An investigation of the nexus between natural resources, environmental performance, energy security and environmental degradation: Evidence from Asia

Abstract

Sustainable development requires having a healthy environmental system with an increasing growth rate over the time. But most of the Asian economies have pursued economic growth at the cost of environment and this needs careful analysis. This study focuses on the environmental degradation, measured by ecological footprint, of the 45 resource-rich countries of Asia. It utilizes several panel techniques including the instrumental variable two-stage least square technique over the period from 1990 to 2018, in order to examine the determinants of ecological footprint with significant emphasis on the role of resource rent. Our empirical findings show that natural resource rent is negatively related to ecological footprint. We equally observed a negative nexus between energy security and ecological footprint, indicating that countries need to be secured in terms of energy to reduce the degradation of environment. Our estimates also revealed a non-linear relationship between ecological footprint and economic growth – even though it contrasts the EKC hypothesis. Additionally, while environmental performance index has been observed to promote ecological footprint, population growth reduces environmental sustainability. This study, therefore, offers a roadmap to stakeholders and policymakers regarding the ways to improve the environmental quality in respective economies.

Keyword: Ecological Footprint; Environmental Performance Index, Natural Resources, Energy Security; Economic Growth

1. Introduction

Environmental degradation is increasingly becoming a subject of debates among scholars in the literature and this is as a result of the threats the emissions of greenhouse gases (GHGs) are posing towards global sustainable development and ecological footprint which keeps on increasing, with the biggest amount and uppermost rate of increase affiliated to carbon emissions from the consumption of renewable resources (Global Footprint Network 2015). The ecological footprint measures the demand for nature by humans, which is also referred to as the number of natural resources humans use to support and meet their needs. It follows this demand through the use of an ecological accounting system which takes into consideration the comparison of the quantity of biologically produced goods people take for their consumption and the biologically productive area of the location in question.

Furthermore, ecological footprint as a measure of the impacts of humans on the earth's ecosystem, shows the dependence of the human economy on biologically produced resources produced by nature. The point of call of Ecological footprint accounting is biological resources rather than non-renewable resources like oil or minerals because biological resources are the most limiting resource factor for human economic activity. For instance, while the amount of fossil fuel still underground is limited, even more limiting is the biosphere's ability to cope with the CO_2 emitted when burning it. This inherent prowess is one of the competing advantages of the earth's biocapacity. In the same vein, the limiting factors of the ability to renew biomass include water availability, climate, soil fertility, solar energy, technology, and management practices and the capacity to renew the biomass is known as biocapacity.

The increasing human exploration of land and water resources has a whole lot of impact on their immediate environment as the human demands for the resources have totally overwhelmed the capacity of the earth to produce the resource and therefore leading to environmental degradation. In affirmative form, Ecological Footprint Atlas (Ewing et al., 2010) stated in their study that human beings generally have overstayed the ecological overshoot since the 1970s, which indicates that the demand for earth's resources is far ahead of the capacity of the earth to meet (WWF, 2014). From 1961 to 2010, Ecological Footprint accounts show that human demand for renewable resources and ecological services increased by more than 100%, getting to the point where the planet's biocapacity area is no longer sufficient to support the competing demands (WWF, 2014).

However, the concept of Ecological footprint emerged to be an indicator ton measure the overall impact of human pressure on the environment in terms of the area of lands and water that are produced biologically which are required to produce goods and services consumed and the management of waste generated. The ecological footprint is now generally accepted all over the world as an indicator of environmental sustainability. It can be used to measure and put the use of resources under control throughout the economy and It can also be used to manage and ensure the sustainability of healthy lifestyles for individuals, goods and services, organizations, industry sectors, neighbourhoods, cities, regions, and nations. There are several practical benefits of examining the convergence of environmental indicators. The ecological footprint is seen as a key target of the efforts to curb environmental degradation. The indicators like C02 emissions, oil spillage, soil, mining activities, and forest explorations are the reasons for the ubiquitous climatic changes and this challenge makes countries join together to find a lasting solution to the increasing environmental threats. The continuous climatic changes have caught the attention of economists and policymakers to evaluate the impact of environmental degradation using ecological footprint as its measurement scale.

Asia is known to be the biggest and most crowded landmass on earth's surface which covers about 30% of the all-out land zone and generally 60% of the total populace. The landmass is additionally perceived with the monetary ability and it is wealthy in regular assets oil, woodlands, fish, water, rice, copper, and silver among others. Disregarding the all-around situated economy and topography of the mainland, it despite everything experiences a delicate biological condition because of a deceptive investigation of normal assets in some rich pieces of the landmass. Along these lines, it is vitally relevant for Asian nations to accomplish reasonable advancement of their individual social economies and natural situations by concentrating on the control and the executives of their environmental impressions. The environmental impression in Focal Asia likewise increment, and as the significant method for analyzing the vitality base of the mainland, vitality carbon discharges have expanded temperatures fundamentally higher than the worldwide normal (Chen et al., 2009; Hu et al., 2014), which further increment the complete biological impression of the landmass. As an issue of direness, Asia needs to figure achievable approaches and measures to decrease the territorial biological impression most particularly the instance of carbon impression.

