The Long Run Dynamics of Sustainable Economic Development on Ecological Footprint in Developed and Developing Countries: Panel Quantile Regression

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ARTICLE DETAILS

ABSTRACT

Rapid human consumption increases natural resource consumption, which damages the environment. The present study links sustainable economic development and Ecological Footprint in 78 developing and 93 developed countries from 1990 to 2020. This study measures sustainable economic development using the Human Development Index (HDI). The study uses panel quantile regression (PQR) to analyze data from the lower, middle, and higher ecological footprint groups. The study concluded that in developed countries with lower ecological footprint groups, a U-shaped relationship exists while in higher ecological footprint groups the inverted U-shaped EKC is valid between ecological footprint and HDI. It shows that developed countries initially degrade the environment by increasing their ecological footprint. Furthermore, as these countries grow, they divert their attention to more environmentally friendly technologies, resulting in a declining ecological footprint. However, developing countries demonstrate a U-shaped relationship in all quantile groups, indicating that these countries are prioritizing economic growth over environmental concerns. This study recommends that developing countries should follow the developed countries to reduce their ecological footprint by using environmentally friendly practices.

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1. Introduction

Human beings have enjoyed economic prosperity at the expense of environmental deterioration. The massive human demand is fueled by using the excessive natural resources consumption, which badly damage the environmental quality (Abid et al., 2022; Amjad et al., 2021; Asghar, Amjad, Rehman, et al., 2022). Natural resource consumption is measured by using ecological footprint (EF) based on cropland, fishing, grazing, built-up land, forestation, and carbon demand (Asghar et al., 2023). Higher
consumption of these resources increase the EFP which badly depletes environment, leading to different chronic diseases which inversely impact the human well-being (Jie et al., 2023).

In the light of Robbins (1935) human wants are unlimited, but resources are limited. In this scenario, energy is responsible for environmental deterioration (Rehman et al. 2021). To meet the energy demand, all countries rely on traditional energy resources consisting of fossil fuels energy consumption (FFEC) that discharge carbon emissions (Khan et al. 2020). FFEC includes coal, oil, and gas consumption. Sial et al. (2022) explored that one British thermal unit (Btu) of coal, crude oil, and gas emits carbon elements of about 216 lbs, 161.3 lbs and 117 lbs, respectively. So, these sources are an essential component to enhancing EFP (Hadj et al. 2021; Baz et al. 2020).

Figure 1 shows the world map of EFP in 2020 which shows that developed countries have higher EFP than developing countries. This is because developed countries have higher per capita income, resulting in a greater level of natural resources consumption which causes an increase in EFP (Nair et al., 2021). However, it is important to note that some newly rapid-growing developing countries have higher EFP than lower-growing developing economies (Destek & Manga, 2021).

The present study tries to achieve a sustainable environment in developing and developed countries by exploring the linkage between sustainable economic development and EFP. Achieving a sustainable environment involves promoting sustainable practices and policies that reduce environmental degradation, protect natural resources, and ensure the long-term health and resilience of ecosystems (Jhariya et al., 2021).

A sustainable environment can be achieved through sustainable development by controlling environmental degradation through urbanization, deforestation, industrialization, and depletion of natural resources (Hossain et al., 2023). A sustainable development approach identifies the interdependence between economic, social, and environmental progress (Ahmed & Wang, 2019). For this purpose, UNDP (2022) measured sustainable economic development by using the Human development index (HDI) which is measured by three dimensions: income, education, and health (H. Wang et al., 2022). In order to achieve sustainable development, these three dimensions are closely connected to economic, social, and environmental progress.
Figure 2 shows the world map of HDI in 2020 which shows the developed countries having higher values of HDI as compared to the developing countries. In developed countries, productivity and GDP per capita are higher due to more robust and diversified economies. It also leads to better infrastructure and technology as well as higher incomes and better access to education and healthcare (Dasic et al., 2020)

![World map of HDI in 2020](image)

This study achieves the objective to derive the EKC hypothesis by using sustainable economic development (HDI) and EFP in both developed and developing countries. In the previous literature, there are several studies which derived the EKC by using economic growth and environmental degradation (Ahmad et al., 2021; Caglar et al., 2021; Destek et al., 2018; Jahanger et al., 2022; Nathaniel, 2021). This study is very significant because it correctly measures sustainable economic development by using HDI and environmental degradation by using EFP. Furthermore, this study uses a unique econometric approach.

