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Asymmetric effect of human capital on the ecological footprint within the EKC framework in Saudi Arabia[1]

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ABSTRACT

In contrast with previous studies exploring the linear effect of increasingly educated human capital on environmental degradation, this study examined the non-linear relationship utilizing the Environmental Kuznets Curve (EKC) framework. It offers empirical evidence considering the developing and oil-rich economy of Saudi Arabia. The ARDL model was estimated, to reveal that the gross tertiary enrolment ratio has an inverse-U shaped relationship with ecological footprint. This is consistent with our assumption within EKC model, in that when schooling enrolment rates are low in the early stages of economic development, environmental degradation is augmented. However, after reaching the turning point in education, the increase in enrolment rates reduces degradation. This indicates that human capital can exert opposing effects on environmental quality, relative to level of economic development and expansion in education. The empirical findings suggest education is vital to reduce environmental degradation and upgrade energy efficiency and sustainability in the context of Saudi Arabia. The study suggests raising individuals' awareness, environmental education, and increasing knowledge concerning the significance of climate change actions must be integrated into environmental policies and strategic agendas.

Keywords: *environmental degradation; ecological footprint; education; human capital; sustainable development; Saudi Arabia.*

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1. INTRODUCTION

Achieving high economic growth rates while also respecting the quality of the global environment is a major challenge worldwide, especially for developing economies. However, Hanifet al. (2019) pertinently observe, "it is understandable that caring for the environment might be seen as a luxury in developing countries, and why populations may not yet be willing to prioritize or pay for environmental in human health" (p.494). In developing economies, regulations that are relevant to environmental preservation are less rigorous than in the developed world (Murshed et al., 2021). Environmental degradation and its different impacts on economic and demographic aspects has attract attention of researchers. Human capital or education is one of potential and important determinants of environmental quality as discussed in the literature of environmental economics. Kumar et al. (2023) say "climate literacy serves as the foundation for well-informed adaptation and mitigation measures" (p.2).

1-1 Research objective

The study aims to analysing the asymmetric relationship between human capital and ecological degradation in the case of Saudi Arabia in the long-term and short - term.

1-2 Research problem and importance

The problem and the importance of this study manifest in considerable challenges and hazards that surrounding eco-system, thus this issue is a hot topic today and it has become utmost priority for policy makers and governments around the world. As notably by researchers sustainable development is linked to environmental sustainability, implying the significance of environmental performance in achieving sustainability for economy. Shahbaz and Sinha (2019) state that "environmental sustainability is a part of the broader sustainable development"(p.157). In addition, environmental quality and its related issues has investigated deeply in the literature among economists, environmentalists, and other scholars to highlight the critical factors that damage environment to draw significant policy implications. The importance and motivation of study being stems from considering Saudi Arbia for a variety of factors.

First, Saudi Arabia is resource-based economy and is one of the greatest oil exporters globally. According to EIA (2021), Saudi Arabia represents the second largest energy consumer in the Middle East and the 11th largest in the world in 2020. Saudi vision 2030 aims to improve industrialization in the non-oil sectors, coupled with expansion in industries linked to natural resources. Industrialization reduces air, water, and soil quality, as evidenced in many countries; and improvements to industry have received great attention from economies in the Middle East (Mahmood et al., 2020).Thus, one of the strategic goals of Saudi vision 2030 is to develop clean and renewable energy through establishing vital programmes and projects. To adopt advanced green and energy-efficient technology, utilizing tertiary education level is appropriate, as skills related to production. Human capital gauged by tertiary education level, fosters renewable energy usage via three channels: supplying skilled labour, increasing the environmental knowledge of both individuals and society, and reinforcing the role of economic development (Mehrara et al., 2015). In addition, highly educated workers at college participate in environmental performance of firm, and the latter with high human capital assist in acquiring superior environmental compliance (Lan and Munro, 2013).

Second, another related issue is population increase, as this will heighten pressure on the earth's limited resources, due to greater energy consumption. Population size is one of factors that contributes most to developing a connection between human activities and environmental degradation (Harte, 2007). The population in Saudi Arabia represents the biggest in the Middle East countries at about 35 million, and it is expected to reach 50 million by 2030. Furthermore, road transportation, which is one of the source categories for the energy sector in Saudi Arabia releases the second largest quantity of greenhouse gases after electricity generation (Rahman et al., 2017). The authors state that increasing population growth, urbanization, transportation, and industrialization, in addition to high prices for oil globally and cheap fuel prices locally gives rise to growing demand non-clean energy sources. Thus, we believe that education is imperative as an instrument to lower environmental degradation resulting from these factors and to diffuse awareness among the population.

Finally, there is a large ecological deficit in the country, as apparent from Figure 1, as ecological footprint (EF) is greater than biocapacity. EF per capita rose from

2.94 in 1986 to 5.72 in 2017, representing an increase of about 2.78. On the other hand, education has progressed considerably in Saudi Arabia along with high government expenditure on this sector. In addition, the enrolment ratio at higher education level has witnessed a significant increase as shown in the Figure 2, reaching more than 70% in 2021. It would be interesting to explore whether such a significant expansion in education may contribute to reducing ecological footprint and increases biocapacity in the long-term. Based on all these considerations we believe Saudi Arabia importantly is the appropriate case in which to examine the effect of human capital on the quality of environment.