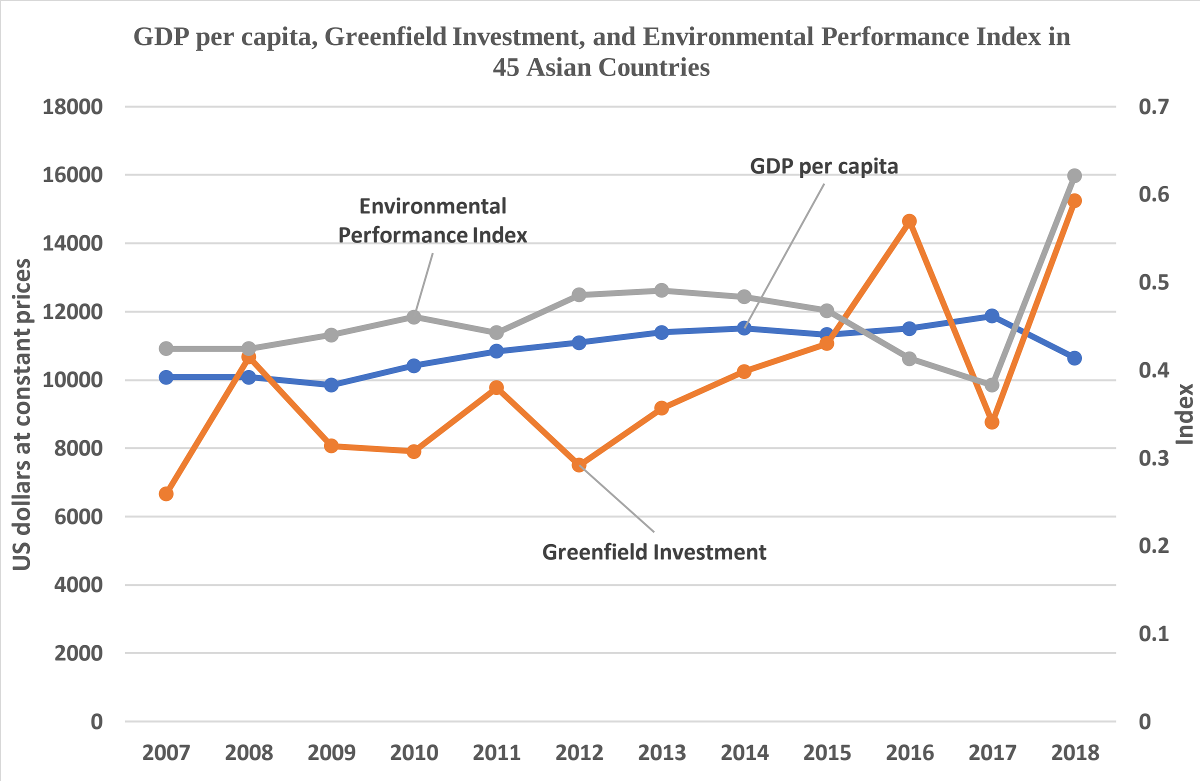

Figure1

Nexus between Economic Growth, Greenfield Investments and Environmental Performance Index for Asia.

The figure above shows the relationship between green field investments and GDP which are used to measure the natural resources and economic growth respectively. Also, the environmental performance index for 12 years (2007-2018). In 2007 the green field investments was 300035.12 and 19.1 and a resultant GDP per capital of about 45,3734.52 US dollars. In 2008, the Gross domestic product was 453737.20 US dollars as a result of a Greenfield investment of 480212.91 and a environmental performance index of 19.0. Further, in 2009, the Green field investment was 362957.43 and the environmental performance was 19.8 but the Gross domestic product reduced to 443207.48 US dollars. Even though, in 2010 the environmental performance increased 20.7 and their green field investment reduced to 355963.57 and an increase in Gross domestic product increased to 468606.98 US dollars. The further reduction of the environmental performance index was experienced to 19.9 in 2011 and green field investment of 439896.26 and a Gross domestic product of 487926.068 US dollars.

However, a significant in Gross domestic growth between 2012 and 2016 this may however be because of certain environmental policies put in place by the Asian countries or they embraced the renewable energy sources at the period which positively affect their GDP growth. However, in 2012, the Asian environmental performance index was 499351.7993 US dollars and a Greenfield investment of 337674.74, in 2013, the Gross domestic product was 512469.31 US dollars and Greenfield investments of 412491.91. Further, in 2014, the Gross domestic product was 517966.13 US dollars and green field investments of 461016.00. In 2015, the Gross domestic product was 509602.8725 US dollars and green field investments of 497963.84 US dollars. Also, in 2016, the Gross domestic product was 517610.40 US dollars with a green field investment of 658916.93 US dollars.

The environmental performance index for Asia was 21.8, 22.0, 21.76, 21.05, 18.59 from 2012-2016. This is fluctuating as it increases and decreases at one point or the other. Finally, in 2018, when the Gross domestic product reduced to 478976.39 US dollars and green field investments increased to 685960.24 which seem to be the highest within the period considered and the environmental performance of 27.97 which is also the highest in the period. From the above, it can be deduced that as the environmental performance index increases and the Greenfield investments also increases there is an increase in the economic growth of countries in Asia. This makes it more of a necessity to study the impact of the ever-increasing human activities on the immediate environment in Asia as there were more economic activities and environmental utilization from 2007 to 2018.

Consequently, this paper presents fresh evidence on the nexus between ecological footprint and some energy and macroeconomic variables in resource-rich Asian countries. Previous studies on this subject matter such as (Bekhet, Matar, & Yasmin, 2017; Bekun, Alola, & Sarkodie,2019; Danish, Zhang, Wang, & Wang, 2017; Solarin & Bello, 2019) employed C02 emissions as a proxy for environmental degradation. However, this paper makes environmental degradation more comprehensive by using other proxies such as GDP per capita and Greenfield investment which is in line with proxies employed in Al-mulali et al. (2015). The novel of this paper is to revisit the study of the relationship between ecological footprint, energy and macroeconomic variables in Asia, using the data covering 1990 – 2018. The study tends to add to the existing knowledge through the new shreds of evidence offered in the paper and it is not only limited to energy variables like Carbon dioxide, fuel but also macroeconomic variables such as Greenfield investment and Gross Domestic Product (GDP) as postulated in Al-mulali et al. (2015).

The next sections present a review of relevant literature, while section three discusses the data, methodology and econometric technique used. Section four presents the results and discussions, while section five concludes the study with implications and recommendations for environmental sustainability policies.

2. Literature Review

Although Climate change is accepted as fact by an overwhelming majority of scientists and other stakeholders, but its causes and economic, scientific and political implications have been subject to critical debate. The causes, especially, varies from geography to geography and a great many explanations regarding the factors affecting climate change and environmental degradation have been put forward in the previous literatures. The original work of Grossman and Krueger (1991) on the environmental Kuznets curve (EKC) hypothesis, which states that there exists a nonlinear relationship between pollution and income, provided an impetus for further research on environment. Apart from the examination of interrelationship among economic growth, energy consumption and environmental quality in much of the empirical literatures, recent studies have documented the effects of natural resource rents, energy security and other traditional factors on environmental degradation.