2. Literature Review

Recent environmental research uses the EFP as the proxy for environmental degradation (Asghar et al., 2023; Danish et al., 2020; Sabir & Gorus, 2019). Several pieces of literature examined the relationship between EFP and economic growth (EG) (Ahmad et al., 2021; Hassan et al., 2019; Pata et al., 2021). The researcher and policymakers failed to examine the exact relationship between these variables. Higher EG often means more consumption and production, which increases EFP (Jie et al., 2023; Z. Wang et al., 2023). However, EG may also reduce EFP by implementing sustainable practices such as reducing pollution and waste using eco-friendly technologies (Zia et al., 2021).

Several studies divert their attention to deriving the Ecological Kuznets Curve (EKC) hypothesis. The basic concept of EKC was developed by Kuznets (1955) using the income inequality theory. This theory demonstrates that the initial level of EG upsurges the income inequality but later on lessens it, and further, Grossman and Kruger (1995) used it in environmental science. It shows that the lower EG deteriorates the environment, while the higher EG improves the environment and proposes an inverted U-shaped EKC.

Nowadays, several studies explored the EKC hypothesis as the inverted U-shaped curve, showing
that the level coefficient of EG increases EFP while its quadratic coefficient declines the EFP (Aydin et al., 2023). Jahanger et al. (2022) explored that the EKC hypothesis existed based on EG and EFP in African, Latin American, and Caribbean countries. Wang et al. (2022) pointed out the association between EFP and EG in four groups of 166 countries lower, lower-middle, middle-higher, and higher-income countries. The second-generation technique explored that inverted U-shaped EKC existed in higher-income countries; however, this relationship did not exist in lower-income countries. Ahmad et al. (2021) verified EKC by using EG and EFP in G7 nations from 1980 to 2016. Danish et al. (2020) applied FMOLS and DOLS techniques and verified the EKC in BRICS countries during 1992-2016. Sabir and Gorus (2019) also proved the EKC in South Asian countries from 1975 to 2017. Hassan et al. (2019) also demonstrated EKC in Pakistan.

Nathaniel et al. (2021) proved the EKC from 1990 to 2016 using energy consumption, trade, and environmental technologies. It is found that energy consumption and trade increase EFP while environmental technologies decline EFP. Sultana et al. (2022) verified the validity of the EKC in Bangladesh during 1972-2018 by using the ARDL and FOLS econometrics technique.

In addition to EKC, several pieces of literature examined failed the EKC, suggesting EG and EFP may have a U-shaped relationship (Hatmanu et al., 2022). The U-shaped curve shows the level coefficient of EG decline EFP while its quadratic coefficient increases EFP. Caglar et al. (2021) established the U-shaped relationship using renewable and fossil energy, financial development, and ICT in the top 10 pollutant countries. Destek and Sinha (2020) also revealed a U-shaped curve by using renewable and fossil energy from 1980 to 2014. The advanced econometrics technique culminated in that renewable energy and trade lessened EFP while fossil energy raised EFP. Destek et al. (2018) proclaimed the U-shaped EKC from 1980 to 2013. Mehmood (2021) failed to confirm the EKC curve using the FMOLS and DOLS econometrics technique from 1990 to 2016.

There are limited studies that examine the role of HDI on EFP. Wang et al. (2022) measured HDI based on health, education, and income. Ahmed and Wang (2019) examined the impact of human capital (HC) on EFP in India from 1971 to 2014. This study revealed that HC based on education diminished the EFP. Ahmed et al. (2020) found that HC mitigated the EFP in China. Pata et al. (2021) analyzed the role of the HDI and renewable energy on EFP in the ten largest EFP countries from 1992 to 2016. The empirical results found that level and quadratic coefficients of HDI inversely impact the EFP. These results highlighted that higher HDI declines the EFP. Zia et al. (2021) focused on the impact of HC on EFP in China from 1985 to 2018. The study found that HC upsurges the negative influence on the EFP.

Fossil fuels energy consumption (FFEC) contain the highest amount of carbon elements, increasing carbon footprints. Ibrahim and Hanafy (2020) examined the role of FFEC on EFP in Egypt from 1971 to 2014. The study concluded that FFEC increased the EFP. Akalin et al. (2021) investigated that FFEC escalated the EFP. Asghar et al. (2023) pointed out the role of FFEC on EFP in Pakistan from 1990 to 2020. The non-linear ARDL approach examined the positive and shocks of the FFEC increased the EFP.

