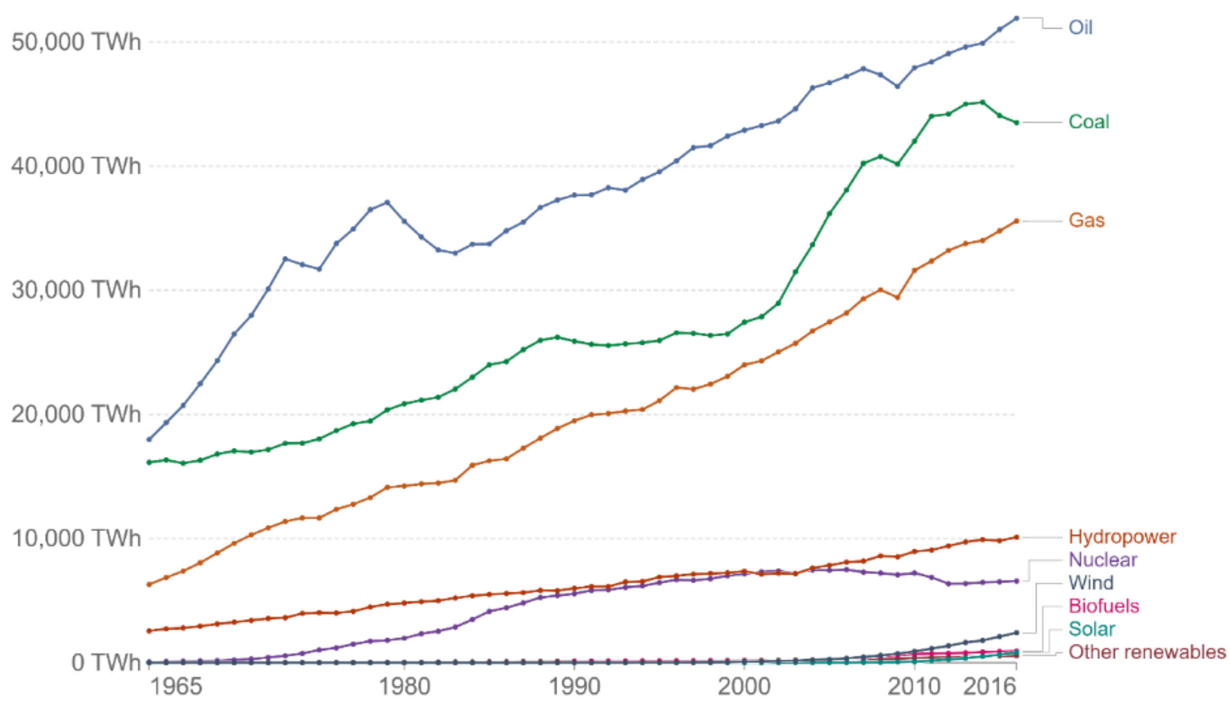
2. Overview of fossil fuel consumption and ecological footprint

Fossil fuel usage as the main input in energy production systems damages the global environment via numerous negative ecological impacts, which contribute to global warming, and air pollution. Air pollution further leads to several health problems and bad social and economic conditions (Martins et al., 2019). Although the share of renewable sources is rapidly increasing around the world, most of the global energy consumption depends upon fossil fuels. It is recorded that in 2017, fossil fuels had 81 percent share in the total energy consumption. There is estimation that consumption of fossil fuels is about 15 billion metric tons every year (Cassidy, 2019).

Global shift towards renewable energy use is in process but the speed of this shift is not in pace to meet the challenges formed in shape of economic expansion throughout the globe and rapid growth of population (IEA, 2019). As there is recognition of significance of transitions towards a carbon-neutral climate, the world still depends upon fossil fuel consumption in energy generation and it is expected to follow the same path dependence unless some major changes in the policies are introduced (IEA, 2019).

As time passed, the consumption of natural gas, coal and oil is increasing in energy generation system. The global share of different energy sources in different years (see figure 2) shows that conventional sources contribute more in the energy system across the world.

Figure 2 ***World Energy Consumption by Sources (TWh)***



Source: BP Statistical Review of World Energy, 2018

The continuity of path dependence in energy system by using the higher share of fossil fuels consumption for energy production has been worsening the environment. It means that by following this path, consuming more fossil fuels leads to environmental damage and increases the value of ecological footprint in the globe (Alkhathlan & Javid, 2015).

Despite using conventional measure of ecological footprint (hectare), a more comprehensive and better measure is global hectare (gha) This unit can be adjusted as a single unit in the way that it equalizes the fertility of different land areas. A given area of a cultivation zone has more productive capacity naturally as compared to the same area of land of a desert. Hence, the unit global hectare relates to biological hectare productive capacity worldwide. Therefore, the comparison of different ecosystems with different bio capacities in different areas in the world is possible using the same unit, global hectare (gha). Table 2 shows the global bio capacity and ecological footprint per person for years 1981 to 2014 and includes overall values along with the values of six components of ecological footprint.

Table 2: ***Ecological Footprint and Biocapacity Per Person***

Year	Record	Built-up land	Carbon	Cropland	Fishing grounds	Forest products	Grazing land	Total
1981	Biocapacity/ Person	0.02	0	0.35	0.08	0.03	0.01	0.49
	Ecological footprint/ person	0.02	0.17	0.34	0.03	0.1	0.01	0.66
1985	Biocapacity/ Person	0.02	0.18	0.35	0.02	0.1	0.01	0.68
	Ecological footprint/ person	0.03	0	0.36	0.07	0.03	0.01	0.49
1990	Biocapacity/ Person	0.03	0	0.34	0.06	0.03	0.01	0.46
	Ecological footprint/ person	0.03	0.23	0.37	0.02	0.1	0.01	0.76
1995	Biocapacity/ Person	0.03	0	0.35	0.05	0.02	0.01	0.46
	Ecological footprint/ person	0.03	0.28	0.38	0.03	0.09	0.01	0.81
2000	Biocapacity/ Person	0.04	0	0.36	0.05	0.02	0.01	0.46
	Ecological footprint/ person	0.04	0.28	0.38	0.03	0.11	0.01	0.84
2005	Biocapacity/ Person	0.04	0	0.34	0.04	0.01	0	0.44
	Ecological footprint/ person	0.04	0.36	0.36	0.02	0.09	0.01	0.88
2010	Biocapacity/ Person	0.04	0	0.3	0.04	0.01	0	0.39
	Ecological footprint/person	0.04	0.38	0.31	0.02	0.09	0.01	0.85
2014	Biocapacity/ Person	0.04	0	0.3	0.03	0.01	0	0.39
	Ecological footprint/ person	0.04	0.36	0.32	0.01	0.09	0	0.83

Source: Global Footprint Network (2019)

Growth in renewable resources will be higher in future lead by hydro, wind and solar power. Slow speed of this growth will not be sufficient to offset the impact of expanded global economies in future alongside a rapid growth of the population. Demand for energy will increase by 1 percent per year through 2040, and the emission level will be reduced as 50 percent of the increased demand will be fulfilled by using renewable sources, and almost 35 percent by gas (IEA, 2019). According to a recent projection, solar is anticipated to become the most sought-after source of energy by 2040 due to its declined costs. The wind energy source is also projected to increase by 15 folds. Energy consumption is projected to increase by 28 percent by 2040 (IEA, 2019).