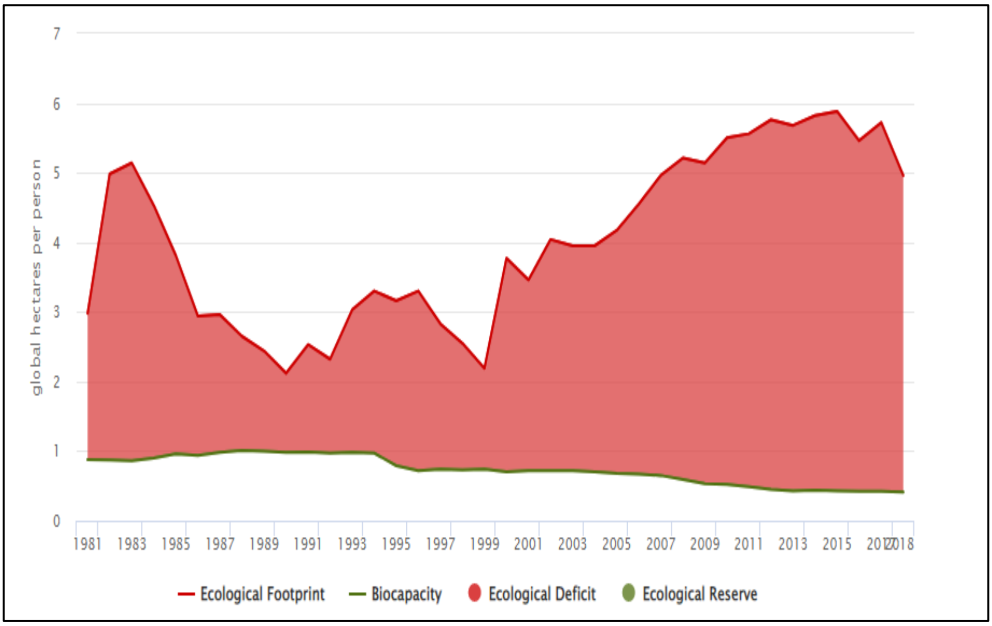

Figure 1: Ecological footprint per capita and biocapacity per capita in Saudi Arabia

Source: The figure was produced by the Global Footprint network (2022)

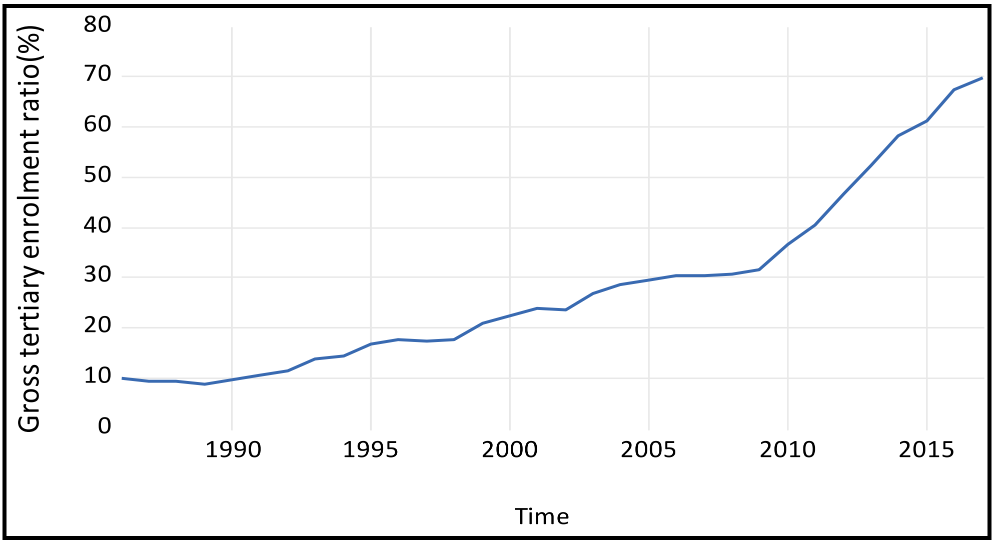

Figure 2: Gross Tertiary enrolment ratio (1986-2017) in Saudi Arabia

Source: The figure was produced by the author using the World Bank database (2022)

1-3 Research hypothesis within the EKC framework

This study seeks to address the question of whether human capital via education contributes to lowering environmental damage. Thus, the study assumes the presence of non-linearity relationship between human capital and environmental degradation. The Environmental Kuznets Curve (EKC) model assumes the presence of an inverted U-shaped relationship between environmental degradation and income, in that environmental deterioration is augmented with growing income in the initial stages of development until achieving the optimum level of income per capita, at which point it starts to diminish. Accordingly, the level of environmental degradation and its undesirable consequences depend on the stage of economic development. The explanation for this inverse U-shaped relationship is attributed to three effects: the scale, the composition, and the technical effects (Ozcan et al., 2020).