The manufacturing sector (MAN) has negative and positive impacts on EFP, depending on different factors like the material used and the efficiency of the production process. Chowdhury et al. (2020) investigated that MAN negatively impacted the EFP in 92 countries from 2001 to 2006. Yang and Khan (2022) explored that industrialization mitigated the EFP in IEA countries. Chen et al. (2022) analyzed the role of industrial robots in measuring the EFP in 72 countries from 1993 to 2019. This
study found that industrial robots declined EFP. Conversely, Khan et al. (2021) examined that MAN positively increased the EFP in the top 10 manufacturing sectors from 1970 to 2016. Liao et al. (2023) explored that industrialization contributed to higher EFP in OECD countries from 1990 to 2019.

The export sector (EXPO) has both positive and negative impacts on EFP, depending on the specific context and circumstances. Khan et al. (2021) investigated the effect of merchandise trade on EFP. The study concluded that merchandise trade positively increased the EFP. In contrast, Topcu and Altay Topcu (2021) pointed out the role of the EXPO on EFP in Turkey from 1990-2015. This concluded that the EXPO declined the EFP. Raimo et al. (2022) examined the impact of EXPO on EFP in India from 1970 to 2017. The study explored that India’s exports based on less energy-intensive, which led to reduce EFP. Kazemzadeh et al. (2022) analyzed trade openness and EFP in 16 countries from 1990 to 2014. The PQR approach determined that trade openness significantly diminished the EFP.

Urbanization (UR) has a mixed effect on EFP, depending on the nature of the UR. Danish et al. (2020) investigated different determinants of EFP in BRICS countries from 1992 to 2016. The FMOLS and DOLS approaches concluded that urbanization decreased EFP. Sahoo and Sethi (2021) analyzed the impact of UR on EFP in newly industrialized countries from 1990 to 2017. The study found UR positively increased the EFP. Kassouri (2021) examined the effect of UR on water and built-up land EFP in Sub-Saharan countries. The study found that UR expands the water and built-up EFP. Qayyum (2021) studied the role of UR on EFP in South Asian Countries. It found that UR positively contributed to EFP.

After reviewing the literature, numerous studies derived the EKC by using EG and EFP in different regions (Ahmad et al., 2021; Jahanger et al., 2022; Nathaniel, 2021). Several studies failed to verify the EKC and derived the U-shaped relationship between EG and EFP (Caglar et al., 2021; Destek et al., 2018). There is not much literature that derived the EKC using human capital and EFP from a global perspective. Keeping in view of the research gap, human capital is used as the linear and quadratic term to determine the EFP by using the unique econometric approach of PQR at three groups lower, middle, and higher quantile groups.

3. Theoretical Framework

This study is based on the concept of EKC which was initially developed by Kuznets (1955) to derive income inequality from economic growth. It shows that lower EG increases income inequality while higher EG declines income inequality. Later on, Grossman and Krueger (1995) extended this concept using the EKC using EG and environmental pollution. The EKC shows that lower EG worsens the environment, while after a certain limit, the higher level of EG improves the environment quality, which proposes the inverted U-shaped relation (Ahmad et al., 2021; Jahanger et al., 2022; Nathaniel, 2021). According to Haans et al. (2016) there is also the possibility of a U-shaped curve, which shows that lower EG improves environmental quality while higher EG decreases environmental pollution (Caglar et al., 2021; Destek et al., 2018). The present study extends the application of EKC or U-shaped curves by using the HDI and EFP. The EKC shows lower HDI declines the EFP while a higher HDI increases the EFP. While the U-shaped curve shows lower HDI increases the EFP and higher HDI reduces the EFP. Figure 2 depicts the conceptual framework for this study.
4. Data and methodology

To explore the link between sustainable economic development and ecological footprint (EFP) to achieve a sustainable environment. For this purpose, sustainable development is measured by using the human development index (HDI) and EFP per consumption to measure environmental degradation. This study is based on panel data of 93 developed and 78 developing countries from 1990 to 2020. We categorize developed countries as higher middle-income countries and higher-income countries. In contrast, developing countries are considered lower-income and lower-middle-income countries by the recommendation of the world bank (WDI, 2022). In this study, three quantile groups are built on the original EFP value as lower EFP, middle EFP, and higher EFP groups at 25%, 50%, and 75% quantiles. Further, Table 1 lists the variables.