Mert et al. (2019), for example, examined the EKC hypotheses for 26 European countries along with the implication of both renewable and non-renewable energy on environment. Applying panel co-integration method, they found the validity of EKC hypothesis in all European economies the group of the 5th enlargement countries, but not for 1–4th enlargement countries. Renewable energy consumption was found to reduce greenhouse gas emissions, but fossil fuel deteriorated the pollution level overall EU countries. The study by Destek and Okumus (2019), on the other hand, found that energy consumption and economic growth lead to deterioration of environmental quality.

Bekun et al. (2019) incorporated resource rent variable along with renewable and non-renewable energy consumption on CO2 emissions model for 16 European countries. In line with Shahbaz et al. (2017), the study significantly identified a positive linear relationship between economic growth and carbon emissions. The result revealed a positive relationship between resource rent and CO2 emissions in the long run but the relationship was found to be negative in the short run. Renewable energy was found to have adverse effects on CO2 whereas non-renewable energy consumption had positive relation both in the short run and long run. In assessing environmental quality, it is always difficult to choose what variables or what econometric methods should be used. Taking this factor into account, Fakher (2019) investigated the determinants of Ecological footprint index as a proxy for environmental quality by using two Bayesian approaches such as Bayesian model Averaging (BMA) and Weighted Averaging Least Squares (WALS). These two can help overcome the uncertainty in the models and variables used. The study used 22 explanatory variables including some economic, social and political variables for 7 OPEC countries. The study identified energy consumption and FDI as main factors that contribute positively toward ecological footprint and that EKC hypothesis holds for 7 countries as a whole. Human development has inclusion probability of. 26 whereas literacy rate has inclusion probability of. 41 and they both negatively affect ecological carbon footprint.

Ecological footprint has been identified as a comprehensive measure of environmental degradation and has received major attention in recent literatures. Developed by Wackernagel and Rees (1998), this indicator can produce estimates that can be easily understandable and it is much simpler than other conventional indicators of environmental quality (Sarkodie 2018). Danish et al. (2019), for instance, examined the effects of economic growth, renewable energy consumption and natural resources on ecological footprint for BRICT countries. The study utilized AMG estimation and found that natural resources have no significant effect on CO2 for Brazil, China and India. But it helps in reducing CO2 in Russia whereas in South Africa it increases CO2 emission. The study confirmed the existence of EKC hypothesis for all BRICT countries except India. Renewable energy helps in mitigating CO2 emission in all countries except South Africa.

On the other hand, Zafar et al. (2019) analyzed the determinants of ecological footprint for USA covering the period of 1975 to 2010. Given that US was subject to recession and global financial crisis in the studied period, they included structural breaks in their analysis and included natural resources, human capital, FDI as main variables and economic growth and energy consumption as control variables. They found that in USA both energy consumption and ecological footprint decreases the quality of the environment. Natural resources improve environmental quality so they recommended that USA control the use of natural resources excessively. In line with Ahmed and Wang (2019), the study demonstrated that there exists negative relationship between ecological footprint and human capital and also between ecological footprint and FDI. However, the study didn’t include several important variables like institutional quality which has massive influence on a country's development.

In another recent study, Hassan et al. (2019) examined the relationship among ecological footprint, natural resources, human capital and economic growth for Pakistan taking 44 years of data starting from 1970 to 2014.From ARDL bound testing approach, they found that natural resources positively and significantly affect ecological footprint for Pakistan but human capital, bio capacity are insignificant in explaining ecological footprint. The study confirmed EKC hypothesis for Pakistan. The validity of EKC hypothesis for Pakistan was also confirmed later by Mahmood et al. (2019) but unlike Hassan et al. (2019) they found that human capital helps in mitigating environmental damage. The reason for the discrepancy could be attributed to the econometric methodologies and variables used by these two studies. Mahmood et al. (2019)

used 3SLS for simultaneous equation modelling following Stern (1998), Borghesi (2002), Hung and Shaw (2004) and Youssef (2016), which is efficient and consistent as compared to estimates of single equation whereas Hassan et al. (2019) used ARDL bound testing approach. Moreover, Mahmood et al. (2019) used CO2 emissions as dependent variable whereas Hassan et al. (2019) used ecological footprint. As stated by Borghesi (2002), when analysing the relationship between income and environment, it is more appropriate to apply simultaneous equation model since both income and environmental quality are considered endogenous variables (Hung and Shaw,2004).

If there is cross sectional dependence in a panel data study but it is ignored, then it might lead to inconsistent estimation of parameters (Sarafidis and Wansbeek, 2012). Ulucak and Bilgili (2018) therefore took cross sectional dependence into their analysis and examined EKC hypothesis in terms of ecological footprint by dividing countries into low, middle- and high-income countries. The study also incorporated human capital as control variable to see whether it has any effects on environment. The EKC hypothesis was confirmed for all three groups and human capital was found to decrease ecological footprint. This means that Human capital can significantly reduce emissions level under Paris climate agreement. Destek et al. (2018) used second generation panel techniques like Ulucak and Bilgili (2018) to estimate EKC hypothesis for EU countries. The study decomposed energy consumption into renewable and non-renewable energy consumption. Even though EU has Most extensive environmental laws among any organisations, the study found that EU regulations are still not sufficient for decreasing environmental pollution since EKC does not hold for EU. It was also found that renewable energy consumption reduces environmental degradation while non-renewable energy consumption increases it.

Central Asian Region is considered as important region in terms of climate change since it is located at crossroads of Eurasia (Zhang, 2019). So, in this context, taking 5 central Asian countries, Zhang (2019) analysed the nexus among several variables such as CO2 emission per capital, renewable energy consumption, economic growth etc. But no evidence of EKC hypothesis was revealed for these countries as a whole and renewable energy consumption was found to decrease CO2 emission. These countries, therefore, must take advantage of its renewable energy resources which are largely untapped to accelerate the turning point of EKC. The Belt and Road Initiative or BRI is a massive infrastructure project proposed by China in 2013 and runs across inter nations covering a greater part of the world. The initiative encompasses more than 60 countries and aims to connect Asian countries with China, African and European economies. One of the objectives of BRI is to build a project that is green and sustainable. Therefore, a lot of discussions and analyses are unfolding globally with respect to environmental Sustainability in the countries involved with these projects.