Following Balaguer and Manuel Cantavella (2018), similar to income, the linear effect of education on the environment is relaxed in the EKC model, having two opposite effects, since education and income are connected. Thus, the non-linear effect of human capital on ecological footprint is modelled in the EKC model as shown in the section (3) in our empirical model. Put another way, as per the EKC hypothesis when enrolment rates in higher education are low, environmental degradation increases, until it is reaching a certain threshold education level when education expands, environmental damage then reduces. The authors also postulate that, due to its significance, the second effect may outweigh the first. This is consistent with Grossman and Krueger (1991), who noted that environmental awareness heightened by education can encourage policymakers to formulate environmentally friendly policies, which then pushes the (EKC) to adopt an inverted U-shaped form (Zafar et al., 2020).

1-4 Research contribution

This study contributes by filling the gap in a time-series studies that investigate this relationship from three main perspectives. First, the findings reported in the previous literature are paradoxical. While some papers identify the negative effect of human capital on environmental degradation, other consider the relationship is positive. Certainly, more education would be expected to increase the knowledge of society regarding environmental matters. To determine the extent of these effects, the present study tests for the existence of an inverted U-shaped correlation between ecological footprint and education human capital. Testing for asymmetric impact may help to combine both opposite effects based on expansion in education, and the level of economic development, to better understand the nature of the relationship and reconcile the divergent findings present in the prior literature. Contrasting with the limited number of studies that examine the non-linear effects from education in developed countries, we will provide different assessment by evaluating a developing economy.

In addition, these studies employed CO_2 emissions to measure environmental degradation, whereas we use an ecological footprint that considers multiple types of environmental degradation. CO_2 represents just one dimension of environmental degradation in the form of air pollution, which make it a weak indicator (Ozcan et al., 2020). Furthermore, this measure ignores the adverse impacts of the population on the land area required for sustainable utilization of natural resources, which in turn harms the environment (Nathaniel et al., 2019). In terms of sustainability, Galli et al. (2012) noted: "Ecological Footprint and biocapacity values are used to measure one key aspect of sustainability: the human appropriation of the Earth's regenerative capacity"(p.102). Thus, ecological footprint inclusively reflects environmental deterioration to enables us to examine this relationship from a broader vantage point. This is in turn helps when obtaining more valid estimates that appropriately interpret the role of human capital in improving environmental quality.

Finally, as aforementioned, to the best of our knowledge, this is the first study to consider the Saudi economy when analysing the effect of human capital on environmental quality. Thus, this research will encourage policy makers to take education as a vital component of active initiatives on climate change and the environment and highlight its integrative role in line with other mitigating policy measures as at this time Saudi Arabia is undergoing a major transformation towards the adoption of clean energy and sustainable environment.

The rest of the paper is organized as follows. The literature is reviewed in section (2) provides. The methodology is offered in section (3). This section is divided into two sections: sub-sections (2.1) and (3.2) show the empirical model and estimation method and data sources, respectively. The prime findings are presented and discussed in section (4). The section (5) presents the conclusions.

2. LITERATURE REVIEW

Education can influence environmental behaviour through two channels as explicated by Chankrajang and Muttarak (2017): the first channel is direct, comprising knowledge, skills, and competencies attained through formal education enhancing favourable attitudes among the population towards the environment; while the second channel is indirect, informing actions to mitigate environmental damage. Importantly, increasing level of awareness through education spurs individuals over time to utilize renewable energy, which is cleaner than fossil fuels (Irfan et al., 2021; Altuntaş and Turan, 2018). As debated by Zafar et al. (2019) that in the absence of highly educated and skilled human capital, the sustainable usage of natural resources cannot be achieved. In their research, Arora and Mishra (2019) note the "Building of awareness through education should be encouraged and intensified to support sustainability agendas" (p.341). In addition, education has been found to foster pro-environmental behaviour, based on acquired knowledge and improved realization of environmental matters (Mayer, 2015; Chankrajang and Muttarak, 2017). Among these are conserving water, recycling, ensuring energy efficiency, utilizing green technology, reducing deforestation, ecolabelling food to alter consumption patterns (Ahmed and Wang, 2019).

Additionally, Huang et al. (2021) suggest that technological innovation is enhanced by the inclusion of skilled human capital within enterprises, and this reinforces energy efficiency and the optimization and allocation of energy sources. In their theoretical analysis, Karakul (2016) highlight the green economy and identify jobs in the renewable energy sector that can be realized by educating the labour force through a specific educational system which assist in developing green collar industry. Empirical findings reported by Naseer et al. (2022) note the significance of fostering education and training as a way of encouraging employees to adopt green technology that in turn curbs CO_2 emissions, concurring with results reported by Ullah et al. (2021) showing technology innovation and environmental quality are correlated.