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Description</th>
<th>Units</th>
<th>Sources</th>
</tr>
</thead>
<tbody>
<tr>
<td>EFP</td>
<td>Ecological footprint consumption</td>
<td>per capita</td>
<td>GFN (2022)</td>
</tr>
<tr>
<td>HDI</td>
<td>Human development</td>
<td>Index (0-1)</td>
<td>UNDP (2022)</td>
</tr>
<tr>
<td>FFEC</td>
<td>Fossil fuel energy consumption</td>
<td>% of total</td>
<td>WDI (2022)</td>
</tr>
<tr>
<td>MAN</td>
<td>Manufacturing, value added</td>
<td>% of GDP</td>
<td>WDI (2022)</td>
</tr>
<tr>
<td>EUVI</td>
<td>Export unit value index</td>
<td>2015 = 100</td>
<td>WDI (2022)</td>
</tr>
<tr>
<td>URP</td>
<td>Urban population</td>
<td>% of total population</td>
<td>WDI (2022)</td>
</tr>
</tbody>
</table>
This study is examining the effect of EFP as the dependent variable as part of the analysis. In the literature, several studies used EFP as the dependent variable (Ahmed & Wang, 2019; Danish et al., 2020; Pata et al., 2021). A key independent variable is HDI, and it is viewed as the most important one when determining EFP. There has been extensive literature that identifies HDI as the primary determinant of EFP in numerous studies (Ahmed et al., 2020; Q. Wang et al., 2022). In order to derive the EKC hypothesis, the level and quadratic terms of the EFP and fossil energy have been employed. It can be inferred from this that the functional form based on the conceptual framework can be presented as follows:

$$EFP=f(HDI, HDI^2, LNFFEC, LNMAN, LNEUVI, LNURP)$$ \hspace{1cm} (1)

Based on equation (1), multiple regression can be written as

$$EFP = \beta_0 + \beta_1 HDI_{it} + \beta_2 HDI_{it}^2 + \beta_3 LNFFEC_{it} + \beta_3 LNMAN_{it} + \beta_3 LNEUVI_{it} + \beta_3 LNURP_{it} + \varepsilon_{it}$$ \hspace{1cm} (2)

In equation (2), $\beta_1$ and $\beta_2$ shows the level and quadratic coefficient of HDI which is used to check the validity of the EKC hypothesis. To calculate the cut-off value of the EKC shaped, partial derivative with respect to HDI is used as:

$$\frac{\partial EFP}{\partial HDI} = \beta_1 + 2\beta_2 HDI = 0$$

$$HDI^* = -\frac{\beta_1}{2\beta_2}$$ \hspace{1cm} (3)

Expression (3) shows the cut-off value of the EKC hypothesis.

In this study, the different determinants of EFP are estimated using a robust panel quantile regression approach (PQR). There is no specific distributional assumption in the PQR model, so it is treated as non-parametric. Additionally, it is also suitable for outliers and non-normality distribution. The Ususall OLS model may provide misleading results in the presence of outliers but the PQR approach minimizes the influence of outliers. OLS can only be applied to normally distributed data, whereas non-normally distributed data can cause spurious results. Therefore, this study uses three quantile groups based on EFP. These groups have built lower EFP groups, middle EFP groups, and higher EFP groups at 25%, 50%, and 75% quantiles. Rani et al. (2022a) and Asghar, Amjad, and Rehman (2022) developed a similar estimation technique.

5. Results and Discussion

It is pertinent to note that Tables 2 and 3 provide statistics that describe the characteristics of the empirical dataset for developed and developing countries. This helps to summarize and describe the characteristics of this empirical dataset in an easy-to-understand way. Furthermore, it is also helpful to understand the distribution of the variables, identify potential outliers or errors, and gain insight into the relationship between variables (Asghar, Amjad, Rehman, et al., 2022; Rani et al., 2022b). It measures the central tendency and dispersion of EFP, HDI, LNFFEC, LNMAN, LNURP, and LNEUVI. A higher kurtosis value indicates the presence of outliers which is considered the pre-condition of the PQR estimation approach. The significant probability value shows that variables are not normally distributed (Amjad et al., 2022).
Table 2: Descriptive statistics of the Developed countries