3. Literature Review

Some studies found significant results whereas, some found insignificant effect of the fossil fuel consumption path dependence on the ecological footprint of their respective study region. It has been analysed that recently ecological footprint has become a more appropriate and innovative measure and indicator of environmental deterioration relative to CO_2 emissions (Sarkodie & Strezov, 2018; Aydin, Esen & Aydin, 2019; Destek & Sarkodie, 2019; Wang & Dong, 2019). Perera (2018) advocates the idea of the impacts of fossil fuel combustion in the form of pollution given our carbon-based economies as a serious concern. The study suggests that if we do not take any strong action, our generation and their descendants may be inherited a progressively more unsustainable and biased world where they and all of their communities will unable to survive, adjust, raise and transmute as required.

Ibrahiem and Hanafy (2020) investigated the link between consumption of fossil fuels and ecological footprint of Egypt. The study covers time period of forty-three years (1971- 2014). Empirical analysis using Fully Modified Ordinary Least Squares (FMOLS) and Dynamic Ordinary Least Squares (DOLS) methods identified and confirmed a positive and significant association between fossil fuel consumption and ecological footprint.

Destek and Sinha (2020) studied the relationship between conventional energy sources and ecological footprint of OECD economies from 1980 to 2014 using second-generation panel data methodologies. Results suggested positive and significant association amid use of non-renewable sources of energy and ecological footprint.

Alola, Bekun and Sarkodie (2019) investigated effect of fossil fuel consumption in energy systems on ecological footprint of sixteen European Union member countries. This study analysed data of 1997 to 2014 using estimation technique of Panel Pool Mean Group Auto Regressive Distributed Lag (PMG-ARDL) model and found a direct and significant association between consumption of fossil fuels and ecological footprint. Gokmenogolu and Sadeghieh (2019) explored association between fossil fuel consumption and ecological footprint of Turkey from 1960 to 2011. Empirical findings showed that fossil fuel consumption has a long run direct and elastic effect on ecological footprint.

Hanif et al. (2019) studied the effect of fossil fuels consumption on ecological footprint for both long and short run for fifteen developing Asian countries with panel data of twenty-three years [1990 to 2013]. Auto Regressive Distributed Lag (ARDL) model results showed that fossil fuels combustion contributes to the environmental degradation through increase in ecological footprint. Martins et al. (2019) selected 29 European countries and analysed that majority of the European countries profoundly rely on fossil fuels in energy systems and the findings suggested consumption of fossil fuels has adverse impact on ecological footprint of European countries.

Bello, Solarin and Yen (2018) explored the effect of fossil fuels combustion on environmental degradation for Malaysia using four measurement tools encompassing ecological footprint, carbon footprint, water footprint, and CO_2 emissions. VECM Granger Causality method is employed to assess annual time-series data of 1971-2016, for long-run association between study variables. The findings suggest that fossil fuel consumption has a negative effect on all four measures used for environmental degradation.

Sinha, Shehbaz, and Balsalobre (2017) empirically observed the association between non-renewable sources of energy, consumption of fossil fuels, and environmental damage. The study used the data for N-11 countries for the time period from 1990-2014 segregated in three forms (renewable, non-renewable, and biomass). The Generalized Method of Moments (GMM) analysis found that there exists a significant direct association between fossil fuel consumption and ecological footprint in N-11 countries.

Alkhathlan and Javid (2015) empirically investigated the effect of fossil fuels combustion on ecological footprint employing annual data from 1971 to 2013 for Saudi Arabia using Structural Time Series Models (STSMs). Study findings depict that the consumption of fossil fuels has a significantly direct effect on ecological footprint. Lotfalipour, Falahi and Ashena (2010) studied the association between fossil fuel consumption and carbon emissions as a measure of environmental damage in Iran from 1967-2007. Toda-Yamamoto estimation method was employed to explore this causal association. Results suggested a direct relationship between fossil fuel consumption and carbon emissions which ultimately increases ecological footprint and lead to environmental damage.

Ahmed et al. (2019) investigated the effect of population density on ecological footprint for Malaysia using annual time series data from 1971 to 2014. Bayer and Hanck co-integration test and ARDL estimation results disclosed that population density has significantly negative impact on carbon footprint and ecological footprint. Asici and Acar (2018) studied the effect of population density on ecological footprint using panel data for 87 countries from 2004 to 2010. The study found negative and significant relationship between the population density and ecological footprint and positive and significant impact of biocapacity on ecological footprint.

Alola et al. (2020) examined the association of biocapacity and ecological footprint for Africa from 1990 to 2014 employing Bound testing approach of ARDL. Estimation results establish that biocapacity and ecological footprint has a positive and significant association portraying that increase in biocapacity causes a considerable increase in the value of ecological footprint in Africa. Usman, Alola and Sarkodie (2020) empirically analyzed the dynamic effect of bio capacity on environmental damage in United States taking ecological footprint as a measure of environmental damage. Analysis of time series data of 1985 to 2014 for the long run as well as short run dynamic results, using ARDL estimation technique confirmed the presence of positive and significant relationship between biocapacity and ecological footprint.

Rehman et al. (2019) explored the relationship of biocapacity and environment using data of 16 Central and Eastern European Countries (CEECs) from 1991-2014. The study used ecological footprint as a measure for the climate conditions. Results of Dynamic Seemingly Unrelated-co-integration Regression (DSUR) established long-term positive and significant association of biocapacity and ecological footprint. Saleem, Rehman and Jun (2019) explored the dynamic effect created by human capital and biocapacity on environmental condition of BRICS countries. Proxy of ecological footprint was used for environment covering the period 1991-2014 and long-run dynamic coefficients obtained by DSUR imply the presence of significantly direct link amid biocapacity and ecological footprint.