Recently, human capital or education has come increasingly considered in the empirical literature as a crucial determinant of environmental quality. Examples on the studies that recently consider the linearity relationship on a multi-country basis considering developing countries and the linear impacts of educated human capital on ecological footprint (e.g., Amer et al., 2022; Jahanger et al., 2022; Nathaniel et al., 2021; Iorember et al., 2021; Langnel et al., 2021). In addition, a portion of the literature employs time-series data for this purpose as in our case, see for example Dada et al. (2022) for Nigeria, Ahmed and Wang (2019) for India, Ahmed et al. (2020), Pata and Caglar (2021) for China, Danish et al. (2019), Zhang et al. (2021) for Pakistan, Chankrajang and Muttarak (2017) for Thailand. The above studies obtained mixed results by providing different perspectives and contributions, with no consensus as yet.

However, as our study focuses on the non-linear effect, those studies that scrutinize the non-linear relationship between education and environmental degradation are very limited. Leading work of Balaguer and Cantavella (2018) examined the non-linear association between education and environmental degradation within the EKC model. The study considers a developed country of Australia and using CO_2 emissions as a measure for environmental damage for the period between 1950 and 2014. The estimates of ARDL model identified that education measured by total number of students at higher education has the asymmetric impact on CO_2 emissions.

The following study is Zafar et al. (2020) in the OECD. The study explored the relationship between renewable energy and CO_2 over the time periods

(1990-2015) among other variables including education, natural resources, FDI and economic growth. The authors examined both linear and non-linear effect, to find out that education relates asymmetrically with CO2 emissions as reported by the Cup-FM and pooled mean group (PMG) estimates.

Building on previous literature that considers non-linearity, the current study will provide evidence of time-series data by considering developing country and using the measure of ecological footprint for environmental degradation rather than weak proxy of CO2 emissions that frequently used in the literature.

3. METHODOLOGY

3.1 Empirical model and estimation method

Based on what discussed in theoretical and empirical literature through the paper, we utilize the Environment Kuznets Curve (EKC) model as written below to test our hypothesis:

$$lnEF_t = \alpha_0 + \beta_1 lnPGDP_t + \beta_2 lnPGDP_t^2 + \beta_3 lnTHC_t + \beta_4 lnTHC_t^2 + \beta_5 lnX_t + u_t \quad (1)$$

As $lnEF_t$ is the log for ecological footprint per capita, $lnPGDP_t$ and $lnPGDP_t^2$ indicates the log for per capita GDP and the log for $PGDP$ squared, respectively to account for inverse-U shaped relationship of economic development and ecological footprint as proposed by Grossman and Krueger (1991) as displayed in the EKC model. The model is extended to introduce our interest variable, which is the log of human capital and its quadratic denoted by $lnTHC_t$ *and* $lnTHC_t^2$ respectively to capture the non-linear effect according to our hypothesis as discussed in the section (1). Furthermore, lnX_t contains other control macroeconomic variables, and u_t is the unobservable error term.

In our model, we also control for the additional variables that influence environmental degradation, as suggested in the previous literature. We consider in particular energy consumption, trade openness and air transport. However, considerable attention has been directed towards energy consumption as a critical determinant to environmental damages in the literature. To promote economic growth in developing economies, energy is considered an essential factor with fossil-fuel comprising the main conventional energy source (Sinha et al., 2017) that results in environmental degradation (Hanif, 2018). We also include trade openness in our model, as many studies have explored the trade openness and environmental quality nexus (Kongbuamai et al., 2020; Udeagha and Ngepah, 2022; Liu et al., 2022). Finally, we control for air transport, which is considered a further possible variable with potential to augment environmental degradation. With continuous growth in aviation, unfavourable effects on the environment including noise, air pollution and climate change are expanding accordingly (Schäfer and Weitz, 2014). Emissions resulting from aviation negatively affect the climate system (Lee et al., 2021).

In estimating the link between human capital and ecological footprint, the current research used the econometrics and analytical approach, in particular, the autoregressive distributed lag (ARDL) technique. According to Pesaran et al. (2001), the presence of different order of integration at level I (0) or first difference I (1) is possible with the ARDL approach, on the condition that there is no variable is stationary at I (2); and also, it efficiently works with small datasets. These merits make such approach is more appeal and useful in the literature, in comparison with the other prevalent cointegration methods that frequently utilized in prior studies such as Johansen et al. (1990). Thus, prior to proceeding to estimate the ARDL model, it is fundamental to test the order of integration for variables first. To this end, we employed two-unit root tests: Augmented Dicky Fuller (1979) denoted by (ADF) and Phillips and Perron (1989) signified by (PP). The ARDL model including our study variables can be written by the equation (2) is as follows:

$$\begin{aligned}\Delta lnEF_t = {} & \alpha_0 + \alpha_1 lnEF_{t-1} + \alpha_2 lnPGDP_{t-1} + \alpha_3 lnPGDP^2_{t-1} + \alpha_4 lnEC_{t-1} + \alpha_5 lnTHC_{t-1} + \alpha_6 lnTHC^2_{t-1} \\ & + \alpha_7 lnAT_{t-1} + \alpha_8 lnOP_{t-1} + \sum_{i=1}^{p} \gamma_i \Delta lnEF_{t-i} + \sum_{j=1}^{q} \delta_j \Delta lnPGDP_{t-j} + \sum_{l=1}^{q} \vartheta_l \Delta lnPGDP^2_{t-l} \\ & + \sum_{m=1}^{q} \mu_m \Delta lnEC_{t-m} + \sum_{s=1}^{q} \pi_s \Delta lnTHC_{t-s} + \sum_{n=1}^{q} J_n \Delta lnTHC^2_{n-1} + \sum_{h=1}^{q} \theta_h \Delta lnAT_{t-h} \\ & + \sum_{k=1}^{q} \varphi_k \Delta lnOP_{t-k} + u_t \end{aligned} \tag{2}$$