Saud et al. (2019) used these BRI countries to understand the impacts of FDI, economic growth and electricity consumption on environmental quality. They applied a dynamic seemingly unrelated regression (DSUR) method developed by Mark et al. (2005) and found the validity of EKC hypothesis for selected BRI countries in line with Rauf et al. (2018) who found the similar result for every region involved with this project via mean group estimator. Although FDI improved environmental quality but electricity consumption contributed negatively towards environment in these economies. Hafeez et al. (2019a) investigated the effect of energy inequality on environment for BRI and its region whereas for computing energy inequality they adopted Theil's entropy approach. They found that energy inequality significantly and positively affects environmental degradation in all BRI countries as well as in regions such as MENA, Southeast Asia, central Asia and East Asia. On their another major study for BRI countries, Hafeez et al. (2019b) found that both economic growth and energy consumption enhance carbon footprint. Like Hafeez et al. (2019b), similar findings were also reported Baloch et al. (2019) for BRI countries.

Considerable attention has been also given in analysing environmental quality with respect to different variables in Asian countries. Apergis and Ozturk (2015), for example, tested the EKC hypothesis for 14 Asian countries over 1990-2011 period. Evidence from GMM methodology confirmed the existence of EKC hypothesis for all 14 countries. In addition to finding support for EKC, the study found that environmental quality in Asian countries can be improved if higher per capita income can be accompanied with a better political system. Rather than employing Panel data framework, Uddin et al. (2019) separately examined the 14 Asian countries to see if EKC hypothesis holds for these countries. They stated that reason for doing time series analysis rather than panel is because it is unlikely that these countries will have same policies with respect to environment and same environmental endowment. Their study validated EKC hypothesis for 4 out of 14 countries.

In their seminal work, Ansari et al. (2019) used 29 Asian countries to see how the factors affecting environmental quality over the period of 1994-2014.These 29 countries were again divided in 5 sub categories such as West Asia, South Asia, Southeast Asia, East Asia and central Asia. FMOLS analysis revealed that both GDP and energy consumption significantly determine CO2 for global panel.

The Asian countries such as China, India and Southeast Asian economies have experienced rapid increase in their growth over the past several decades but environmental issues of Asian region cannot be solved only by the economic growth (Apergis and Ozturk, 2015). Therefore, in contrast to previous research, this study uses several explanatory variables such as natural resource, energy security and EPI to highlight their effects on ecological footprint for Asian countries. Moreover, to the best of our knowledge, this is the first study to use ecological footprint as a measure of environmental degradation for resource rich economies of Asia and hopefully it will provide a more robust understanding of environmental quality in these countries.

3. Data and Methods

3.1. Data Source and Variable Description

This study utilized the data from world development indicator for energy security, capital and labour stock, natural resource rent and GDP per capita. However, Ecological Footprint data is retrieved from National Footprint and Biocapacity Accounts (NFAs). The Ecological Footprint measures the amount of biologically productive land and sea area an individual, a region, all of humanity, or a human activity that compete for biologically productive space. Environmental performance index from Yale university data bank. Additionally, the data spanned from 1990 to 2018 for all Asian countries to prevent the issue of sampling bias. Ecological Footprint indicates the consumption of biocapacity by a country's inhabitants. Biocapacity is measured by calculating the amount of biologically productive land and sea area available to provide the resources a population consumes and to absorb its wastes, given current technology and management practices. The Energy Security Index differs from the existing measuring methods precisely in a way that it includes environmental and social aspects. The energy security indicator index obtained based on 83 individual indicators assessing geopolitical indicators, economic development, environmental concerns and reliability. The summary of variables, symbols, definition, measure and data source are shown Table 1.

Table 1

Description of variables and data source

Variable	Description	Measurement	Expected sign
EFP	Ecological Footprint	Ecological Footprint Consumption which measures the amount of natural resources needed to satisfy the consumption requirements and waste assimilation needs a country or the world in a given year.	+
K	Capital Stock	Gross capital formation (% of GDP).	+/-
L	Labour Stock	Labour force, total	+/-
EPI	Environmental Performance Index	EPI measure sum of Environmental Health (i.e. threats to human health), and Ecosystem Vitality.	+
NNR	Natural Resource Rent	Total natural resources rents (% of GDP)	+
Energy Security	EnergySecurity Index	Energy Security Risk Index Score	+
GDPPC	GDP Per Capita	GDP per capita (current US$)	+

Source: Security Index, https://www.globalenergyinstitute.org/energy-security-risk-index, and for GDP, Renewable and non-renewable energy, World Bank's World Development Indicators.

3.2. Model Specification

To examine the relationship between ecological footprint consumption, energy security, natural resource rent, environmental performance index, GDP per capita and Labour and Capital stock into the single multivariate framework, we develop the following model:

$$EFP_{it} = \beta_0 + \beta_1 K + \beta_2 L_{it} + \beta_3 EPI_{it} + \beta_4 NNR_{it} + \beta_5 ES_{it} + \beta_6 gdppc_{it} + \beta_7 gdppcsqr_{it} + \varepsilon_{t} \text{---}(1)$$

To avoid dynamic properties associated with data series we have transformed the data into the natural logarithmic form. Thus, Eq. (1) can be converted into the logarithmic form of the equation given as follows:

$$EFP_{it} = \beta_0 + \beta_1 (LogK)_{it} + \beta_2 (LogL)_{it} + \beta_3 (LogEPI)_{it} + \beta_4 (LogNRR)_{it} + \beta_5 (LogES)_{it} + \beta_6 (LogGDPPC)_{it} + \beta_7 (LogGDPPCsqr)_{it} + \varepsilon_t \text{---}2$$

where EFP represent ecological footprint consumption, K is the capital stock, L is the Labour stock, EPI represents the environmental performance index, NRR is natural resource rent percentage of GDP, ES is the energy security index, and GDPPC is GDP per capita, and GDPPCSQR is GDP per capita square, and ε is the stochastic error term. The expected sign for the impact of capital stock on EFP is positive and significant ($b1 > 0$). The expected sign of labour stock is positive, ($b2 < 0$). Furthermore, the expected sign for the impact of environmental performance on EFP is positive ($b3 > 0$), which implies that environmental performance should improves ecological footprint. Also, natural resource rent has a positive impact on EFP ($b4 < 0$), energy security has a positive impact on EFP ($b5 < 0$). GDP per capita can be positive or negative on ecological footprint. In the case of GDP per capita, the sign is positive means that GDP per capita will improve the EPF ($b6 > 0$) and so as GDP per capita square which means environmental Kuznet curve is validated.