Danish et al. (2019) assessed the relationship of economic growth and ecological footprint as it links to biocapacity and human capital and analyzed data of 43 years from 1971-2014. ARDL model estimation results with a structural break revealed that economic growth escalates ecological footprint and, hence, environmental degradation. Increase in biocapacity increases ecological footprint and contributes to environmental deterioration significantly. Mrabet et al. (2017) explored the association of financial development and ecological footprint in 15 MENA countries. An experimental panel analysis for these countries identified a positive but insignificant effect of foreign direct investment (FDI) on carbon dioxide emissions, ecological footprint, and carbon footprint.

Hassan et al. (2019) assessed the effect of economic growth, biocapacity and natural resources on ecological footprint of Pakistan. Results of ARDL bounds test found a long run direct and significant association between biocapacity and ecological footprint. Nathaniel et al. (2020b) found association between renewable sources of energy, urbanization, economic growth, trade openness and ecological footprint for CIVETS (Colombia, Indonesia, Vietnam, Egypt, Turkey, and South Africa) countries. The Augmented mean group estimator, panel co-integration and causality test results found that urbanization has a long-run inverse but significant association with ecological footprint.

Nathaniel (2020a) analyzed the relationship between energy consumption, urbanization, economic growth and trade for Indonesia. The study estimated annual time series data from 1971 to 2014 using ARDL technique and found negative but significant effect of urbanization on ecological footprint. Danish, Ulucak and Khan (2019) analyzed the relationship between urbanization and ecological footprint for BRICS economies using panel data for twenty-four years, from 1992 to 2016. The study used Fully Modified Ordinary Least Square (FMOLS) and Dynamic Ordinary Least Square (DOLS) for estimating the long-run estimators. Empirical results explored the relationship between income and urbanization and analyzed its impact on ecological footprint. Higher income leads to a surge in urbanization which reduces the value of ecological footprint in those developing countries.

4. Research Methodology

4.1 Data Sources and Description of Variables

This study employed annual time series data of Pakistan from 1981-2014 (see table 3 for details on variables). Data on ecological footprint and biocapacity is obtained from National footprint account, whereas, data on fossil fuel consumption, population density, urbanization and foreign direct investment is taken from World Development Indicators of World Bank.

Table 3: Description of the Variables

Variable	**Description**	**Data Source**
EF	Ecological Footprint (gha)	National footprint Account
FFC	Fossil fuel consumption (% of total energy consumption)	World Development Indicators (WDI). World Bank
BC	Bio-capacity (gha)	National Footprint Account
POP	Population density (Population per sq.km of land area)	WDI, World Bank
URB	Urbanization (Urban population as % of total population)	WDI, World bank
FDI	foreign direct investment inflow (% of GDP)	WDI, World Bank

4.2 Empirical Model

Equation (1) empirically estimates the effect of fossil fuel consumption in energy systems on the ecological footprint of Pakistan (Nathaniel, 2000);

$$EF_t = \beta_0 + \beta_1 (FFC)_t + \beta_2 (BC)_t + \beta_3 (POP)_t + \beta_4 (URB)_t + \beta_5 (FDI)_t + \mu_t \qquad (1)$$

where EF denotes ecological footprint, FFC depicts fossil fuel consumption in energy system, BC refers to biocapacity, POP refers to population density, URB depicts urbanization and FDI represents foreign direct investment. In equation 2, the model is converted into logarithmic form,

$$\ln EF_t = \beta_0 + \beta_1 (\ln FFC)_t + \beta_2 (\ln BC)_t + \beta_3 (\ln POP)_t + \beta_4 (\ln URB)_t + \beta_5 (\ln FDI)_t + \varepsilon_t \qquad (2)$$

In equations (1) and (2), βs are the coefficients of independent variables. Coefficient values state the magnitude of change in dependent variable caused by the explanatory variables. The signs of βs determine the relationship of each explanatory variable with the dependent variable. If $\beta > o$, it shows that the variable has a direct relationship with the dependent variable. If $\beta < 0$, it confirms that explanatory variable has a negative impact on the dependent variable, whereas, if the value of $\beta = 0$, it implies no effect on the dependent variable as a result of change in independent variable.

After checking the stationarity of the variables using Augmented Dickey Fuller (ADF) test, ARDL approach is determined to analyze the data. First step in ARDL analysis is to carry out bound testing to figure out the F-statistics for ensuring presence of long-term relationship among the variables. F-statistic is computed for each variable. Typical ARDL model for co-integration suggested by Pesaran and Shin (2001) is as follows (see equation 3);

$$\begin{aligned}\boldsymbol{\Delta \ln Y_t = c + \textstyle\sum_{i=1}^{n} \alpha \Delta \ln Y_{t-i} + \sum_{i=1}^{n} \beta \Delta \ln X_{t-i} + \sum_{i=1}^{n} \gamma \Delta \ln Z_{t-i} +} \\ \boldsymbol{\delta_1 \ln Y_{t-1} + \delta_2 \ln X_{t-1} + \delta_3 \ln Z_{t-1} + \varepsilon_t} \qquad \textbf{(3)}\end{aligned}$$

Where c is intercept; Δ depicts first difference lag operator; ε refers to the white noise error term. The series is in natural logarithmic form (ln) (see equation 3). Both the long run and short run coefficients can be calculated by ARDL model, and error correction model (ECM). The ARDL for the long run model is presented in equation 4;

$$\ln Y_t = \beta_0 + \textstyle\sum_{i=1}^{n} \beta_1 \Delta \ln Y_{t-i} + \sum_{i=1}^{n} \beta_2 \Delta \ln X_{t-i} + \sum_{i=1}^{n} \beta_3 \Delta \ln Z_{t-i} + \varepsilon_t \qquad (4)$$

Where β_s are long-run coefficients of ARDL model. Short run coefficients computed by ECM model are shown in equation (5):

$$\begin{aligned}\Delta \ln Y_t = \alpha_0 + \textstyle\sum_{i=1}^{n} \alpha_1 \Delta \ln Y_{t-i} + \sum_{i=1}^{n} \alpha_2 \Delta \ln X_{t-i} + \sum_{i=1}^{n} \alpha_3 \Delta \ln Z_{t-i} + \\ \theta ECM_{t-i} + \varepsilon_t \qquad (5)\end{aligned}$$

Where, α_s are short run coefficients of ARDL error correction (ECM) model; where ECM is the error-correction term, and θ represents the speed of adjustment parameter.