Based on equation 2, we test ARDL bounds using F-test. In order to check the presence of cointegration relation, we compare computed F-statics with two asymptotic critical statistics that provided by Pesaran et al. (2001). Put another way, if outcomes found that the calculated F-statistic is higher than upper critical bound I (1) it means there is cointegration relationship among the variables and (Ho) hypothesis that states the cointegration relation between variables is no exist is rejected. However, if the result shows that the computed F-statistic is under than the lower critical bound I (0) the cointegration relationship among the variables is not exist and the null hypothesis is accepted. In the case of the F-statistic located between I (0) and I (1), the result is inconclusive.

In the case of the cointegration relationship is found, we estimate the long-term and short-term relationship per equations (3) and (4) as follows:

$$lnEF_t = \alpha_0 + \sum_{i=1}^{p} \gamma_i \Delta lnEF_{t-i} + \sum_{j=1}^{q} \delta_j \Delta lnPGDP_{t-j} + \sum_{l=1}^{q} \vartheta_l \Delta lnPGDP_{t-l}^2 + \sum_{m=1}^{q} \mu_m \Delta lnEC_{t-m} + \sum_{s=1}^{q} \pi_s \Delta lnTHC_{t-s} + \sum_{n=1}^{q} \beth_n \Delta lnTHC_{n-1}^2 + \sum_{h=1}^{q} \theta_h \Delta lnAT_{t-h} + \sum_{k=1}^{q} \varphi_k \Delta lnOP_{t-k} + u_t \quad (3)$$

$$\Delta lnEF_t = \alpha_0 + \sum_{i=1}^{p} \gamma_i \Delta lnEF_{t-i} + \sum_{j=1}^{q} \delta_j \Delta lnPGDP_{t-j} + \sum_{l=1}^{q} \vartheta_l \Delta lnPGDP_{t-l}^2 + \sum_{m=1}^{q} \mu_m \Delta lnEC_{t-m} + \sum_{s=1}^{q} \pi_s \Delta lnTHC_{t-s} + \sum_{n=1}^{q} \beth_n \Delta lnTHC_{n-1}^2 + \sum_{h=1}^{q} \theta_h \Delta lnAT_{t-h} + \sum_{k=1}^{q} \varphi_k \Delta lnOP_{t-k} + u_t \quad (4)$$

After estimating the model, we used the diagnostic tests comprising of serial correlation, heteroscedasticity, and functional form, using Ramsey's RESET test to check whether the model estimates are sufficient, valid, and well-specified. Besides, the stability of the estimated coefficients is examined by computing the cumulative sum of the recursive residuals (CUMSUM) and the cumulative sum of the squares of the recursive residuals (CUMSUMSQ).

3.2 The data

To achieve the aims of the study we use time-series data for Saudi Arabia for the period 1986 to 2017, acquired from various sources. Ecological footprint per capita (EF) is sourced from the Global Footprint Network (2022). The dataset for the main explanatory variable; human capital (THC) proxied by the total gross tertiary education enrolment ratio are extracted from World Bank (2022).

The control variables included in the model for ecological footprint are gathered from various sources. Income (PGDP) is measured by gross domestic product (GDP) per capita in constant 2015 US dollars, and energy consumption (EC) describes primary energy consumption. The data for PGDP and EC was obtained from World Bank (2022) and EIA (2022) respectively. Trade openness (OP) is the portion of exports and imports total for goods and services in GDP, and air transport (AT) is defined as "air passengers carried and includes both domestic and international aircraft passengers of air carriers registered in the country". The dataset for these two variables was also derived from the World Bank (2022).

4. MAIN RESULTS AND DISCUSSION

4.1 Unit root tests findings

It is crucial to check the order of integration for variables as this step is required prior to performing the ARDL bounds testing approach to cointegration. To this end, we used different unit root tests to verify there is no presence for variable is stationary at I (2). These unit root tests include Augmented Dickey–Fuller (ADF), and Phillips and Perron (PP). The findings of these unit root tests are displayed in Table 1 and Table 2. The outcomes reported from all the tests confirms the order of integration for the variables of study is at first difference I (1) at significance at 1%, 5% and 10% .