In additional, the study traditional control variables are labour and capital stock. Best (2008) suggest that environmental impact and natural resource improve ecological footprint. With an increase in per capita, the living standard of the people improves. As a results health, education and environmental performance would improve. For instance, Uddin, Salahuddin, Alam, and Gow (2017) confirmed a positive relationship ecological footprint and national income. They conclude the economic growth improves ecological footprint in a society. Since national income growth may stimulates fossil fuels usage in a society, thus increasing the country's ecological footprint. Furthermore, ecological footprint improvement has a direct connection with energy security. Lu et al. (2014) conclude that energy security improves ecological footprint. In the same view, Zafar et al. (2019) in United States found a causality among human capital, natural resource and ecological footprint. This is also confirmed by (Hassan, Baloch, Mahmood, & Zhang, 2019) hints on the role of human capital in reducing environmental stress.

3.3. Econometric methodology

In the present study, panel ordinary least squares method, fixed and random effect (i.e. mixed model) and IV (2SLS) methods were preferred. These methods were used in order to eliminate the biases related to the correlation between the delayed dependent variable and the error term, to exclude individual effects and to prevent the endogeneity between natural resource, environmental performance, energy security and the ecological footprint. Meanwhile, the mixed is cater for heterogeneity bias may result in pooled regression. The existence of the correlation between random individual effects and some of the regressors in a panel data, the reason for inconsistent in random effect. Meanwhile, the fixed effect (FE) solve this problem including heterogeneity issue making the estimator consistent. Scholars recommend the combination of RE and FE estimator to form a combined estimator which can be better than using these estimators in isolation. This study includes the simulation experiment for all degrees of endogeneity in terms of mean squared forecast errors reason for including the 2SLS model.

3.3.1 Two-Stage Least Square Model (2SLS)

With simultaneous equations modelling, there are two options regarding estimation: single-equation and system estimation. Wooldridge (2010, p. 252) covered the pros and cons of both, while Arminen, Puumalainen, Pätäri, and Fellnhofer (2018) discussed simultaneous equations modelling in the environment context. The model specification plays a key role here: system estimation is asymptotically more efficient than single equation estimation if the model is correctly specified, but if even one of the structural equations is mis-specified, all structural parameters in the entire model are contaminated in system estimation.

Numerous studies employed 2SLS to establish a long-run relationship dependent and independent variable (Chakraborty & Mazzanti, 2019; Ozturk & Al-Mulali, 2015). Most these studies used a small sample size which such estimation may produce inconsistent results. To resolve the issue of spurious regression, 2SLS captured this vacuum. This technique is the extension of the OLS method. It is used when the dependent variable’s error terms are correlated with the independent variables. Additionally, it is useful when there are feedback loops in the model. In structural equations modelling, we use the maximum likelihood method to estimate the path coefficient. In additional, the 2SLS estimator is also applied when dependent variable correlate with the error term. This paper solved the endogeneity issue in ASIAN via 2SLS to investigate the relationship between ecological footprint consumption, energy security, natural resource rent, environmental performance index, and GDP per capita in the region. Following the notation of (Greene, 2008) and Arminen et al. (2018), a structural equation of a simultaneous equations model can be written

$$y_{it} = x_{it}'\beta + \delta y_{i,t-1} + c_i + \varepsilon_{it}, \quad \text{……(3)}$$

where the subscript i denotes cross-sectional units (here: countries) and t time (here: study period). It is assumed that the error term is composed of the fixed individual effects c_i and the idiosyncratic shocks ε_{it}, with the following properties: $E[c_i] = E[\varepsilon_{it}] = E[c_i\varepsilon_{it}] = 0$.

Differencing Eq. (3) eliminates the individual effects c_i, resulting thus in:

$$\Delta y_{it} = (\Delta x'_{it})\beta + \delta(\Delta y_{i,t-1}) + \Delta\varepsilon_{it}, \quad \ldots\ldots (4)$$

where Δ is the first-difference operator. Predetermined variables become endogenous in first differences, but deeper lags of the explanatory variables are still potential instruments.

4. Results and Discussion

The correlation matrix (Table 2) measures the degree and direction of a linear relationship between two variables; a -1 indicates perfect negative, +1 denotes perfect positive, and 0 implies the absence of correlation.

Table 2
Correlation Matrix

	EFP	K	L	EPI	NNR	ES	GDPPC	GDPPCsqr
EFP	1.0000							
K	0.0536	1.0000						
L	0.0427	0.4338	1.0000					
EPI	-0.0263	0.4133	0.7655	1.0000				
NNR	0.0593	-0.0558	-0.0231	-0.0273	1.0000			
ES	-0.0821	0.2106	0.1452	0.0774	0.0145	1.0000		
GDPPC	0.0328	0.2742	0.0517	0.0260	-0.0054	0.0526	1.0000	
GDPPCsqr	0.0645	0.3211	0.0469	0.0452	-0.0165	0.0270	0.9178	1.0000

In relation to EFP, we observe a positive correlation between each of K, L, NRR, GDPPC, and GDPPCsqr; while a negative correlation coefficient is found for each of EPI and ES.

Table 3 presents the coefficient estimates obtained from the traditional panel and the instrumental variable techniques.

