The Potency of Eco-Innovation, Natural Resource and Financial Development on Ecological Footprint: A Quantile-ARDL Based Evidence from China

Dr. Sahar Afshan (sahar_khan09@hotmail.com)
Universiti Utara Malaysia
Tanzeela Yaqoob
University of Karachi

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Sahar Afshan
(Corresponding author)

[a]School of Economics, Finance and Banking
Universty Utara Malaysia, Sintok, Malaysia
Email: sahar.afshan15@gmail.com

Tanzeela Yaqoob

Department of Statistics,
University of Karachi, Pakistan
Email: tanzeela@uok.edu.pk

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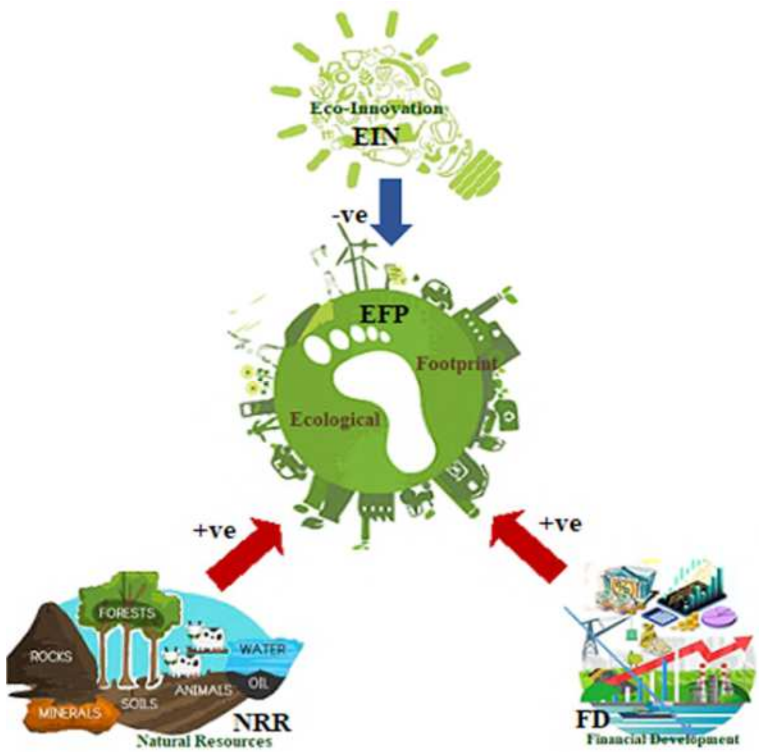
Abstract

Given the alarming deterioration of the environment, the present analysis investigates the role of eco-innovation, natural resources and financial development in influencing the environmental degradation of China. Applying the novel method of Quantile-ARDL, the current research is beneficial in portraying the dependence patterns of the variables with special emphasis on the nexus of eco-innovation and ecological footprint across numerous quantiles of the distribution which has not been examined so far in the literature. The empirical findings reveal that in the long run, eco-innovation reduces the level of ecological deterioration in China across all quantiles. On the other hand, the results suggest that the increase in credit to the private sector and natural resource rents augment environmental degradation. The outcomes imply that the over-dependence on natural resources and financial development can worsen the goals of sustainable development in China if the strategies of conservation and management are ignored. Moreover, witnessing the favourable role of eco-innovation, competent policies and regulations can be made towards sustainable efficient technologies and eco-friendly energy sources to halt global warming.

Graphical Abstract



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1. Introduction

The emission of the green-house gases is cumulating every day, results in the rise of global warming that ultimately responsible for environmental degradation on earth. Among the many other global encounters, dreadful environment is one of the principal challenges of this century (Li, 2016). In compliance to increasing global competition, many countries are urging to increase their growth potential. However, increase in growth without focusing the standards of sustainability could lead to poor quality of environment (Yasmeen et al., 2019), thus much attention is needed to maintain the quality environment along with the significant economic evolution. With the growing knowledge related to environmental threats and necessary actions taken globally, such as Conference of the Parties (COP21), make it realize that excessive usage of energy resources is intimidating our surroundings; hence assimilating the use of technology in numerous growth dependent industries could become a useful tool to improve the quality of environment through sustainable ecological innovations (henceforth, eco-innovation).

The idea of eco-innovation arises when strategic policies are fit with ecological assumptions. It is characterized as the number of patents available in the economy particularly in the field of environment. The idea of eco-advancement was first evolved by Fussler and James in 1996 and characterized as the decrease of negative ecological effects while giving new products or services critical for business growth (Hojnik & Ruzzier, 2016). Ecological innovation adds to the natural supportability objectives through the acknowledgment of groundbreaking thoughts, processes, inventions, and cycles (Rennings, 2000). Arundel and Kemp (2009) portray eco- innovation as essentially improved business strategy that assists in diminishing ecological dangers, contamination, and the negative impacts of resource utilization rather than conventional strategies that do not consider the deteriorating impact of economic growth on the nature.