<table>
<thead>
<tr>
<th></th>
<th>EFP</th>
<th>HDI</th>
<th>LNFFEC</th>
<th>LNMAN</th>
<th>LNURP</th>
<th>LNEUVI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean</td>
<td>4.2289</td>
<td>0.7658</td>
<td>24.8801</td>
<td>14.2985</td>
<td>15.1136</td>
<td>2.7911</td>
</tr>
<tr>
<td>Median</td>
<td>3.7588</td>
<td>0.7700</td>
<td>24.7803</td>
<td>14.8153</td>
<td>15.2582</td>
<td>3.2634</td>
</tr>
<tr>
<td>Maximum</td>
<td>17.7261</td>
<td>0.9620</td>
<td>30.6233</td>
<td>20.4946</td>
<td>20.5803</td>
<td>5.3481</td>
</tr>
<tr>
<td>Minimum</td>
<td>-4.6903</td>
<td>0.4120</td>
<td>18.9630</td>
<td>0.0000</td>
<td>10.0120</td>
<td>-1.2385</td>
</tr>
<tr>
<td>Std. Dev.</td>
<td>2.5856</td>
<td>0.1014</td>
<td>2.2083</td>
<td>3.5014</td>
<td>2.0622</td>
<td>1.2511</td>
</tr>
<tr>
<td>Skewness</td>
<td>1.4276</td>
<td>-0.3096</td>
<td>-0.0384</td>
<td>-2.7620</td>
<td>-0.2953</td>
<td>-1.4776</td>
</tr>
<tr>
<td>Kurtosis</td>
<td>6.3791</td>
<td>2.6373</td>
<td>2.6798</td>
<td>12.2465</td>
<td>3.0784</td>
<td>3.8326</td>
</tr>
<tr>
<td>Jarque-Bera</td>
<td>2350.9210</td>
<td>61.8555</td>
<td>13.0205</td>
<td>13935.960</td>
<td>42.6318</td>
<td>1132.345</td>
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<tr>
<td>Probability</td>
<td>0.0000</td>
<td>0.0000</td>
<td>0.0015</td>
<td>0.0000</td>
<td>0.0000</td>
<td>0.0000</td>
</tr>
<tr>
<td>Observations</td>
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<td>2883</td>
<td>2883</td>
<td>2883</td>
<td>2883</td>
<td>2883</td>
</tr>
</tbody>
</table>

Table 3: Descriptive statistics of the Developing countries

<table>
<thead>
<tr>
<th></th>
<th>EFP</th>
<th>HDI</th>
<th>LNFFEC</th>
<th>LNMAN</th>
<th>LNURP</th>
<th>LNEUVI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean</td>
<td>1.5332</td>
<td>0.5106</td>
<td>2.2757</td>
<td>2.1669</td>
<td>3.5147</td>
<td>4.2349</td>
</tr>
<tr>
<td>Median</td>
<td>1.2961</td>
<td>0.5010</td>
<td>2.8998</td>
<td>2.3192</td>
<td>3.5609</td>
<td>4.4318</td>
</tr>
<tr>
<td>Maximum</td>
<td>10.6394</td>
<td>0.9230</td>
<td>4.8335</td>
<td>4.3092</td>
<td>4.4878</td>
<td>5.9521</td>
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<tr>
<td>Minimum</td>
<td>-0.8673</td>
<td>0.0280</td>
<td>0.0000</td>
<td>-1.7037</td>
<td>1.6894</td>
<td>0.0000</td>
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<tr>
<td>Std. Dev.</td>
<td>0.9954</td>
<td>0.1298</td>
<td>1.8825</td>
<td>0.8603</td>
<td>0.4983</td>
<td>0.8649</td>
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<td>Skewness</td>
<td>3.3327</td>
<td>0.1526</td>
<td>-0.1941</td>
<td>-1.2157</td>
<td>-0.3972</td>
<td>-3.5233</td>
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<tr>
<td>Kurtosis</td>
<td>20.5895</td>
<td>2.9331</td>
<td>1.3062</td>
<td>4.4064</td>
<td>2.6962</td>
<td>17.7357</td>
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<tr>
<td>Jarque-Bera</td>
<td>35646.9900</td>
<td>9.8361</td>
<td>304.2322</td>
<td>794.8797</td>
<td>72.8782</td>
<td>26879.8300</td>
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<td>0.0000</td>
<td>0.0000</td>
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<tr>
<td>Observations</td>
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<td>2418</td>
<td>2418</td>
<td>2418</td>
<td>2418</td>
<td>2418</td>
</tr>
</tbody>
</table>

Figure 4 shows the correlation plot of the developed and developing countries. Light colour illustrates a weak correlation between the independent variables which shows the lower issue of multicollinearity and the model can be used for further estimation(Asteriou & Hall, 2006; Gujarati, 2016).