5. Results and Discussion

Unit root analysis using ADF test evaluates the presence of unit root in the variables of the underlying model.

Table 4 Augmented Dickey-Fuller (ADF) Test Results

Variables	At level		At 1st difference		
	Intercept	Trend and intercept	Intercept	Trend and intercept	Decision
LEF	-1.875	2.456	7.168	7.154	I(1)
LBC	-2.550	4.627	6.871***	6.782	I(1)
LFDI	-1.743	1.945	4.894***	4.911***	I(1)
LFFC	-3.061	1.719	-4.902***	5.517***	I(0)
LPOP	-7.663***	1.072	-0.7586	-1.464	I(0)
LURB	-0.180	-3.413	2.745	2.747	I(0)

*Note: *** p <0.01, **p<0.05. *p<0.1.* Source: Authors' own calculations.

Stationarity test results (see table 4) suggest that fossil fuel consumption, population density and urbanization are stationary at level, whereas, ecological footprint, biocapacity and foreign direct investment are stationary at first difference. Overall, variables of the model are integrated of mixed order, and no variable is found integrated of order 2, i.e. I (2). Therefore, ARDL estimation technique is employed to analyze the relationship between ecological footprint and fossil fuel dependence of energy system in Pakistan.

The first step of estimation in ARDL co-integration technique is to compute the bounds test values which help to evaluate existence of long-run relationship between the dependent and independent variables. F- test Statistics are computed and matched with the lower and upper bounds values provided by the Pesaran et al. (2001).

Table 5 ARDL Bounds Test: Testing for Existence of a Level Relationship

Dependent variable: Ecological footprint

F-Statistics	7.921841	
Critical Bound Values	**Lower Bound**	**Upper Bound**
1%	3.41	4.68
5%	2.62	3.79
10%	2.26	3.35

Source: Critical values from Pesaran et al. (2001)

The calculated F-statistic value should be greater than the lower and upper bound values (table 5). Higher tabulated value of F-statistic (7.92) than the lower and upper bound values at all levels of significance endorses the long run correlation between explanatory and explained variables (table 5).

Long-run analysis estimation results in table 6 show that biocapacity has significant direct effect on ecological footprint. 1 percent increase in biocapacity increases ecological footprint by 1.14 percent at 1 percent significance level. Increase in fossil fuel consumption in energy systems in Pakistan by 1 percent, increases ecological footprint by 2.07 percent (table 6). Population density is inversely related with ecological footprint, where, one percent increase in the population density decreases ecological footprint by 0.97 percent at 5 percent significance level. An increase in urbanization of 1 percent results in 3.2 percent decrease in ecological footprint of Pakistan. Results found a direct but insignificant relationship between foreign direct investment and ecological footprint (table 6).

Table 6 *Results of Long-Run Analysis*				
Variables	**Coefficient**	**SE**	**T-Statistic**	**Prob.**
LFFC	2.0704***	0.6719	3.0808	0.0064
LBIO	1.1409***	0.3757	3.0414	0.0070
LFDI	0.014	0.0227	0.6213	0.5422
LPD	-0.967**	.3942	2.4542	0.0245
LURB	-3.274**	1.2835	2.5512	0.0200
Constant	0.778	0.4666	-0.6060	0.5520
Diagnostic Tests				
R^2	0.936	**Adj.R^2**	0.8947	
F-Statistic	22.252	**Prob. F-stat**	0.00	
*Note: *p<0.1, **p<0.05, *** p <0.01.* Source: Authors' own calculations				

In short run analysis, model is assessed for convergence with ECM term (equation 5) (see table 7). ECM depicts the speed of adjustment of the model to equilibrium in the long run showing that if the system experiences an unexpected shock, how much time it takes to get back to equilibrium. Ecological footprint is directly related to fossil fuel consumption, biocapacity and foreign direct investment, whereas, it is inversely associated with urbanization and population density (table 7).

Table 7 Short Run Estimation Analysis				
Variables	**Coefficients**	**Standard Error**	**t-Statistic**	**Prob.**
DLFFC	0.3165	0.3809	-0.831001	0.4169
DLBIO	0.25980**	0.1086	2.390379	0.0280
DLBIO(-1)	0.1263	0.1092	-1.187596	0.2504
LBIO(-2)	-2.467	0.0916	-2.693026	0.0149
DLFDI	0.0119	0.0199	0.596898	0.5580
DLPD	112.031	45.335	2.471176	0.0237
DLPD(-1)	48.55	23.854	-2.035326	0.0568
DLURB	-2.7600	0.9284	-2.972718	0.0568
ECM(-1)	-0.8428***	0.1378	-6.112941	0.0000
Source: Authors' Own calculations				

In short run, urbanization has a significantly negative relationship with ecological footprint, whereas, fossil fuel consumption, biocapacity, foreign direct investment and population density are directly related to ecological footprint. The negative and significant value of co-integration coefficient (ECM) shows that if there is an unexpected shock faced by the system, the whole system will move back towards the equilibrium annually at the speed of 84.2 percent (see table 7). Hence, the results suggest that there exists a short-run equilibrium based on this model which supports the long run impact of fossil fuel use on ecological footprint of the country.