At present, economies around the globe are anxiously seeking ways to enhance their growth to excel global competency. Among them, China is considered as the fastest growing economy, accounting thirty percent of the total worldwide growth (Khan et al. 2020). Although, the process of its economic and financial development promotes resource-intensive manufacturing owing to high consumption thereby leaving severe inscriptions on atmosphere (Danish et al. 2019). The country is deemed richest in terms of resources as it is a chief coal producer having big mining industry and the largest user of fossil fuel (Ahmed et al. 2020). On the other hand, it is believed that the increase extraction of natural resources can provide financial gains to the country but cause environment hazard by decreasing bio capacity and enhancing natural burden of the region, in terms of ecological footprint (Panayotou, 1993). Moreover, higher financial advancements motivate foreign direct investments and financial intermediation making consumption easier and prompts energy utilization, diminution of minerals, deforestation, depletion of resources, etc., thereby worsen the climate deterioration by increasing environmental imbalance in the form of higher ecological footprints (Suki et al. 2020).

This study attempts to sightsee the influence of eco-innovation, financial development and natural resources on ecological footprint in case of China. Given the augmented emphasis of literature in analyzing the environmental quality of emerging nations, the current study focuses on the Chinese economy. China has been successful in maintaining the crucial global position being the fastest growing nation and largest manufacturing and exporting economy. However, despite the substantial growth driven policies, the country is considered as the prime carbon emitter in the World (Guo et al. 2019). Given its huge population, China also tops in terms of total ecological footprint around the World. Hence, the current study is significant to analyze the environmental degradation in China since the country is augmenting its focus on innovation and Made-in-China narrative, for which economic and environmental sustainability play significant part. Also, it gives more attention to strong and stable financial structure in order to strengthen the association between real and financial sector of the economy which is prime to resource management and technology innovation.

The current study is novel in many ways. First, it seeks to expand EKC theory by incorporating the fundamental aspect of eco-innovation. To the best of our knowledge, the present study is pioneer in analyzing eco-innovation in EKC framework of China, along with the critical variables of natural resource and financial development that have also shown disagreements in the literature regarding their link with the environment (Ahmed et al. 2020). Second, despite the traditional measure of environmental quality in the form of carbon-di-oxide emission (CO_2), the current study has opted the ecological footprint to reflect environmental deterioration in China. The measure of CO_2 has been traditionally utilized in various earlier literatures (Lantz & Feng, 2006; Lindmark, 2002; Tisdell, 2001) as it holds the prime segment of green-house gases. However, it only reflects the air quality of the environment. Hence, understanding the importance of the need of an aggregate indicator Solarin and Bello (2018) emphasizes on the alternate of CO_2 emission as a proxy of ecological degradation. In this regard, ecological footprint is characterized as an inclusive measure of environmental quality for considering the environmental impact of economies in terms of soil, air and water (Sharif et al. 2019). Third, observing the emphasis of the literature in adopting advanced econometric methods, the current study has adopted the empirics of Quantile ARDL to perform empirical estimations.

Lastly, suitable economic techniques, such as the Bayer-Hanck cointegration test, bootstrap causality, and the ARDL test following the pathway proposed by Kripfganz and Schneider (2018), are employed. These recent econometric techniques offer numerous advantages and are appropriate for reliable estimates. The semi parametric technique Quantile ARDL takes high place among many of the recent econometric and time series techniques. The relaxation of statistical distribution assumptions grabs attention of researchers to consider QARDL for drawing various conclusions related to several stages of ecological footprint. Unlike traditional econometric methodologies, Quantile ARDL elaborates clearer picture of dependent variable by considering numerous quantiles rather than its average relationship with covariates. Understanding the importance of association of environmental degradation with eco-innovation and natural resources, in terms of long-run and short-run dynamics, Quantile ARDL provides the best parameter estimation method for several quantiles of ecological footprint. In order to access the behavior of fat-tail dependent variable by taking its conditional distribution and explore its association with explanatory variables by capturing its asymmetric effects, Quantile ARDL technique is best suited. Lahiani (2018) asserts the significance of Quantile ARDL in the framework of co integration as it empowers the parameters of co integrated vector to vary across the quantiles of ecological footprint arises from structural changes in the time series variable. Furthermore in making policy strategies this technique provides us an opportunity to observe the behavior of innovation at low as well as high quantiles in detail. Due to such benefits QARDL considers one of the sophisticated methodologies to explore the association among the variables in the frame work of co integration in depth.

2. Review of Literature

An ample literature has been well recognized to detect the impact of technological innovation, financial development and natural resources on environmental degradation. Numerous research employed carbon dioxide (CO_2) emissions as a measure of ecological degradation and produce various outcomes leading to valuable policy inferences (need three references of such studies, preferably before 2015). However, a recent shift of literary research has been identified in studying ecological footprint as an indicator of environmental degradation (need three references ideally of last three years).

In order to explore the influence of technological on carbon dioxide (CO_2) emissions, Chen and Lee (2020) utilized spatial econometrics model named as STIRPAT (Stochastic Impact by Regressions on population, Affluence and technology) for balanced panel data of 96 countries spanning from 1996-2018. For technological innovation several variables have studied such as innovation total population, GDP, Research and Development expenditures, industrial value added, forest area, urban population, energy use, globalization index, economic, political and social globalization. The study classifies the 96 nations into high, middle and low income economies. The comprehensive analysis exposes that spatial models plays an important role in accessing such kind of relationships. The openness and globalization index plays vital role in decreasing carbon dioxide (CO_2) emissions and raise technological innovations in developed nations.