![Figure 4 Correlation plot](image-url)
Table 4 presents the detailed results of the PQR model for both developed and developing countries in the lower, middle, and higher EFP groups. The PQR is a non-parametric technique, so there is no need to check the stationary behavior using unit roots and co-integration of the model because these concepts refer to the time series behavior. PQR focuses only on estimating the conditional quantile of the dependent variable (Koenker & Bassett, 1978).

In table 4, three groups are constructed on the base of the original value of the EFP at 25%, 50%, and 75% quantile in developed and developing countries. In this study, manufacturing value added (LNMAN), Export volume index (LNEUVI), and urbanization (LNURP) are used as the control variables. LNMAN inversely impacts the EFP in all quantile groups except the lower EFP group of developing countries (Jorgenson & Burns, 2007). LNEUVI has a mixed effect on EFP across each quantile group. It inversely impacts the EFP in lower and middle EFP groups in developing countries and high EFP groups in developed countries (Kazemzadeh et al., 2022; Raimo et al., 2022; Topcu & Altay Topcu, 2021) and positively impacts the EFP in lower and middle EFP in developed countries (Khan et al., 2021). LNURP has also a mixed effect on EFP. It positively impacts the EFP in developing countries at all quantile groups (Kassouri, 2021; Qayyum et al., 2021) while it inversely impacts the EFP in all quantile groups in developed countries (Danish et al., 2020; Sahoo & Sethi, 2021).

In this study, EKC is derived by using the level and quadratic coefficients of HDI on EFP in both developed and developing countries. In developing countries, the HDI level coefficient inversely impacts EFP in all quantile groups. This is because a lower HDI shows a lower level of income, education, and human health which reduce the consumption of natural resources, resulting in the decline of EFP. Additionally, low HDI countries usually have less advanced infrastructure which tends to lower resource consumption (Dialga & Ouoba, 2022; Q. Wang et al., 2022).

The quadratic coefficient of HDI positively impacts the EFP in all quantile groups in developing countries. It shows a higher level of HDI causes a higher level of resource consumption which increases EFP. Usually, in developing countries when their HDI increases, most citizens tend to consume more natural resources due to poor industrial and technological capabilities. The level negative coefficient of HDI and positive quadratic coefficient of HDI propose the U-shaped relationship and failed to verify the EKC (Mehmood, 2021).

In the case of developed countries, lower EFP groups propose the U-shaped relationship between EFP and HDI (Caglar et al., 2021; Destek et al., 2018). This relationship is thought to arise due to several factors. At lower levels of HDI, people tend to consume fewer resources and live more sustainably, leading to a lower EFP. However, as countries become more developed and wealthier, they tend to consume more resources and engage in more environmentally damaging activities, leading to a higher EFP. It is worth noting that this relationship is not universally observed across all countries and that many other factors can influence a country’s EFP, including its geography, climate, population size, and political and economic systems.

While on the other hand, higher EFP groups propose the EKC hypothesis in developed countries (Ahmad et al., 2021; Jahanger et al., 2022; Nathaniel, 2021). It suggests that as countries initially develop, their EFP tends to increase as a result of industrialization, urbanization, and increasing consumption of resources. However, as countries become wealthier and more technologically advanced, they begin to adopt more sustainable practices and shift towards a service-oriented economy, leading to a decrease in EFP. This relationship is believed to arise from a combination of factors, including the adoption of cleaner technologies, improvements in energy efficiency, and changes in consumption...
Several studies used fossil fuels (LNFFEC) to derive the EKC hypothesis. In this study, in most of the quantile groups, LNFFEC positively impacts the EFP (Akalin et al., 2021; Asghar et al., 2023; Ibrahiem & Hanafy, 2020).