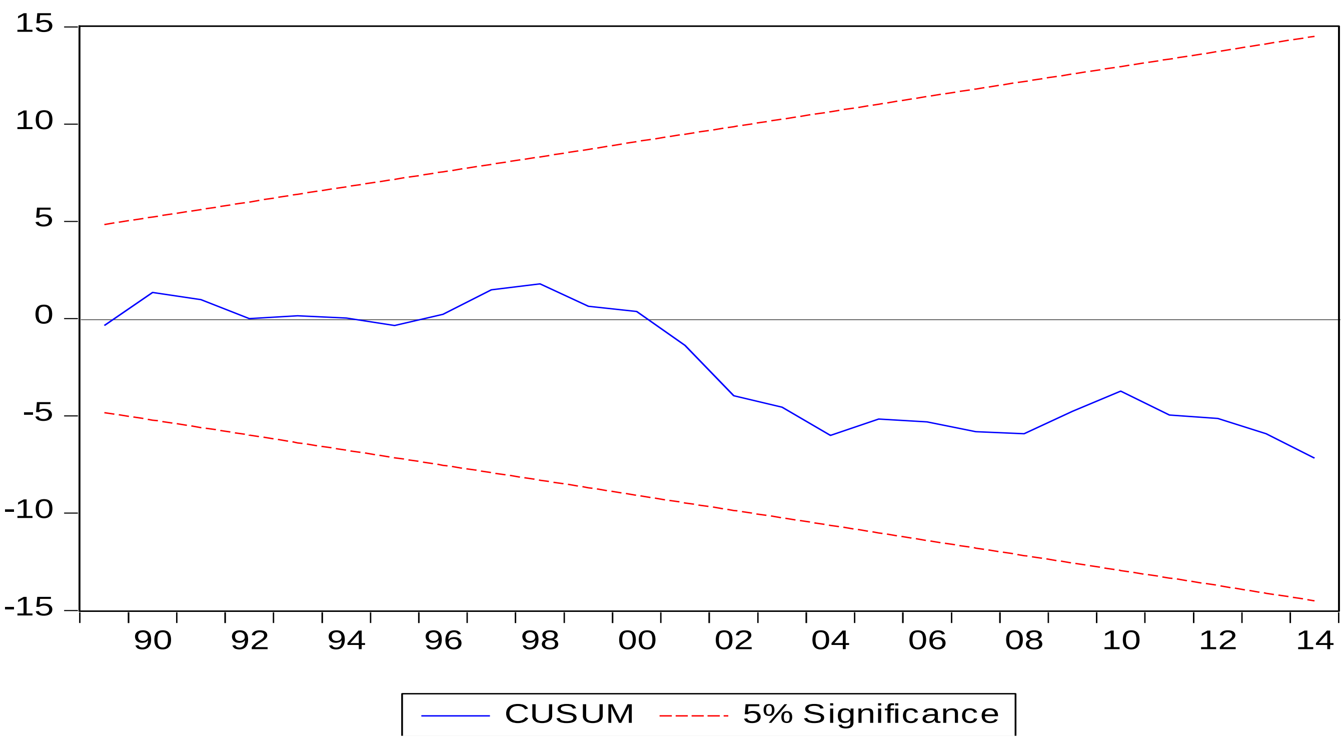
6. Diagnostic tests

Breusch-Godfrey LM test and Breusch-Pagan-Godfrey test evaluated the presence of serial correlation and heteroscedasticity in the model, respectively. The probability value of LM test statistic is greater than 0.05, conforming that serial correlation does not exist and the null hypothesis of no serial correlation could not be rejected at the 5 percent level of significance (see table 8). The null hypothesis of no heteroscedasticity could also not be rejected as probability value of test statistic is more than 0.05.

Table 8 *Diagnostic Tests for Error Correction Mechanism Model*			
Serial Correlation LM Test (BP)			
F-statistic	0.028	**Prob.**	0.9724
R-squared	0.07318	**Prob. Chi-Square**	0.9641
Heteroscedasticity Test (Breusch-Pagan-Godfrey)			
F-statistic	2.0942	**Prob.**	0.0959
R-squared	9.2542	**Prob. Chi-Square**	0.0993
Source: Authors' Own Calculations			

"CUSUM" and "CUSUM SQUARE" tests gauge the long-term stability of variables of the model. Figure 3 depicts model consistency tests, where the middle line shows the reliability of variables in the long run. If the middle line is in the middle of two upper and lower lines, it means that model variables are consistent or stable in long run. If the middle line does not lie amongst the upper and lower boundary or it reaches outside upper and lower lines, it implies that in long-run, variables of the underlying model are not stable.

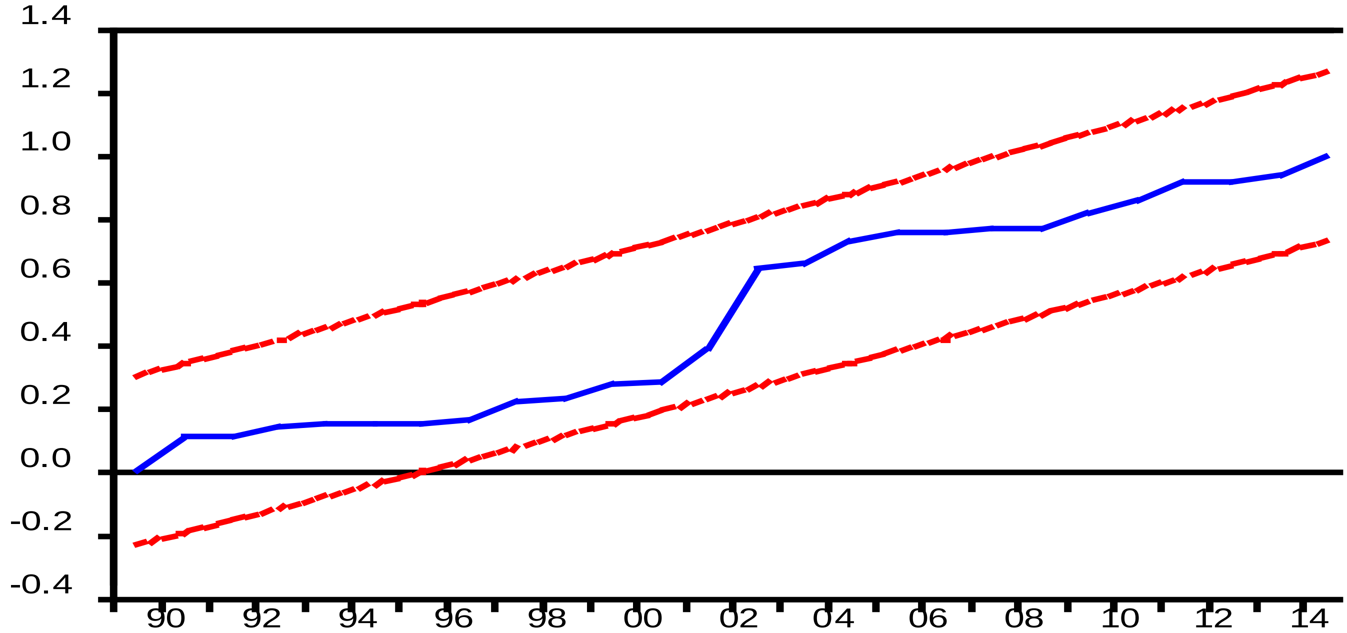
Figure 3 CUSUM Test Result



Source: Authors' Own Calculations.