Keeping the panel data of seventeen oil refining companies from all over the globe, Fethi and Rahuma (2020) explored the influence of ecological innovation to reduce carbon dioxide (CO_2) emissions from their operation process. In the context of oil refining companies, the Research & development and training & investment variables have taken as the proxy of economic innovation for all economies. The panel cointegration test and ARDL approach has utilized to achieve the required goals of the study. The study inclusively concludes that ecological innovation is the determinant of reducing carbon dioxide (CO_2) emissions and operation process of the oil refining companies.

Taking the panel of top 20 oil refining economies Fethi and Rahuma (2018) inspects the role of ecological innovation on the reduction of carbon dioxide (CO_2) emissions in the scenario of environmental Kuznets curve covering from 2007 till 2016. The selection of specific 20 countries is due to the pledge signed to reduce greenhouse gases down to the prescribed level. Research and development of investment countries was used as a proxy of eco-innovation. The study concludes that all countries under study plays positive role to maintain environment standards and also helping in reducing carbon dioxide (CO_2) emissions.

The comparative study between symmetric and asymmetric ARDL by Ahmed et al. (2021) also explored the link between economic globalization, economic growth, financial development and ecological footprint. The aim of the study is to highlight the asymmetric characteristics among the said variables for Japan. Keeping the importance of Population density and energy consumption the study also includes the variables in their econometric model. The study favor the asymmetric ARDL estimates as it captures the nonlinear dynamics. Results of symmetric ARDL clinches that economic globalization and financial development motivate the ecological footprint while asymmetric ARDL indicates that positive and negative variations in the globalization may decrease the footprint in Japan. Overall both the models support the environmental Kuznets curve hypothesis.

Understanding the importance of energy consumption, financial development, economic growth and ecological foot print, Destek and Sarkodie (2019) scrutinized the rationality of environmental Kuznets curve. The enormous yearly data of 11 newly industrialized economies spanning from 1977 to 2013 was taken for empirical investigation. It was found that energy consumption in industrialized countries and ecological footprints are positively related with each other. The group panel estimation method supports the inverted U-shaped EKS hypothesis along with the existence of bi-directional causal relationship between GDP and ecological footprint in the countries under study.

On the other hand, Ahmed et al. (2020) studied the influence of natural resources, economic growth and technological innovations on ecological foot prints. Taking the panel data of 22 emerging countries from 1984 to 2016, the required objective has been achieved by authors under the framework of panel cointegration and causality tests. The fallouts of the study indicate that natural resources, GDP, technological innovation and ecological footprint possess long run relationship with each other. The CS-ARDL test urges that economic growth and ecological foot prints hold environmental Kuznets curve hypothesis. Moreover technological innovations reveal negative relationship with ecological footprint thus output growth, natural resources and technological innovations leave marks on ecological footprint.

Hassan et al. (2019) also inspects the link among natural resources, output growth and ecological footprint along with the control variables human capital, bio-capacity and urbanization of Pakistan for the yearly data over the period 1970-2014. The objective of the study is to examine the cogency of environmental Kuznets curve hypothesis in Pakistan. The ARDL approach reveals that economic growth is playing positive role and favors EKC hypothesis while human capital and bio-capacity do not improving the ecological footprint progression in the scenario of Pakistan. Furthermore the bidirectional causality is evident by employing ARDL granger causality test between ecological footprint and bio capacity.

Emphasizing on the role of financial development, Baloch et al. (2018) collect the data of 59 belt and road Countries (BRI) and attempts to investigate the impact of financial development on ecological footprint over the period of 1990-2016. Along with financial development, the authors also take in account the role of GDP, energy, FDI and urbanization as explanatory variables. As per suggestion of World Bank, the study utilized domestic credit provided by the private sector, domestic credit provided by the financial sector, and domestic credit provided by the banking sector as the measure of financial development which provides deep insight for BRI nations. The estimation result reveals that financial development and economic growth have positive influence while foreign direct investment leads in an increment of ecological footprint.

Recently, Aydin and Turan (2020) consider the BRICS nation to sightsee the impact of financial openness, trade openness, and energy intensity on ecological footprint for the data set comprising from 1996-2016 under the shade of environmental Kuznets curve hypothesis. Authors employed three different models for the assessment of EKC one with financial openness, second with trade openness and third is interaction model with both variables. The study founds cointegration between the variables by utilizing the Westerlund's (2008) panel cointegration test. Overall the study clinches that energy intensity contributes to raise the pollution in all BRICS countries except Russia. For China and India trade openness has dropping effect on environment pollution. The results also specify that the model with financial openness and the model incorporated with trade openness favors EKC hypothesis for India and South Africa respectively.

Wang et al. (2020) explores the role of ecological innovation and export diversification on the level of carbon dioxide (CO_2) emissions. The study covers the panel data of G-7 countries straddling from 1990 to 2017. Taking cross sectional dependence and slope heterogeneity into account the order of integration varies for the selected variables thus CS-ARDL model founds appropriate for estimation. The estimation result exposes that ecological innovation is negatively related while export diversification is positively linked with carbon dioxide (CO_2) emissions thus ecological innovation helps to improve the standard of environment by decreasing the level of carbon dioxide (CO_2) emissions for G-7 economies.