Table 1: The findings of the ADF unit root test

Variable	level				First difference			
	With intercept		With intercept & trend		With intercept		With intercept & trend	
	t-statistics	Prob.	t-statistics	Prob.	t-statistics	Prob.	t-statistics	Prob.
$lnEF_t$	-0.98	0.77	-3.39	0.07	-6.94	0.00	-6.86	0.00
$lnPGDP_t$	-1.74	0.40	-2.66	0.25	-6.52	0.00	-6.42	0.00
$lnPGDP^2{}_t$	-1.73	0.41	-2.66	0.26	-6.48	0.00	-6.37	0.00
$lnEC_t$	0.40	0.98	-3.16	0.11	-8.26	0.00	-8.19	0.00
$lnTHC_t$	0.83	0.99	-2.61	0.28	-4.86	0.00	-4.75	0.00
$lnTHC^2{}_t$	1.89	0.99	-1.78	0.69	-4.37	0.00	-4.59	0.00
$lnAT_t$	2.17	0.99	-0.81	0.95	-4.35	0.00	-5.33	0.00
$lnOP_t$	-1.62	0.46	-1.82	0.67	-4.47	0.00	-4.42	0.01

Source. It was estimated by the author, using EViews - 12

Table 2: The findings of the PP unit root test

Variable	level				First difference			
	With intercept		With intercept & trend		With intercept		With intercept & trend	
	t-statistics	Prob.	t-statistics	Prob.	t-statistics	Prob.	t-statistics	Prob.
$lnEF_t$	-0.57	0.86	-3.22	0.09	-7.88	0.00	-7.81	0.00
$lnPGDP_t$	-1.72	0.41	-2.55	0.31	-6.44	0.00	-6.34	0.00
$lnPGDP^2{}_t$	-1.71	0.42	-2.53	0.31	-6.39	0.00	-6.30	0.00
$lnEC_t$	0.27	0.97	-3.13	0.12	-8.35	0.00	-8.29	0.00
$lnTHC_t$	0.75	0.99	-2.84	0.19	-4.86	0.00	-4.73	0.00
$lnTHC^2{}_t$	1.76	0.99	-1.99	0.58	-4.37	0.00	-4.58	0.00
$lnAT_t$	3.27	1.00	-0.78	0.96	-4.33	0.00	-5.87	0.00
$lnOP_t$	-1.78	0.385	-1.464	0.820	-4.42	0.001	-4.35	0.01

Source: It was estimated by the author, using EViews -12.

4.2 The ARDL model estimations

Based on the unit root tests findings above, it is evident that there is no series was stationary at I (2), which endorses use of the ARDL model. We used equation 2 to estimate the long-term relationship, with the proper lag length is set by the Schwarz information criterion (SIC), using optimal lag order of 1 with considering the number of observations and variables. The empirical findings for the ARDL bounds testing are detailed in Table 3, with each variable normalised to a dependent variable. The calculated F-statistic for $F_{EF} =$ is 3.61, where the ecological footprint per capita was normalized to a dependent variable. The calculated F-statistic is higher than the upper critical bound at the 5%, and 10% significance levels. This empirical result implies a long-term relation among the variables.

Table 3: The findings of ARDL bounds testing

Dependent variable is normalized to ecological footprint per capita (EF), the ARDL specification is (1,0,0,0,0,0,1,0)				
F-statistics	***p-value***	***I*(0)**	***I*(1)**	**Cointegration**
3.61	*10%*	*2.08*	3^{***}	*Yes*
	5%	*2.39*	3.38^{**}	
	1%	3.06	4.15	

Source: It was estimated by the author, using EViews – 12.

Note: *, ** and *** are significance level at 1%, 5% and 10% respectively

The existence of a cointegration relation requires estimating long-term effect by equation 3. The findings are also demonstrated in Table 4 in Panel A. The results indicate that human capital and its squared has a significant positive and negative impact on ecological footprint per capita respectively. When tertiary education enrolment ratio is low, ecological footprint per capita rise by 2.49, while increasing the squared tertiary education enrolment ratio by 1% decreases ecological footprint by 0.44. It can be noted that the magnitude of positive impact is greater than the negative impact, confirming that a low-level of education in the initial stages bring greater disadvantage to the environment, indicating the importance of improving environmental knowledge via education.

Table 4: Long- and short-term ARDL estimates

Variable Dependent variable: EF_t	Coefficient	Standard error	t-statistics	p-value
Panel (A): Long - run result				
$lnPGDP_t$	-89.65	101.45	-0.88	0.39
$lnPGDP^2{}_t$	4.54	5.19	0.87	0.39
$lnEC_t$	-0.01	0.34	-0.02	0.98
$lnTHC_t$	2.49	0.94	2.64	0.02
$lnTHC^2{}_t$	-0.44	0.19	-2.30	0.03
$lnAT_t$	1.33	0.59	2.24	0.04
$lnOP_t$	0.64	0.25	2.59	0.02
Constant	416.00	497.32	0.84	0.41
Panel (B): Short-run result				
$\Delta lnPGDP_t$	-78.89	88.33	-0.89	0.38
$\Delta lnPGDP^2{}_t$	3.99	4.52	0.88	0.39
$\Delta lnEC_t$	-0.01	0.29	-0.02	0.98
$\Delta lnTHC_t$	2.19	0.86	2.56	0.02
$\Delta lnTHC^2{}_t$	-0.39	0.18	-2.20	0.04
$\Delta lnAT_t$	0.25	0.22	1.12	0.28
$\Delta lnOP_t$	0.56	0.22	2.55	0.02
ECM_{t-1}	-0.88	0.13	-6.69	0.00
Constant	366.09	433.00	0.85	0.41

Variable Dependent variable: EF_t	Coefficient	Standard error	t-statistics	p-value
Panel (C): ARDL model diagnostic tests	**F -statistics**	**P-value**		
χ^2LM-Serial correlation	0.02	0.98		
χ^2 Heteroskedasticity (Breusch-Pagan-Godfrey)	2.05	0.08		
χ^2Functional Form (REMSAY)	2.90	0.05		

Source: It was estimated by the author, using EViews -12.