CUSUM plot to check the model stability (see figure 3) shows that the middle line in the graph lies amid upper and lower lines of the graph which means that all the variables of empirical model are consistent and stable in the long run. The results of CUSUM SQUARE test (see figure 4) show that the estimated values are in the middle of the upper and lower lines/bounds of the graph conforming the long-run consistency and stability of the underlying model.

Figure 4 CUSUM Square Results



Source: Authors' Own Calculations

7. Conclusion and Policy Recommendations

As the population of Pakistan is increasing, demand for energy is on the rise accordingly. To meet the increasing energy demand, Pakistan has to depend on fossil fuels to come across the requirement. Fossil fuel consumption for energy production thus becomes a major source that adds to environmental degradation through soaring ecological footprint of the country. The consumption of renewable energy sources in energy production is not adequate to safeguard the deteriorating environmental conditions in the country. Economies with smaller portion of fossil fuel consumption in energy mix observe lower levels of ecological footprint and better environmental conditions. This study analyzed impact of fossil fuel consumption on ecological footprint of Pakistan using annual time series data from 1981 to 2014. After analyzing the stationarity of all variables, the variables of the model are found to be integrated of mixed order, hence, ARDL estimation technique is employed to analyze the relationship of ecological footprint with fossil fuel dependence of energy system in Pakistan. Results endorse the presence of direct and significant association between fossil fuel consumption and ecological footprint in Pakistan. The long-run results confirm that ecological footprint is directly and significantly associated with fossil fuel consumption and biocapacity, whereas, population density and urbanization are negatively and significantly related with ecological footprint. The negative and significant value of ECM shows the convergence of system towards equilibrium in long run-in case of any shocks in the short-run.

1 percent increase in fossil fuel consumption causes 2.07 percent increase in the ecological footprint of Pakistan. The coefficient value of biocapacity suggests that if there is 1 percent increase in biocapacity, it causes 1.14 percent rise in the value of ecological footprint of Pakistan. The results confirmed that there is a negative and significant relationship between urbanization and ecological footprint. In case of a one percent increase in urbanization, ecological footprint declines by 3.27 percent. Population density has an inverse association with the ecological footprint of Pakistan. A one percent rise in population density causes 0.96 percent decrease in the ecological footprint. ECM term coefficient value of -0.84 depicts the adjustment speed of the model towards equilibrium. All the

diagnostic test results support the model results and show that the issues of heteroscedasticity and autocorrelation do not exist and the model is consistent and stable.

Increased burden on the cities and suburbs along with increased population density has increased the burden on the ability of the environment to absorb and process the environmental pollution. Superfluous consumption of the existing population has increased the speed of extraction of resources from the environment giving it less time to recover and replenish. Economies like Pakistan are at the verge of both economic and environmental crises where the growth of the economy is profoundly dependent on energy sources. If economy is not fuelled by energy sources, then it will face hurdles in terms of long-run growth. If fossil fuel dependence in the energy systems is not addressed in time, it will lead to a shortage and worsening of biocapacity and increased ecological footprint, risking the sustainable development and future supply of renewable resources of Pakistan.

Results recommend introduction of energy policies by federal government which support the use of alternative fuels in energy production, and increase biocapacity by preserving existing environmental and natural resources. Inefficient extraction and excess consumption of renewable resources can deplete their future supply and hence can lead to different sets of issues pertaining to sustainable development. Reliance on domestic sources of renewable energy based on conservation and careful usage principles should be emphasized. Government should restrict excessive consumption of fossil fuels in energy production system and must devise and implement environment-friendly policies that enforce the replacement of the non-renewable sources of energy by renewable and green energy sources so that the ecological footprint of the country can be improved. SDG 12 of ensuring responsible and sustainable consumption and production can be achieved by working on sustainable management and use of natural resources including biocapacity. Implementation of long-term production frameworks under target 12.1 and integrating climate change measures into policy and planning under SGD13 are imperative to attain the climate change targets by 2030.

Authors' Contribution: All authors contributed to the study’s conception and design. Material preparation, data collection, and analysis were performed by Abre-Rehmat Qurat-ul-Ann and Sana Noreen. The first draft of the manuscript was written by Sana Noreen and both authors commented on previous versions of the manuscript. All authors read, reviewed and approved the final manuscript.

References

Ahmed, Z., Wang, Z., Mahmood, F., Hafeez, M., & Ali, N. (2019). Does globalization increase the ecological footprint? Empirical evidence from Malaysia. Environmental Science and Pollution Research, 26(18), 18565-18582.

Alkhathlan, K., & Javid. M. (2015). Carbon Emissions and Oil Consumption in Saudi Arabia. Renewable and Sustainable Energy Reviews. 48, 105-111.

Alola, A. A., Arikewuyo, A. O., Ozad, B., Alola, U. V., & Arikewuyo, H. O. (2020). A drain or drench on biocapacity? Environmental account of fertility, marriage, and ICT in the USA and Canada. Environmental Science and Pollution Research, 27(4), 4032-4043.

Alola, A. A., Bekun, F. V., & Sarkodie, S. A. (2019). Dynamic impact of trade policy, economic growth, fertility rate, renewable and non-renewable energy consumption on ecological footprint in Europe. Science of the Total Environment, 685, 702-709.

Asici. A., & Acar. S. (2018). How Does Environmental Regulation Affect Production Location of non-Carbon Ecological Footprint? Journal of Cleaner Production. 178, 927-936.

Aydin, C., Esen, O., & Aydin, R. (2019). Is the ecological footprint related to the Kuznets curve a real process or rationalizing the ecological consequences of the affluence? Evidence from PSTR approach. Ecological Indicators, 98, 543–555.

Barbir, F., Veziroğlu, T. N., & Plass Jr, H. J. (1990). Environmental damage due to fossil fuels use. International journal of hydrogen energy, 15(10), 739-749.

Batool, M. & Jamil, M. (2016). Environmental Degradation in Developed and Developing Countries from the Stand Point of Financial Development and Institutional Quality. Pakistan Institute of Development Economics.

Bello, M. O., Solarin, S. A., & Yen, Y. Y. (2018). The impact of electricity consumption on CO2 emission, carbon footprint, water footprint and ecological footprint: the role of hydropower in an emerging economy. Journal of environmental management, 219, 218-230.

Cassidy, E. (2019). Which Countries Use the Most Fossil Fuels: World Resource Institute. Retrieved from www.wri.org.

Charfeddine, L. (2017). The impact of energy consumption and economic development on Ecological Footprint and CO2 emissions: Evidence from a Markov Switching Equilibrium Correction Model. Energy Economics, 65, 355–374.