Utilizing the Quantile ARDL model Godil et al. (2020) studies the asymmetric impact of tourism, financial development and globalization on ecological footprint for Turkey in terms of environmental Kuznets curve hypothesis. The nonlinear and asymmetric behavior of variables has been evident through Wald test of parameter dependency. The estimates are observed at different quantiles for accessing the short and long run association among the said variables. Overall the explanatory variables are showing substantial effect on ecological footprint as well as the validity of environmental Kuznets curve hypothesis was also observed in Turkey.

The relationship between natural resources, human capital, urbanization, economic growth, and ecological footprint for the emerging economy China has been studied by Ahmed et al. (2020). The large span of data over the period of 1970 to 2016 was collected and ARDL model was employed to explore the short and long run dynamics. The environmental Kuznets curve hypothesis is no more valid according to the long run coefficients while ecological footprint exhibits the positive relationship with economic growth. The short run estimates disclose that economic growth and urbanization in China increases ecological footprint whereas human capital is found to be negatively insignificant.

Considering the ASEAN countries Kongbuamai et al. (2019) analyzed the influence of economic growth, energy consumption, tourism, and natural resources on the ecological footprint. The Driscoll-Kraay panel regression has been deployed over the data from 1996 to 2016. The estimation results asserts that tourism brings ASEAN countries towards good environment conditions along with the validity of inverted U-shaped EKC performance between GDP and ecological footprint.

The above review reveals that several studies took carbon dioxide (CO_2) emissions as an environmental degradation and numerous bases of the ecological footprint have explored comprising technological innovation, human capital, foreign direct investment, natural resources and financial development but none of the studies has considered the influence of ecological innovation on the ecological footprint. To bridge the gap in the literature, this lacking inspires us to estimate the effect of ecological innovation on the ecological footprint in the scenario of China.

3. Methodology

In order to examine the association of eco-innovation, natural resource rent and financial development with ecological footprint over a range of quantiles, the application of QARDL is the suitable approach for providing an inclusive dependence structure among the variables in different levels of the criterion variables in both short-run and long-run. Therefore, to investigate the short-run and long-run association of the studied variables under the EKC framework, we have applied the QARDL framework and Wald test to inspect the significance and constancy of the parameters across the series of quantiles.

The model of QARDL initiated from the traditional ARDL framework, written in equation 1 as;

$$Y_t = \alpha + \sum_i^p \beta_1 Y_{t-i} + \sum_i^q \beta_2 X1_{t-i} + \sum_i^q \beta_3 X2_{t-i} + \sum_i^q \beta_4 X3_{t-i} + \sum_i^q \beta_5 X4_{t-i} + \sum_i^q \beta_6 \mathrm{X5t} - 1 + \epsilon_t \quad (1)$$

where, ϵ_t is the error term, explained as $Y_t - \Sigma[Y_t/\delta_{t-1}]$, with δ_{t-1} indicated the least $\sigma -$ field produced by$\{Y_t, X1_t, X2_t, X3_t, X4_t, X5_t, Y_{t-1}, X1_{t-1}, X2_{t-1}, X3_{t-1}, X4_{t-1}, X5_{t-1}\}$, also, p & q identified the lag-orders measured via Schwarz information criterion and Y_t the studied criterion variables, i.e. ecological footprint, whereas, X1, X2, X3, X4 and X5 represent GDP, squared GDP, eco-innovation, natural resource rent and financial development respectively.

Linking from equation (1), the QARDL model is identified as;

$$Q_{Y_t} = \alpha(\tau) + \sum_i^p \beta_1(\tau) Y_{t-i} + \sum_i^q \beta_2(\tau) X1_{t-i} + \sum_i^q \beta_3(\tau) X2_{t-i} + \sum_i^q \beta_4(\tau) X3_{t-i} + \sum_i^q \beta_5(\tau) X4_{t-i} + \sum_i^q \beta_5(\tau) X5_{t-i} + \epsilon_t(\tau) \quad (2)$$

In which, $\epsilon_t(\tau) = Y_t - Q_{Y_t}(\tau/\epsilon_{t-1})$ (Kim and White, 2003) and $0 < \tau < 1$ is the quantile. For empirical purposes, the subsequent quantiles represent a total of nine quantiles represented from τ showing the quantiles of {0.05, 0.10, 0.20, 0.30, 0.40, 0.50, 0.60, 0.70, 0.80, 0.90 and 0.95}. Furthermore, suspecting the probability of having serial correlation in the residual, the generalization of QARDL model is presented in Equation (3) as;

$$Q_{\Delta Y_t} = \alpha(\tau) + \rho Y_{t-i} + \beta_1 X1_{t-i} + \beta_2 X2_{t-i} + \beta_3 X3_{t-i} + \beta_4 X4_{t-i} + \beta_5 X5_{t-i} + \sum_{i=1}^p \varphi_i \Delta Y_{t-1} + \sum_{i=1}^q \omega_i \Delta X1_{t-1} + \sum_{i=1}^q \lambda_i \Delta X2_{t-1} + \sum_{i=1}^q \theta_i \Delta X3_{t-1} + \sum_{i=1}^q \mu_i \Delta X4_{t-1} + + \sum_{i=1}^q \gamma_i \Delta X5_{t-1} + \epsilon_t(\tau) \quad (3)$$