Table 3
Coefficient Estimation
Dependent Variable: EFP

Variable	POLS	FE	RE	IV-2SLS
K	0.459*	0.899	0.459*	0.458*
	[0.257]	[0.928]	[0. 257]	[0.262]
L	2.95e-08***	1.17e-08	2.95e-08***	2.97e-08***
	[6.97e-09]	[9.21e-09]	[6.97e-09]	[7.04e-09]
EPI	-4.41e-06***	-2.78e-06***	-4.41e-06***	-4.44e-06***
	[9.67e-07]	[1.13e-06]	[9.67e-07]	[9.76e-07]
NRR	0.580*	0.699	0.580*	0.580*
	[0.314]	[0.488]	[0.314]	[0.316]
ES	-0.322***	-1.011***	-0.322***	-0.329***
	[0.076]	[0.136]	[0.076]	[0.776]
GDPPC	-6.83e-07***	-1.51e-06**	-6.83e-07***	-7.13e-07***
	[2.44e-07]	[6.50e-07]	[2.44e-07]	[2.49e-07]
GDPPCsqr	0.004***	0.007**	0.004***	0.004***
	[0.001]	[0.003]	[0.001]	[0.001]
Hausman		56.74***		
Observation	1022	1022	1022	1002
F-Statistic / Wald chi2	57.05***	16.36***	57.05***	57.14***

The values of standard errors are presented in parenthesis [ ]
***, ** & * denote significance at 1%, 5% & 10% respectively
Instrumented: gdppcsqr
Instruments: K L EPI NRR ES gdppc L.gdppcsqr
Arellano-Bond test for autocorrelation of the first-differenced residuals

H0: no autocorrelation of order 1: z = -3.694***
H0: no autocorrelation of order 2: z = 0.732

Sargan-Hansen test of the overidentifying restrictions
H0: overidentifying restrictions are valid
2-step moment functions, 2-step weighting matrix chi2(38) = 22.935
Prob > chi2 = 0.9745
2-step moment functions, 3-step weighting matrix chi2(38) = 34.791
Prob > chi2 = 0.6186

In Table 3, our estimates of the non-linear relationship between EFP and GDPPC depicts a U-shaped nexus; as such, the EKC hypothesis could not be established. This result is inconsistent with the findings of Apergis and Ozturk (2015), Shittu et al. (2018), and Ota (2017) who found that EKC holds for several south Asian countries. However, our result is largely consistent with the results of Aydin and Esen (2017) and with that of Aye and Edoja (2017). This finding implies that economic growth cannot solve environmental problem alone and there are needs of other factors. Beyond a certain threshold level of GDP, a rise in GDP will result in environmental degradation. Because at the higher income regime, countries start to become industrialized and proceed towards manufacturing based economies. This leads to more consumption and more production which ultimately results in higher pollution. (Everett et al., 2010). At one time, companies become so much obsessed with profits that they don’t care about the environment anymore and continue to produce products that are harmful for the environment as well as for human health (Aye and Edoja,2017). This U-shaped relationship between economic growth and ecological footprint is also an indication that Asian countries should not rely on economic growth to reduce pollution and other policy measures must be put in place (Omotor, 2017). Taxes must be imposed on the companies which do not adopt measures to control pollution while producing. Companies that produce environment friendly products should be rewarded by reducing tax levels (Siraj et al., 2017).

Rents from natural resource is observed to raise ecological footprint by 0.58%, given a significant and positive coefficient obtained in POLS, RE, and IV-2SLS estimates. Our study matches with the findings of Hassan et al. (2018) who found a positive significant relation between ecological footprint and natural resource. This indicates that although Asian countries have abundant natural resources, they cannot use them effectively to bring positive benefits out of their rents. Moreover, we obtain a negative relationship between EPI and ecological footprint at even 1% level of significance. This indicates that as environmental performance of a country continues to increase, it positively contributes towards enhancing environmental quality.

Our results also show that energy security is negatively related to ecological footprint indicating that higher the energy insecurity, more damaging it will be for the environment. The result is consistent with Nawaz and Alvi (2018) who found that energy security ensures both socio economic and environmental sustainability in the short run as well as in the long run. Therefore, Asian economies must not rely on imported energy sources which may be subject to external shocks and they should invest more and more in renewable energy resources like hydro and solar. Asian economies have large hydropower potential and they must be put to full use.

In addition, our study also includes traditional variables like labour and capital and find that they both increase the environmental degradation of a country as proxied by ecological footprint as the coefficient of each of L and K is found to be significant and positive, at 1% and 10% level respectively, in the POLS, RE, and the IV-2SLS estimates. The positive relation between labour and ecological footprint can be attributed to huge level of population growth in Asian economies. More population implies economy has more labour and this may increase the demand to produce more which will ultimately lead to deterioration of environment because when pressure is to produce more, agricultural land quality may get deteriorated (Zaman et al., 2011). This also creates pressures on natural resources which are extracted too quickly as a result of higher population growth (Aroh,2018). Moreover, more capital is introduced in an economy which continues to rely increasingly on manufacturing sector, and this negatively affect that economy.

5. Summary and Conclusion

As the population continues to grow worldwide, pollution or environmental degradation is only going to get worse. It threatens mass destruction of everything that makes this world great. Changing over to green energy resources and thereby ensuring the energy security can ensure sustainable development and prevent further degradation of environment. In this regard, this paper includes several explanatory variables including energy security to determine the factors responsible for environmental degradation in resource rich Asian countries. Several estimation methods have been employed in this regard such as pooled OLS, Random effect, Fixed effect and finally instrumental variable techniques.

Among the factors examined, our estimates revealed a non-linear (U-shaped) relationship between ecological footprint and economic growth – in contrast to the EKC hypothesis. Moreover, the coefficient of environmental performance index and natural resource rent are, respectively, negative and positive. Specifically, we find that the rents from natural resources is found to increase ecological footprint by 0.58%, as evident in our POLS, RE, and IV-2SLS estimates. We equally observed a negative nexus between energy security and ecological footprint, indicating that countries need to be secure in terms of energy to reduce the degradation of environment. Finally, we found that Each of labour and capital raises the level of environmental degradation in the countries under consideration.

Given the above relationship, even though the governments of these Asian countries are expected to advance courses that raise the growth rate of their economies, it is not enough to reduce environmetal degradation. As a result, other means of improving the environmental quality should be sought and appropriate policies implemented. One potential programme is the adoption of modern technologies, with tendencies to produce lower emissions. This would go a long way in improving the quality of the environment, especially where governments are proactive enough to assist industries in the adoption of such technologies. The specific possibilities include the imposition of (or where applicable, raising of) emissions taxes beyond a particular threshold; active involvement of governments in the provision of resources for the purchase of such equipment – in the case of firms could not afford the cost of such equipment. Similarly, the rents from natural resources should be channelled into productive activities, so that the effects of environmental degradation may be mitigated on the living conditions of the populace.