Costanza, R. (2000). Social goals and the valuation of ecosystem services. Ecosystems, 4-10.

Costanza, R. (2000). The dynamics of the ecological footprint concept. Ecological economics, 32(3), 341-345.

Danish, Hassan, S.T., Baloch, M.A., Mahmood, N., & Zhang, J. (2019). Linking economic growth and ecological footprint through human capital and biocapacity. *Sustainable Cities and Society*.

Danish, Ulucak, R. & Khan, SU-Din. (2019). Determinants of the ecological footprint: Role of renewable energy, natural resources, and urbanization. Sustainable Cities and Society, 54,101996. doi: https://doi.org/10.1016/j.scs.2019.101996

Destek, M. A., & Sarkodie, S. A. (2019). Investigation of environmental Kuznets curve for ecological footprint: The role of energy and financial development. The Science of the Total Environment, 650, 2483–2489.

Destek, M. A., & Sinha, A. (2020). Renewable, non-renewable energy consumption, economic growth, trade openness and ecological footprint: Evidence from organisation for economic Co-operation and development countries. Journal of Cleaner Production, 242, 118537.

Destek, M. A., Balli. E., & Manga. M. (2016). The Relationship Between CO2 Emissions, Energy Consumption, Urbanization and Trade Openness for Selected ECCCs. Research in World Economy. (7).

Destek, M. A., Ulucak, R., & Dogan, E. (2018). Analyzing the environmental Kuznets curve for the EU countries: The role of ecological footprint. Environmental Science and Pollution Research, 25, 29387–29396.

Dincer, I. (1999). Environmental impacts of energy. Energy policy, 27(14), 845-854.

Ewing, B., Moore, D., Goldfinger, S., Oursler, A., Reed, A., & Wackernagel, M. (2010). Ecological Footprint Atlas 2010. Global Footprint Network, Oakland.

Galli, A., Kitzes, J., Wermer, P., Wackernagel, M., Niccolucci, V., & Tiezzi, E. (2007). An exploration of the mathematics behind the ecological footprint (pp. 249-256). Wit Press: Billerica, MA, USA.

Gokmenogolu, K. K., & Sadeghieh, M. (2019). Financial Development, CO2 Emissions, Fossil Fuel Consumption and Economic Growth: The Case of Turkey. Strategic Planning for Energy and Environment.

Haines, A., Kovtas, R.S., Campbell-Lendrum, D., & Corvalan, C. (2006). Climate Change and Human Health: Impacts, vulnerability and Public Health. Public Health, 120 (7), 585-596.

Hanif, I., Raza, S. M. F., Gago-de-Santos, P., & Abbas, Q. (2019). Fossil fuels, foreign direct investment, and economic growth have triggered CO2 emissions in emerging Asian economies: some empirical evidence. Energy, 171, 493-501.

Hassan, S. T., Xia, E., Khan, N. H., & Shah, S. M. A. (2019). Economic growth, natural resources, and ecological footprints: Evidence from Pakistan. Environmental Science and Pollution Research, 26(3), 2929-2938.

Hidayatullah, N. A., Blagojce, S., & Kalam, A. (2011). Analysis of Distributed Generation Systems, Smart Grid Technologies and Future Motivators Influencing Change in The Electricity Sector. Scientific Research. 2, 216-229.

HDIP (Hydrocarbon Development Institute of Pakistan). (2018). Pakistan Energy Year Book. Ministry of Energy (Petroleum Division), Government of Pakistan.

Ibrahiem, D.M. & Hanafy, S.A. (2020). Dynamic linkages amongst ecological footprints, fossil fuel energy consumption and globalization: An empirical analysis, Management of Environmental Quality, 31, 6, 1549-1568. https://doi.org/10.1108/MEQ-02-2020-0029.

IEA (International Energy Agency). (2014). Energy Policies beyond IEA Countries. Morocco: Executive Summary and Key Recommendations. 9-11.

IEA (International Energy Agency). (2018). Greenhouse gas emissions from Energy. Annual Time series of GHG Emissions from energy, a major source of anthropogenic emissions.

IEA (2019), World Energy Outlook 2019, IEA, Paris https://www.iea.org/reports/world-energy-outlook-2019.

IPCC (2014). Climate Change 2014: Synthesis Report. Contribution of Working Groups 1, 2, 3 To the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Core Writing Team, R.K. Pachauri and L.A Meyer (eds.)]. IPCC, Geneva, Switzerland, 151.

Isman, M., Archambault, M., Racette, P., Konga, C. N., Llaque, R. M., Lin, D., & Ouellet-Plamondon, C. M. (2018). Ecological Footprint assessment for targeting climate change mitigation in cities: A case study of 15 Canadian cities according to census metropolitan areas. Journal of Cleaner production, 174, 1032-1043.

Kitzes, J., Wackernagel, M., Loh, J., Peller, A., Goldfinger, S., Cheng, D., & Tea, K. (2008). Shrink and share: humanity's present and future Ecological Footprint. Philosophical Transactions of the Royal Society B: Biological Sciences, 363(1491), 467-475.

Lotfalipour, M. R., Falahi, M. A., & Ashena, M. (2010). Economic growth, CO2 emissions, and fossil fuels consumption in Iran. Energy, 35(12), 5115-5120.

Martins, F., Felgueiras, C., Smitkova, M., & Caetano, N. (2019). Analysis of fossil fuel energy consumption and environmental impacts in European countries. Energies, 12(6), 964.

Martins, F., Felguieras, C., & Smitkova, M. (2018). Fossil Fuel Energy Consumption in European Countries. Energy Procedia. 153. 107-111.

McDonald, G. W., & Patterson, M. G. (2004). Ecological footprints and interdependencies of New Zealand regions. Ecological Economics, 50(1-2), 49-67.

Monfreda, C., Wackernagel, M., & Deumling, D. (2004). Establishing national natural capital accounts based on detailed ecological footprint and biological capacity assessments. Land use policy, 21(3), 231-246.

Moniz, I. & Galindo, A. (2005). Urban Form and the Ecological Footprint of Community. The Case of Barcelona. Ecological Economics 55, 499-514.

Mrabet, Z., & Alsamara, M. (2016). Testing the Kuznets Curve hypothesis for Qatar: A comparison between carbon dioxide and ecological footprint. Renewable and Sustainable Energy Reviews, 70, 1366–1375.