In addition, Equation (3) can be revised following (Cho et al., 2015) to provide ECM re-estimations of QARDL framework in model Equation (4) as;

$$Q_{\Delta Y_t} = \alpha(\tau) + \rho(\tau)(Y_{t-i} - \omega_i(\tau)X1_{t-i} - \lambda_i(\tau)X2_{t-i} - \theta_i(\tau)X3_{t-i} - \mu_i(\tau)X4_{t-i} - \gamma_i(\tau)X5_{t-i}) + \sum_{i=1}^{p-1}\beta_1(\tau)\Delta Y_{t-i} + \sum_{i=0}^{q-1}\beta_2(\tau)\Delta X1_{t-i} + \sum_{i=0}^{q-1}\beta_3(\tau)\Delta X2_{t-i} + \sum_{i=0}^{q-1}\beta_4(\tau)\Delta X3_{t-i} + \sum_{i=0}^{q-1}\beta_5(\tau)\Delta X4_{t-i} + \sum_{i=0}^{q-1}\beta_6(\tau)\Delta X5_{t-i} + \epsilon_t(\tau) \quad (4)$$

Furthermore, utilizing the delta approximations, the additive short-term influence of historic environmental degradation represented by eco-footprint on present level of eco-footprint is calculated by $\beta_* = \sum_{i=1}^{p-1}\beta_1$, however, the additive short-term influence of concurrent and past level of eco-innovation, natural resources rent and financial development on present level of environmental degradation is measured as $\beta_* = \sum_{i=1}^{q-1}\beta_2$. Similarly, the long-term cointegrating estimate β is measured using the delta approximation β ¼ − γ ρ. Lastly, the speed of adjustment estimates ρ in Eq. (4) is needed to be negative significant (Lahiani, 2018). Finally, in order to estimate the long-term and short-term asymmetric effect of X1, X2, X3, X4 and X5 on Y_t, the study applied the method of Wald to testify the null hypotheses of the long-term and short-term asymmetry (Cho et al. 2015; Lahiani, 2018).

Results and Interpretations

To fulfil the required objective of the present study, preliminarily analysis of the data by descriptive statistics and unit root testing methods has been employed followed by Q-ARDL model. Table 1 presents the outcome of summary statistics for ecological footprint, economic growth, natural resource rent, eco-innovation and financial development. The square of economic growth has also considered observing the validity of EKC hypothesis in the scenario of China. The average of outcome variable i.e. eco-footprint possess minimum value of 0.351 with the least volatility of 0.011 among all the considered variables. Economic growth and financial development holds large mean indicating that both variables posing almost same effect on China's economic cycle. On average, the share of eco-innovation is more than natural resource rent while the normality of all the variables has been rejected at 1% level of significance declaring the heavy tails of the data (Sharif et al. 2019).

Table 1: Results of Descriptive Statistics

Variables	Mean	Min.	Max.	Std. Dev.	J-B Stats
EFP	0.351	0.201	1.123	0.011	16.010***
GDP	2.010	1.101	3.014	1.101	20.106***
GDP2	0.654	0.510	1.010	0.021	18.010***
ECO	1.121	1.010	2.011	1.010	22.101***
NRR	0.985	0.650	1.345	0.032	17.021***
FD	2.101	1.801	3.101	1.001	19.122***

Note: The asterisk ***, ** and * represent level of significance at 1%, 5% and 10% respectively.

The outcome of unit root tests is portrayed in Table 2. Similar to Godil et al. (2020) the study deployed two unit root tests. It has been evident from the results of traditional ADF test and

ZA test incorporating structural breaks in the series that all the variables are integrated of order 1. The break years at first difference for eco-footprint are found to be 2001(Q2) indicating that China revised its environmental regulations to save the environment. Breaks year for eco-innovation at level and at first difference are quite close i.e. 2000(Q3) and 1999(Q1) which is the clue of involvement of this explanatory variable in China. Natural resource rent and financial development is seems to be much affected by few of the financial crisis happened all around the globe at several time periods.

Table-2: Results of Unit root test

Variables	ADF (Level)	ADF (Δ)	ZA (Level)	Break Year	ZA (Δ)	Break Year
EFP	-1.210	-3.015***	-1.425	2013(Q4)	-6.010***	2001(Q2)
GDP	-0.030	-5.010***	-0.654	2016(Q1)	-9.100***	2010(Q4)
ECO	-0.624	-3.009***	-0.741	2000(Q3)	-9.035***	1999(Q1)
NRR	-1.101	-5.011***	-1.357	2015(Q1)	-6.067***	2012(Q2)
FD	-0.451	-4.007***	-0.587	2014(Q3)	-8.020***	2005(Q1)

Note: The values in the table specify statistical values of the ADF and ZA test. The asterisk ***, ** and * represent level of significance at 1%, 5% and 10% respectively. Source: Author Estimation