Future research can look into resource rich countries of Asia by including the interaction effect of natural resource and energy secuirity with governance and political stability as governance quality may affect the relationship between natural resource rents and energy secuirty with environment.

Reference

Ahmed, Z., & Wang, Z. (2019). Investigating the impact of human capital on the ecological footprint in India: An empirical analysis. *Environmental Science and Pollution Research*, 1-15.

Ali, R., Bakhsh, K., & Yasin, M. A. (2019). Impact of urbanization on CO2 emissions in emerging economy: evidence from Pakistan. *Sustainable Cities and Society*, *48*, 101553.

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

Al-Mulali, U., Solarin, S. A., & Ozturk, I. (2016). Investigating the presence of the environmental Kuznets curve (EKC) hypothesis in Kenya: an autoregressive distributed lag (ARDL) approach. *Natural Hazards*, *80*(3), 1729-1747.

Ansari, M. A., Khan, N. A., & Ganaie, A. A. (2019). Does foreign direct investment impede environmental quality in Asian countries? A panel data analysis. *OPEC Energy Review*.

Apergis, N., & Ozturk, I. (2015). Testing environmental Kuznets curve hypothesis in Asian countries. *Ecological Indicators*, *52*, 16-22.

Aye, G. C., & Edoja, P. E. (2017). Effect of economic growth on CO2 emission in developing countries: Evidence from a dynamic panel threshold model. *Cogent Economics & Finance*, *5*(1), 1379239.

Baloch, M. A., Mahmood, N., & 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.

Baloch, M. A., Zhang, J., Iqbal, K., & Iqbal, Z. (2019). The effect of financial development on ecological footprint in BRI countries: evidence from panel data estimation. *Environmental Science and Pollution Research*, *26*(6), 6199-6208.

Bekun, F. V., Alola, A. A., & Sarkodie, S. A. (2019). Toward a sustainable environment: Nexus between CO2 emissions, resource rent, renewable and nonrenewable energy in 16-EU countries. *Science of the Total Environment*, *657*, 1023-1029.

Borghesi, S., 2002. The environmental Kuznets curve: A survey of literature, in Franzini (eds), Economic Institutions and Environmental Policy, Aldershot: Ashgate, P. 201–224.

Destek, M. A., & Okumus, I. (2019). Does pollution haven hypothesis hold in newly industrialized countries? Evidence from ecological footprint. *Environmental Science and Pollution Research*, 1-7.

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

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*(29), 29387-29396.
Fakher, H. A. (2019). Investigating the determinant factors of environmental quality (based on ecological carbon footprint index). *Environmental Science and Pollution Research, 26*(10), 10276-10291.
Grossman, G. M., & Krueger, A. B. (1991). *Environmental impacts of a North American free trade agreement* (No. w3914). National Bureau of Economic Research.
Hafeez, M., Yuan, C., Khelfaoui, I., Sultan Musaad O, A., Waqas Akbar, M., & Jie, L. (2019). Evaluating the energy consumption inequalities in the One Belt and One Road region: implications for the environment. *Energies, 12*(7), 1358.
Hafeez, M., Yuan, C., Shahzad, K., Aziz, B., Iqbal, K., & Raza, S. (2019). An empirical evaluation of financial development-carbon footprint nexus in One Belt and Road region. *Environmental Science and Pollution Research*, 1-11.
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.
Hung, M. F., & Shaw, D. (2004). 13. Economic Growth and the Environmental Kuznets Curve in Taiwan: A Simultaneity Model Analysis. *Human Capital, Trade, and Public Policy in Rapidly Growing Economies: From Theory to Empirics, 269*.
Mahmood, N., Wang, Z., & Hassan, S. T. (2019). Renewable energy, economic growth, human capital, and CO 2 emission: an empirical analysis. *Environmental Science and Pollution Research*, 1-12.
Mark, N. C., Ogaki, M., & Sul, D. (2005). Dynamic seemingly unrelated cointegrating regressions. *The Review of Economic Studies*, *72*(3), 797-820.
Mert, M., Bölük, G., & Çağlar, A. E. (2019). Interrelationships among foreign direct investments, renewable energy, and CO 2 emissions for different European country groups: a panel ARDL approach. *Environmental Science and Pollution Research*, 1-16.
Rauf, A., Liu, X., Amin, W., Ozturk, I., Rehman, O. U., & Hafeez, M. (2018). Testing EKC hypothesis with energy and sustainable development challenges: A fresh evidence from Belt and Road Initiative economies. *Environmental Science and Pollution Research, 25*(32), 32066-32080.
Salim, R., Rafiq, S., Shafiei, S., & Yao, Y. (2019). Does urbanization increase pollutant emission and energy intensity? Evidence from some Asian developing economies. *Applied Economics*, *51*(36), 4008-4024.
Sarafidis, V., & Wansbeek, T. (2012). Cross-sectional dependence in panel data analysis. *Econometric Reviews*, *31*(5), 483-531.
Sarkodie, S. A. (2018). The invisible hand and EKC hypothesis: what are the drivers of environmental degradation and pollution in Africa? *Environmental Science and Pollution Research*, *25*(22), 21993-22022.
Saud, S., Chen, S., & Haseeb, A. (2019). Impact of financial development and economic growth on environmental quality: an empirical analysis from Belt and Road Initiative (BRI) countries. *Environmental Science and Pollution Research*, *26*(3), 2253-2269.
Shahbaz, M., Benkraiem, R., Miloudi, A., & Lahiani, A. (2017). Production function with electricity consumption and policy implications in Portugal. *Energy Policy, 110*, 588-599.
Shahbaz, M., Nasreen, S., Abbas, F., & Anis, O. (2015). Does foreign direct investment impede environmental quality in high-, middle-, and low-income countries? *Energy Economics*, *51*, 275-287.