Note: The ARDL specification is (1,0,0,0,0,0,1,0).

Our results correspond to a study conducted by Balaguer and Cantavella (2018) that considers the case study of Australia to experience a non-linear effect from education on carbon CO2 emissions, and also concur with outcomes of Zafar et al. (2020) in the OECD. Based on our discussion in section 2, this study affirms our hypothesis in that the presence of the inverted U-shaped for human capital via education in light of the EKC model. The empirical evidence delivered by our study presented here may provide different results in terms of human capital and its link to ecological footprint, as prior literature considering single countries have determined the relationship to be negative (Ahmad et al., 2020; Dada et al., 2022; Ahmed and Wang, 2019), while others identified the association between the two variables as positive or insignificant (Zhang et al., 2021; Sarkodie et al., 2020; Danish et al., 2019). In contrast, human capital is detrimental to environmental quality due to two opposite effects associated with the level of economic development and education. The results also correspond to those of Zsoka et al. (2013), in that there is a strong connection between students' level of education at university and environmental education forming knowledge and pro-environmental behaviour.

Concerning the additional explanatory variables in the model, the coefficients for per capita GDP and its square were insignificant, suggesting the hypothesis for EKC is not exist in the country. This result correlates with many studies that focus particularly on verifying this hypothesis (e.g., Rehman and Rashid, 2017; Lind and Mehlum, 2010). While energy consumption was found to relate insignificantly to ecological footprint, trade openness and air had a significant relationship with expected signs as identified elsewhere (Liu et al., 2022; Wang et al., 2022; Adedoyin et al., 2021; Ali et al., 2020).

The results of the short-term relation are shown in Table 5 in Panel B employing equation 4. Similarly, the results revealed that total tertiary education enrolment ratio and its squared had a significant relationship with ecological footprint per capita with expected signs. The error correction coefficient ECM reported in Table 5 in Panel B was negative and significant at-0.88. This value indicates that around 88% of disequilibrium in the short-term is adjusted annually towards long-term equilibrium.

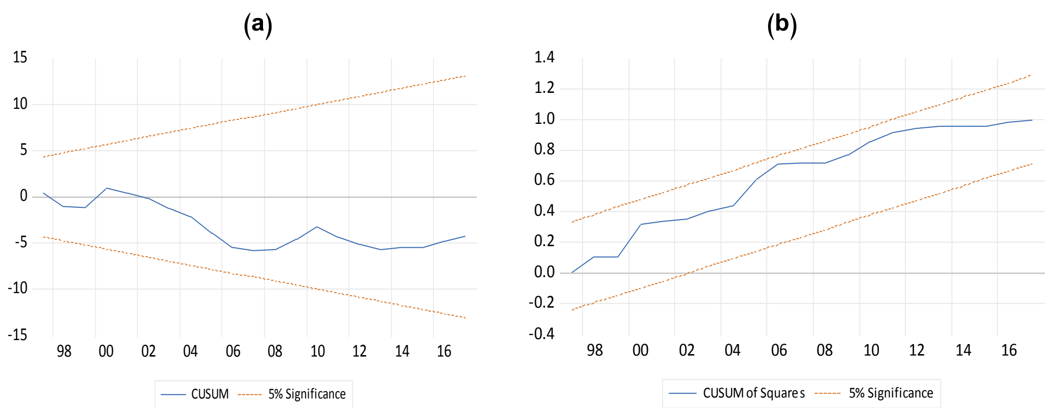

Figure 3: Coefficient stability testing

Note: (a) indicates to cumulative sum of recursive residuals,

and (b) mentions Cumulative sum of squares of recursive residuals.

The results of both serial correlation, heteroscedasticity were shown in Table 5 in Panel C, indicated that the model is correct and did not have misspecification issue. Additionally, the Ramsey test showed the functional form for the model was well-specified. Furthermore, the plots, shown in Figure 3, suggest the stability of estimated coefficients for the period (1985– 2017), because the residuals were located within the critical bounds of the 5% significance level.

5. CONCLUSION AND POLICY IMPLICATIONS

Given extremely the limited studies exploring the asymmetric impact of human capital on environmental degradation, our study examined this non-linear relationship as measured by the gross tertiary enrolment ratio, on ecological footprint, using the EKC model. The study considered oil intensive-based economy for the period of 1986 to 2017, utilizing the ARDL model. We followed Balaguer and Manuel Cantavella (2018), in which education may have two opposite effects on environmental degradation, and accordingly assume the presence of an inverted U-shaped relationship between education and ecological footprint. The empirical findings for long-term estimates identified that enrolment rates at higher education have asymmetric impacts on ecological footprint. This is consistent with our assumption, in that when schooling enrolment rates are low in the early stages of economic development, environmental degradation is augmented. However, after reaching the turning point in education, the increase in enrolment rates reduces degradation. Concerning the other control variables, on per capita GDP coefficient and its square were found to be insignificant, meaning the hypothesis of EKC in terms of income and environment is not proven. Additionally, the relationship between energy consumption and ecological footprint was positive but non-significant. However, trade openness and air transport are both associated positively and significantly with ecological footprint.