Mrabet, Z., AlSamara, M., Hezam, & Jarallah, S. (2017). The impact of economic development on environmental degradation in Qatar. Environmental and Ecological Statistics, 24, 7–38.

Nathaniel, S. P. (2020a). Ecological footprint, energy use, trade, and urbanization linkage in Indonesia. GeoJournal, 1-14.

Nathaniel, S. P. (2020b). Modelling urbanization, trade flow, economic growth and energy consumption with regards to the environment in Nigeria. GeoJournal, 85(6), 1499-1513.

Nathaniel, S., Anyanwu, O., & Shah, M. (2020a). Renewable energy, urbanization, and ecological footprint in the Middle East and North Africa region. Environmental Science and Pollution Research, 1-13.

Nathaniel, S., Nwodo, O., Sharma, G., & Shah, M. (2020b). Renewable energy, urbanization, and ecological footprint linkage in CIVETS. Environmental Science and Pollution Research, 27(16), 19616-19629.doi:10.1007/s11356-020-08466-0.

National Footprint Account (NFA). (2017). Retrieved from https://api.footprintnetwork.org/v1/data/165/all/BCpc,EFCpc. National Footprint Accounts (NFA), 2017. Global Footprint network.

Global Footprint Network. (2010). Ecological footprint atlas 2010.Retrieved May, 25, 2014.

Global Footprint Network. (2015). Global footprint network. Retrieved from http://www.footprintnetwork.org/es/index.php/GFN.

Global Footprint Network. (2019). National Footprint Accounts Data. Global footprint network. Retrieved from http://www.footprintnetwork.org/es/index.php/GFN.

Ozturk, I., Al-Mulali, U., & Saboori, B. (2016). Investigating the environmental Kuznets curve hypothesis: the role of tourism and ecological footprint. Environmental Science and Pollution Research, 23(2), 1916-1928.

Perera, F. (2018). Pollution from Fossil Fuel Combustion is the Leading Environment Threat to Global Paediatric Health, And Equity Solutions Exist. International Journal of environment research and public health, 15 (1).

Pesaran, M. H., Shin, Y., & Smith, R. J. (2001). Bounds testing approaches to the analysis of level relationships. Journal of applied econometrics, 16(3), 289-326.

Rafique, M. and Rehman, S. (2017). National energy scenario of Pakistan: Current status, future alternatives, and institutional infrastructure: An overview. Renewable and Sustainable Energy Reviews.

Rashid, A., Irum, A., Malik, I. A., Ashraf, A., Rongqiong, L., & Liu, G. (2018). Ecological footprint of Rawalpindi; Pakistan's first footprint analysis from urbanization perspective. Journal of Cleaner Production, 170, 362–368.

Rehman, I. & Ali, A. (2016). Impacts of Climate Change on the Energy Sector of Pakistan: With Focus on Punjab.

Rehman, S., Chen, S., Saleem, S., Saud, S. (2019). Nexus between Financial Development, Energy Consumption, Income Level, and Ecological Footprint in CEE Countries: do human capital and biocapacity matter? Environmental Science and Pollution Research. 26, 31856-31872.

Sarkodie, S. A., & Strezov, V. (2018). Empirical study of the environmental Kuznets curve and environmental sustainability curve hypothesis for Australia, China, Ghana and USA. Journal of cleaner production, 201, 98-110.

Saleem, M. W., Tahir, M. H., & Ashfaq, M. W. (2017). Fossil fuel-based Carbon footprint of Pakistan and its role towards sustainable development.

Saleem, N., Shujah-ur-Rahman, & Jun, Z. (2019). The Impact of Human Capital and Biocapacity on Environment: Environmental Quality Measure through Ecological Footprint and Greenhouse Gases. Journal of Pollution Effects and Control,7, 237.doi: 10.35248/2375-4397.19.7.237

Schaefer, F., Luksch, U., Steinbach, N., Cabeça, J., & Hanauer, J. (2006). Ecological Footprint and Biocapacity: The world's ability to regenerate resources and absorb waste in a limited time period. Office for Official Publications of the European Communities: Luxembourg.

Sinha, A., & Bhattacharya, J. (2016). Environmental Kuznets curve estimation for NO2 emission: A case of Indian cities. Ecological Indicators, 67, 1-11.

Sinha, A., Shahbaz, M., & Balsalobre, D. (2017). Exploring the relationship between energy usage segregation and environmental degradation in N-11 countries. Journal of Cleaner Production, 168, 1217-1229.

Solarin, S. A. (2018). Convergence in CO2 Emissions, Carbon Footprint and Ecological Footprint: Evidence from OECD Countries. Environmental Science and Pollution Research, 6167–6181.

Solomon, N., Ozoemena, N., Sharma, G., & Shah, M. (2020). Renewable energy, urbanization, and ecological footprint linkage in CIVETS. Environmental Science and Pollution Research International, 27(16), 19616-19629.

Toderoiu, F. (2010). Ecological footprint and biocapacity–Methodology and regional and national dimensions. Agricultural Economics and Rural Development, 2, 213-238.

Ulucak, R., & Bilgili, F. (2018). A reinvestigation of EKC model by ecological footprint measurement for high-, middle- and low-income countries. Journal of cleaner production, 188, 144-157.

Ulucak, R., & Erdum, (2017). The Environment in Economic Growth Models, An Application Based On Ecological Footprint.

United Nation Development Programme. (2014), Human Development Report (2014). New York, United States of America.

Usman, O., Alola, A. A., & Sarkodie, S. A. (2020). Assessment of the role of renewable energy consumption and trade policy on environmental degradation using innovation accounting: Evidence from the US. Renewable Energy,150, 266-277.

Wang, J., & Dong, K. (2019). What drives environmental degradation? Evidence from 14 Sub-Saharan African countries. The Science of the Total Environment, 656, 165–173.

Wang, Y., Kang, L., Wu, X., & Xiao, Y. (2013). Estimating the environmental Kuznets curve for ecological footprint at the global level: A spatial econometric approach. Ecological Indicators, 34, 15–21.

World Bank. (2010). Annual Report 2010. Retrieved from, https://data.worldbank.org/handle/10986/4387.

WWF (World Wildlife Fund), 2006. Living Planet Report, Avenue du Mont-Blanc CH-1196 Gland, Switzerland.

WWF. 2012. Living Planet Report 2012. WWF International, Gland, Switzerland.

WWF, World Wildlife Fund, 2014. Living Planet Report, Avenue du Mont-Blanc CH-1196 Gland, Switzerland.