Stern, D. I. (1998). Progress on the environmental Kuznets curve? *Environment and development economics*, *3*(2), 173-196.

Uddin, G. A., Alam, K., & Gow, J. (2019). Ecological and economic growth interdependency in the Asian economies: an empirical analysis. *Environmental Science and Pollution Research*, *26*(13), 13159-13172.

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.

Youssef, A. B., Hammoudeh, S., & Omri, A. (2016). Simultaneity modeling analysis of the environmental Kuznets curve hypothesis. *Energy Economics*, *60*, 266-274.

Zafar, M. W., Zaidi, S. A. H., Khan, N. R., Mirza, F. M., Hou, F., & Kirmani, S. A. A. (2019). The impact of natural resources, human capital, and foreign direct investment on the ecological footprint: The case of the United States. *Resources Policy*, *63*, 101428.

Zhang, S. (2019). Environmental Kuznets curve revisit in Central Asia: the roles of urbanization and renewable energy. *Environmental Science and Pollution Research*, 1-13.

Chen, F., Wang, J., Jin, L., Zhang, Q., Li, J., Chen, J., 2009. Rapid warming in mid latitude Central Asia for the past 100 years. Front. Earth Sci. China 3 (1), 42.

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

Global Footprint Network, 2015. Obtenido de Global Footprint Network. http://www.footprintnetwork.org.

Hu, Z., Zhang, C., Hu, Q., Tian, H., 2014. Temperature changes in Central Asia from 1979 to 2011 based on multiple datasets. J. Clim. 27 (3), 1143e1167.

Arminen, H., Puumalainen, K., Pätäri, S., & Fellnhofer, K. (2018). Corporate social performance: Inter-industry and international differences. *Journal of Cleaner Production*, *177*, 426-437.

Chakraborty, S. K., & Mazzanti, M. (2019). Energy Intensity and Green Energy Innovation: Checking heterogeneous country effects in the OECD. *Structural Change and Economic Dynamics*.

Greene, W. (2008). Econometric analysis 6th ed. 2008 Prentice Hall Upper Saddle River. In: NJ.

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*, *47*, 101516.

Lu, W., Su, M., Zhang, Y., Yang, Z., Chen, B., & Liu, G. (2014). Assessment of energy security in China based on ecological network analysis: A perspective from the security of crude oil supply. *Energy Policy*, *74*, 406-413.

Ozturk, I., & Al-Mulali, U. (2015). Investigating the validity of the environmental Kuznets curve hypothesis in Cambodia. *Ecological Indicators*, *57*, 324-330.

Uddin, G. A., Salahuddin, M., Alam, K., & Gow, J. (2017). Ecological footprint and real income: panel data evidence from the 27 highest emitting countries. *Ecological Indicators*, *77*, 166-175.

Wooldridge, J. M. (2010). *Econometric analysis of cross section and panel data*: MIT press.

Zafar, M. W., Zaidi, S. A. H., Khan, N. R., Mirza, F. M., Hou, F., & Kirmani, S. A. A. (2019). The impact of natural resources, human capital, and foreign direct investment on the ecological footprint: The case of the United States. *Resources Policy*, *63*, 101428.

Aroh, K. (2018). Globalization, Industralization and Population Growth the Fundamental Drivers of Pollution in a Given Society (India). *Available at SSRN 3453740*.

Aydin, C., & Esen, Ö. (2017). The Validity of the Environmental Kuznets Curve Hypothesis for CO2 Emissions in Turkey: New Evidence from Smooth Transition Regression Approach. *Mustafa Kemal University Journal of Social Sciences Institute*, *14*(39), 101-116.

Everett, T., Ishwaran, M., Ansaloni, G. P., & Rubin, A. (2010). Economic growth and the environment.

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.

Nawaz, S. M. N., & Alvi, S. (2018). Energy security for socio-economic and environmental sustainability in Pakistan. *Heliyon*, *4*(10), e00854.

Omotor, D. G. (2017). ECONOMIC GROWTH AND EMISSIONS: TESTING THE ENVIRONMENTAL KUZNETS CURVE HYPOTHESIS FOR ECOWAS COUNTRIES. *West African Journal of Monetary and Economic Integration*, *17*(2), 25-56.

Ota, T. (2017). Economic growth, income inequality and environment: assessing the applicability of the Kuznets hypotheses to Asia. *Palgrave Communications*, *3*(1), 1-23.

Shittu, W.O., Musibau, H. and Hassan, S. (2018) 'Revisiting the environmental Kuznets curve in Malaysia: the interactive roles of deforestation and urbanisation', *Int. J. Green Economics*, Vol. 12, Nos. 3/4, pp.272–293.

Sirag, A., Matemilola, B. T., Law, S. H., & Bany-Ariffin, A. N. (2018). Does environmental Kuznets curve hypothesis exist? Evidence from dynamic panel threshold. *Journal of environmental economics and policy*, *7*(2), 145-165.

Zaman, K., Khan, H., Khan, M. M., Saleem, Z., & Nawaz, M. (2011). The impact of population on environmental degradation in South Asia: application of seemingly unrelated regression equation model. *Environmental economics,* (2, Iss. 2), 80-88.

Appendix

S/N	**Asian Country**
1	Afghanistan
2	American Samoa
3	Australia
4	Bangladesh
5	Bhutan
6	Brunei Darussalam
7	Cambodia
8	China
9	Fiji
10	French Polynesia
11	Guam
12	Hong Kong SAR, China
13	India
14	Indonesia

S/N	Asian Country
15	Japan
16	Kiribati
17	Korea, Dem. People’s Rep.
18	Korea, Rep.
19	Lao PDR
20	Macao SAR, China
21	Malaysia
22	Maldives
23	Marshall Islands
24	Micronesia, Fed. Sts.
25	Mongolia
26	Myanmar
27	Nauru
28	Nepal
29	New Caledonia
30	New Zealand
31	Northern Mariana Islands
32	Pakistan
33	Palau
34	Papua New Guinea
35	Philippines
36	Samoa
37	Singapore
38	Solomon Islands
39	Sri Lanka
40	Thailand
41	Timor-Leste
42	Tonga
43	Tuvalu
44	Vanuatu
45	Vietnam