The evidence of highly skewed data points and confirmation of I (1) variables leads the analysis towards Q-ARDL framework. Table 3 reports the empirical findings of the model. Looking towards the error correction terms at each quantile it founds to be negative and highly significant with uniform speed of adjustment i.e. around 40% rate to maintain its equilibrium relationship with explanatory variables under studied. To check the validity of EKC hypothesis, keeps an eye on the quadratic term of economic growth under the caption of long run estimates the coefficient are found to be negative and significant especially at extreme quantiles from 0.6 to 0.95. At 0.2, 0.3 0.4 and median the impact is although negative but it is insignificant, however the U-shaped inverted relationship among economic growth and environmental hazards in China are evident at higher quantiles. Thus in China economic growth leads eco-footprint towards downward trend in the early stage while reaching at maximum level improvement in economy started to harm environment. These results are in consistent with the Godil et al. (2020) as they found positive coefficients of squared economic growth across high quantiles, also not in line with Wang et al. (2013) as they conclude that EKC hypothesis is not valid for the countries holding more than 1 million of population while the results are similar to Dogan et al. (2019) and Destek and Sarkodie (2019).

Furthermore betas of eco-innovation are found to be negative and highly significant at all quantiles indicating the negative association among eco-innovation and eco-footprint in China. This result is consistent with Ahmad et al. (2021) as eco-innovation helps in reducing the environmental degradation. In the light of these outcome it can be stated that enhancement in eco-innovation in China leads it toward healthy atmosphere as it possess same impact at all quantiles of eco-footprint. Eco-innovation is helping China to make their environment clean as health concerns are widely be connected with surroundings.

As far as natural resource rent is concerned. It is exerting positive and significant impact on eco-footprint in the long run, showing that natural resources are not helping China to reduce the consumption of imports, usage of fossil fuels is rising and contaminated energy sources are widely be utilized in the country. These results are dissimilar to the study of Zafar et al. (2019) in which natural resource rent was found to be negative and significant for the scenario of the USA and Hassan et al.(2018) for Pakistan as insignificant relationship has been observed among natural resources and eco-footprint.

It is also noteworthy that financial development is seems to be positive and significant at all quantiles showing upward trending relationship in the long run with environmental degradation. This result is so far match with the study of Baloch et al. (2018) for BRI countries and mismatch to Uddin et al. (2017) asserts that financial development helps to reduce climatic hazards. There are several reasons behind the positive relationship of financial development with eco-footprint for the case of China as FD encourages stakeholders to invest in infrastructure plans by providing flexible loan schemes resulting in increasing land, water and air pollution. Moreover financial development empowers general public to increase their standard of life by purchasing luxuries through loans which ultimately harms the environment.

Like FD Economic growth in China is also found to be positive and significant across all the quantiles. It is well documented that economic progress is extensively based on industrialization and to boost industrial sector conventional sources such as oil, gas and coal are using in China. Furthermore huge investments and purchases in the country bring economic growth but decrease the quality of environment.

Table 3: Results of Quantile Autoregressive Distributed Lag (QARDL) for Ecological Footprint