If we compare developing countries with developed countries, it is noted that there are differences in the relationships between EFP and HDI across each group. In general, developing countries tend to have a U-shaped relationship showing as they become more developed, their EFP eventually increases. In contrast, developed countries tend to have a more complex relationship, with a U-shaped relationship in the lower EFP group, and EKC relationship in the higher EFP group. This suggests that developed countries have reached a turning point where they have started to pay more attention to the environment and adopt more sustainable practices.

Table 5 estimated the turning point of all quantile groups across countries. The value of the turning point lies between the upper and lower limit of EFP which shows the validation of the U and inverted U-shaped curve (Asghar, Amjad, & Rehman, 2022).
Table 5 Cut-off value of HDI

<table>
<thead>
<tr>
<th></th>
<th>Developing countries</th>
<th>Developed countries</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Lower EFP</td>
<td>Middle EFP</td>
</tr>
<tr>
<td>Turning points</td>
<td>0.4064</td>
<td>0.4348</td>
</tr>
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The level and quadratic coefficient of HDI are traced by using the mean and constant terms followed by Dawson (2014). Figure 5 shows the quadratic effect of HDI on EFP in developing countries in all quantile groups. These figures demonstrate the U-shaped curve at lower, middle and higher EFP groups. While on the other hand, figure 6 also labels the quadratic effect of HDI on EFP in developed countries. It shows the U-shaped curve in the lower EFP group while an inverted U-shaped EKC in the higher EFP group.

Figure 5 Quadratic effect of HDI on EFP in developing countries

Figure 6 Quadratic effect of lower EFP in developed countries

Tables 6 and 7 show the linearized effect of the quadratic coefficient of HDI in both developed and developing countries. In the case of developed countries, only Equatorial Guinea country’s HDI inversely impacts the EFP in lower and higher EFP groups. While in the case of developing countries Afghanistan, Burki Faso, Burundi, Central African Republic, Chad, Congo (Dem.), Djibouti, Eritrea, Ethiopia, Guinea, Guinea-Bissau, Liberia, Mali, Mozambique, Niger, Rwanda, Sierra Leone, and South Sudan lie before the turning point of the U-shaped curve while remaining countries lie after the turning point of the U-shaped curve in all quantile groups.
### Table 6 Linearized effect of developed countries

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Table 7 Linearized effect of developing countries

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Note: * shows HDI inversely impacts the EFP countries

6. Conclusion and Policy Recommendations

The key objective is to derive the EKC hypothesis by using the HDI and ecological footprint (EFP) in 78 developing and 93 developed countries from 1990 to 2020. For this purpose, the panel quantile regression (PQR) is used for three quantile groups the lower EFP groups, middle EFP groups, and higher EFP groups at 25%, 50%, and 75% quantiles. The empirical results show at lower EFP groups
exists a U-shaped relationship while higher EFP group shows the evidence of EKC hypothesis in developed countries. This means that developed countries initially focus on increasing economic development without caring about the environment. However, as they continue to develop economically, they may begin to invest in more environmentally friendly technologies and practices, resulting in a decrease in environmental degradation. In the case of developing countries, there exists a U-shaped relationship between HDI and EFP across all quantile groups. This means that as these countries initially underdeveloped and then further developed which increases the natural resource consumption that increases EFP. However, the fact that this relationship is observed across all quantile groups of developing countries suggests that it may be more difficult for these countries to prioritize environmental concerns over economic growth, regardless of their level of development.

This study recommends several policy recommendations that the developed countries with higher EFP should continue to invest in environmentally friendly technologies and practices to reduce their environmental impact. This may include policies to encourage the use of renewable energy, promote sustainable transportation, and incentivize businesses to reduce their carbon footprint. Furthermore, International cooperation and financial support can play an important role in helping developing countries transition to more sustainable development paths. Developed countries and international organizations can provide funding, technical assistance, and knowledge-sharing to support sustainable development in developing countries.

This study can be extended for future research works by extending the analysis to a longer time frame to better understand the longer-term dynamics of the relationship between HDI and EFP. This study focuses on cross-country comparisons, so future research could examine how the dynamics of the EKC hypothesis play out within individual countries over time, taking into account the specific political, social, and economic context of each country.

References


Destek, M. A., Ulucak, R., & Dogan, E. (2018). Analyzing the environmental Kuznets curve for the EU


Gujarati, D. N. (2016). *Basic econometrics*.


manufacturing affect environmental quality? Evidence from the top ten manufacturing
https://doi.org/10.2307/1913643