Quantiles	Constant	ECM	Long-Run Estimation					Short-Run Estimation					
(τ)	$\alpha_*(\tau)$	$\rho_*(\tau)$	$\beta_{GDP}(\tau)$	$\beta_{GDP2}(\tau)$	$\beta_{EIN}(\tau)$	$\beta_{NRR}(\tau)$	$\beta_{FD}(\tau)$	$\varphi_1(\tau)$	$\omega_0(\tau)$	$\lambda_0(\tau)$	$\theta_0(\tau)$	$\mu_0(\tau)$	$\gamma_0(\tau)$
0.05	0.101	-0.450***	0.215	-0.248**	-0.269*	0.108	0.359**	0.204	0.267*	-0.150**	-0.467	0.046	0.076
	(0.011)	(-3.001)	(0.010)	(-2.030)	(-1.649)	(1.609)	(2.098)	(1.151)	(1.930)	(-2.889)	(-1.609)	(0.064)	(0.064)
0.1	0.001	-0.439***	0.241	-0.151*	-0.477*	0.012	0.449**	0.102	0.179*	-0.191***	-0.483	0.037	0.101
	(0.020)	(-2.991)	(0.006)	(-1.961)	(-1.757)	(1.089)	(2.304)	(0.898)	(1.895)	(-3.019)	(-1.617)	(0.150)	(0.080)
0.2	0.010	-0.430**	0.257*	-0. 147	-0.389*	0.103	0.360**	0.315	0.269*	-1.107	-0.437	0.033	0.071
	(0.032)	(-2.700)	(1.856)	(-0.079)	(-1.696)	(1.105)	(2.501)	(0.787)	(1.881)	(-0.689)	(-1.610)	(0.044)	(0.178)
0.3	0.106	-0.413*	0.248*	-0.157	-0.041**	0.208**	0.251**	0.347	0.258*	-0.143*	-0.359***	0.040	0.140
	(0.019)	(-1.864)	(1.780)	(-0.059)	(-1.991)	(2.010)	(2.535)	(1.175)	(1.849)	(-1.651)	(-2.998)	(0.059)	(0.085)
0.4	0.035	-0.433*	0.259**	-0.139	-0.039*	0.250**	0.039	0.138	0.371*	-0.048	-0.432**	0.069	0.029
	(0.011)	(-1.831)	(1.998)	(-0.081)	(-1.781)	(2.589)	(0.089)	(0.161)	(1.769)	(-1.129)	(-2.399)	(0.278)	(0.148)
0.5	0.018	-0.435**	0.249**	-0.131	-0.049**	0.119*	0.023	0.339	0.252**	-0.102**	-0.143	0.044	0.032
	(0.011)	(-2.725)	(2.234)	(-0.061)	(-2.003)	(1.817)	(0.078)	(1.095)	(2.091)	(-2.109)	(-1.561)	(0.257)	(0.167)
0.6	0.052	-0.421*	0.260**	-0.141**	-0.573**	0.290**	0.032	0.241	0.165*	-0.059	-0.031	0.041	-0.051
	(0.021)	(-1.860)	(2.001)	(-1.983)	(-2.701)	(1.968)	(0.062)	(0.096)	(1.666)	(-0.919)	(-0.999)	(0.051)	(-0.059)
0.7	0.109	-0.425**	0.252**	-0.163**	-0.681**	0.279**	0.027	0.223	0.172*	-0.131	-0.069	0.026	-0.038
	(0.041)	(-2.778)	(2.035)	(-2.010)	(-2.089)	(2.059)	(0.049)	(0.189)	(1.879)	(-0.979)	(-0.980)	(0.038)	(-0.089)
0.8	0.078	-0.427*	0.247**	-0.148***	-0.490***	0.282**	0.541***	0.133	0.137	-0.099**	-0.072	0.086	-0.031
	(0.015)	(-1.852)	(2.029)	(-2.991)	(-3.081)	(1.941)	(3.091)	(0.098)	(0.058)	(-1.982)	(-1.236)	(0.147)	(-0.041)
0.9	0.106	-0.429**	0.239**	-0.153***	-0.679***	0.209*	4.392***	0.142	0.106	-0.227*	-0.191	0.045	-0.057
	(0.055)	(-2.710)	(2.050)	(-3.010)	(-3.010)	(1.727)	(2.995)	(0.162)	(0.043)	(-1.714)	(-1.555)	(0.031)	(-0.032)
0.95	0.069	-0.447***	0.251**	-0.172***	-0.688***	0.341**	4.049***	0.337	0.238**	-0.153*	-0.169	0.037	-0.044
	(0.016)	(-3.010)	(2.038)	(-2.996)	(-2.979)	(1.989)	(3.005)	(0.149)	(2.035)	(-1.959)	(-0.971)	(1.021)	(-0.022)

Note: The t-statistics are between brackets. ***, ** and * indicate significance at the 1%, 5% and 10% levels, respectively. Source: Author Estimations

Table 4 reports the parameter constancy outcomes accessed through Wald test. The null hypothesis of linearity in error correction term is rejected at 5% level of significance in the scenario of China. Similarly the long-term integrating parameter β_{EIN} has been tested for the parameter constancy for all quantiles and it found to be significant. This result may assert that the long term relationship among eco-footprint and eco-innovation varies across all the quantiles. The parameter estimates of β_{GDP2}, βGDP, β_{NRR} and β_{FD} contains mixed results as they found insignificant Wald statistics at various quantiles.

Table 4: Results of the Wald Test for the constancy of parameters

Variables	Wald-statistics
ρ	3.010***
	(0.000)
βGDP	4.012***
	(0.000)
β_{GDP2}	1.991**
	(0.051)
β_{ECO}	2.791**
	(0.000)
β_{NRR}	3.101***
	(0.000)
β_{FD}	2.980***
	(0.000)
φ_1	3.099***
	(0.000)
ω_0	2.890**
	(0.000)
λ_0	0.927
	(0.789)
θ_0	3.101***
	(0.000)
$\mu 0$	1.591
	(0.426)
$\gamma 0$	1.357
	(0.321)

Note: The p-values are between square brackets. ***, ** and * indicate significance at the 1%, 5% and 10% levels, respectively.

As a final step of the procedure the Granger Causality test across the quantiles developed by Troster et al. (2018) has also employed (Displayed in Table 5). The purpose of the test is to observe the bi-directional causal relationship from the variations explanatory variables to the outcome variable. The results suggest the presence of bi-directional causality among the variables across all the quantiles. Therefore it can be stated that eco-footprint possess bi-directional relationship with eco-innovation, economic growth, natural resource rent and financial development in China.

Table 5: Granger Causality in Quantile Test Results

Quantiles	ΔEFP_t to ΔGDP_t	ΔGDP_t to ΔEFP_t	ΔEFP_t to ΔEIN_t	ΔEIN_t to ΔEFP_t	ΔEFP_t to ΔNRR_t	ΔNRR_t to ΔEFP_t	ΔEFP_t to ΔFD_t	ΔFD_t to ΔEFP_t
[0.05-0.95]	0.000	0.000	0.000	0.000	0.359	0.000	0.000	0.000
0.05	0.000	0.000	0.006	0.000	0.005	0.002	0.000	0.009
0.10	0.000	0.000	0.010	0.000	0.000	0.000	0.000	0.000
0.20	0.007	0.000	0.001	0.000	0.051	0.008	0.000	0.000
0.30	0.001	0.000	0.005	0.000	0.164	0.000	0.001	0.000
0.40	0.000	0.000	0.011	0.000	0.597	0.000	0.000	0.000
0.50	0.000	0.000	0.015	0.007	0.002	0.045	0.000	0.000
0.60	0.000	0.000	0.012	0.000	0.000	0.000	0.000	0.001
0.70	0.000	0.000	0.009	0.000	0.039	0.000	0.000	0.000
0.80	0.000	0.000	0.013	0.000	0.698	0.000	0.000	0.000
0.90	0.000	0.000	0.004	0.000	0.211	0.001	0.003	0.000
0.95	0.000	0.004	0.000	0.000	0.342	0.000	0.000	0.006

Source: Authors Estimation

Conclusion and Policy Recommendation

The present examination analyzed the validity of EKC in China by analyzing the influence of growth, squared growth, eco-innovation, natural resource rent and financial development on environmental degradation of China by utilizing the measure of ecological footprint over the period of 1990 to 2017. The current study has applied the method of Q-ARDL in examining the association among the studied variables. The research is beneficial in portraying the dependence patterns of the variables with special emphasis on the relationship of eco-innovation with ecological footprint of China across numerous quantiles of the distribution which has not been examined so far in the literature. Also, the novel method of granger causality in quantiles is also applied in the current study to examine the causal connections among the studied variables. The causal outcomes found that all the variables under study preserve feedback association with each other except for natural resource rent. The study found that natural resource has a uni-directional causal connection with ecological footprint in China, where the direction of causality runs from NRR to EFP. Moreover, the results of Q-ARDL revealed that in short-run, GDP and GDP^2 are significant to impact environmental degradation in China. Also in long-run, the study validated the presence of inverted U-shaped relationship among the variable exhibiting that economic activity puts negative pressure on the environment in initial stages, however it transforms to generate positive impact on the ecological condition of the country. Moreover, the outcomes of the Q-ARDL reflected that the error correction is significant across all quantiles with the anticipated negative sign confirming the existence of notable return to equilibrium association in long-run among the studied variables and ecological footprint.

In long-run, the results exhibited that eco-innovation reduces the level of ecological deterioration in China across all quantiles. These results are consistent with the findings of Ahmad et al. (2021) in G-7 countries. Hence, considering the positive role of eco-innovation in reducing the ecological deficit, further training and awareness campaigns should be initiated in cities, rural and remote areas of the country to explain the significance of eco-innovation together with the means to promote reduced resource utilization and sustainable functioning. Moreover, the government policies should contain provisions for financing ecologically innovated projects, particularly for creating suitable technologies that can guarantee desired balance between increased economic developments and reduced ecological deterioration. Finally, higher level of monetary resources and research on eco-innovation can be utilized to decline the potential issue of energy security and obsolete technology convention in the country.

On the other hand, the result of financial development revealed that increase in credit to private sector further enhances the environmental degradation, similar to the outcome of Przychodzen and Przychodzen (2015) for the economies of Poland and Hungary. The results are more evident in the high quantiles explaining that greater ecological deficit is more vulnerable to increased financial development in China. These findings highlight that financial advancements in China is non-sustainable indicating the ignorance of financial sector in preserving the standards of sustainable development in its investments. In order to deal with the current situation, the government needs to regulate the financial sector to consider ecological feasibility of investment projects. Also the utilization of improved technology in rural areas facing the problem of declining labor due to aging and less productivity (Wei, Zhu & Glomsrød, 2018), could also ensure optimistic influence on the level of augmenting ecological deficit of the country.

Moreover, the outcome of natural resource found the positive association of natural resource rent with ecological footprint in China consistent with the outcomes of Ahmed et al., (2020). This imply that increased utilization of natural resources puts negative pressure on environment, not only by causing air and land pollution, but also by augmenting the ecological deficit of the country. This necessitates that the prevailing regulations concerning minerals, soil and emission in China requires modification and enforcement. Moreover, given the higher reliance of coal in the power mix of the country, the shift towards natural gas has been recommended by many studies to lessen the environmental burden (Chen et al., 2020). This may lead to further puts negative pressure on ecological deficit by triggering impending water contamination, exhaustive water utilization and enhanced emissions (Mallapragada et al. 2018) causing enlarged pressure on ecological deficit through higher gas mining. As a more suitable solution, the emphasis of government should be towards the adoption of green energy sources. In doing so, the present policies that intend to attain 40% share of renewables in power sector by 2030 should be sustained. However, this will require hastened development in solar and wind PV along with the utilization of hydro-electricity obliging higher development in grid & transmission aptitude together with the reforms in energy market. Also, the government can modify pricing strategy to decline the mining of oil and coal and encourage the utilization of eco-friendly power sources which may lead to resource restoration with lower natural resource depletion and the protection of bio-diversity with lower ecological footprint.

DECLERATIONS:

Ethical Approval
Not applicable

Consent to Participate
Not applicable

Consent to Publish
The authors provide consent for the publication of manuscript submitted including all the details within the text and tables to be published in the Journal of ESPR.

Authors Contributions

Sahar Afshan	Conceptualization, Writing Introduction, Methodology, Conclusion.
Tanzeela Yaqoob	Writing empirical interpretations and Literature review.

Competing Interests
The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Not applicable

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