To conclude, the findings of study suggest human capital is a determinant of environmental quality with respect to level of economic development and the extent of expansion in education. It also provides a different analysis in which human capital can combine the opposite effects on ecological footprint in developing country, potentially reconciling the mixed results obtained in previous studies that consider the linear relationship.

In light of the empirical findings, this study has an important policy implication. Saudi vision 2030 places significant attention on both educational progress and advancing issues related to environmental sustainability. Accordingly, as Saudi Arabia has launched a series of initiatives and critical projects to combat climate change and improve environmental quality, the role of individuals' awareness has become more prominent. Certainly, environmental knowledge fostered by education must be increased to deliver better understanding of the adverse consequences to humanity, so as to realize the importance of climate change actions adopted globally. Arklof (2017) states that promoting awareness of the public as an end goal constitutes an essential policy for governments. The author also adds that fostering changes in education and improving values and mores at the level of society in the long-term will make it possible to make more cooperative environmental decisions, demonstrating the substantial role of raising awareness. Thus, this issue must be considered when environmental policies and growth strategies are intentionally integrated with existing initiatives relating to the environment. The existence of high human capital in the country may prove helpful in meeting those SDG goals that are relevant to climate change and the environment.

For future research, it would be interesting to analysis the asymmetric linkage between human capital and ecological footprint in oil developing economies, while also considering heterogeneity across countries in regard to quantities of oil consumed and other economic and demographic factors.

REFERENCES

Adedoyin, F., Ozturk, I., Begun, F. V., Agboola, P. O., & Agboola, M. O. (2021). Renewable and non-renewable energy policy simulations for abating emissions in a complex economy: evidence from the novel dynamic ARDL. *Renewable Energy*, *177* (11), 1408-1420. https://doi.org/10.1016/ j.renene.2021.06.018.

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*, *26*(7), 26782-26796. https://doi.org/10.1007/s11356-019-05911-7.

Ahmed, Z., Asghar, M. M., Malik, M. N., & Nawaz, K. (2020). Moving towards a sustainable environment: the dynamic linkage between natural resources, human capital, urbanization, economic growth, and ecological footprint in China. *Resources Policy*, *67*(8), 101677. https://doi.org/10.1016/j.resourpol.2020.101677.

Akerlof, K. (2017). When Should Environmental Awareness Be a Policy Goal?. In Loreto, V., et al. (Eds). *Participatory Sensing, Opinions and Collective Awareness: Understanding Complex Systems* (pp.305-336). Switzerland: Springer, Cham. https://doi.org/10.1007/978-3-319-25658-0_15.

Ali, S., Yusop, Z., Kaliappan, S. R., & Chin, L. (2020). Dynamic common correlated effects of trade openness, FDI, and institutional performance on environmental quality: evidence from OIC countries. *Environmental Science and Pollution Research*, *27*(11), 11671-11682. https://doi.org/10.1007/s11356-020-07768-7.

Altuntaş, E. Ç., & Turan, S. L. (2018). Awareness of secondary school students about renewable energy sources. *Renewable Energy*, *116*(2), 741-748. https://doi.org/10.1016/j.renene.2017.09.034.

Amer, E. A. A. A., Meyad, E. M. A., Gao, Y., Niu, X., Chen, N., Xu, H., & Zhang, D. (2022). Exploring the link between natural resources, urbanization, human capital, and ecological footprint: A case of GCC countries. *Ecological Indicators*, *144*(11), 109556. https://doi.org/10.1016/j.ecolind.2022.109556.

Arora, N. K., & Mishra, I. (2019). United Nations Sustainable Development Goals 2030 and environmental sustainability: race against time. *Environmental Sustainability*, *2*(4), 339-342. https://doi.org/10.1007/s42398-019-00092-y.

Balaguer, J., & Cantavella, M. (2018). The role of education in the Environmental Kuznets Curve. Evidence from Australian data. *Energy Economics*, *70*(2), 289-296. https://doi.org/10.1016/j.eneco.2018.01.021.

Chankrajang, T., & Muttarak, R. (2017). Green returns to education: Does schooling contribute to pro-environmental behaviours? Evidence from Thailand. *Ecological Economics*, *131*(1), 434-448. https://doi.org/ 10.1016/ j.ecolecon.2016.09.015.

Dada, J. T., Adeiza, A., Noor, A. I., & Marina, A. (2022). Investigating the link between economic growth, financial development, urbanization, natural resources, human capital, trade openness and ecological footprint: evidence from Nigeria. *Journal of bioeconomics*, *24*(7) 1-27. https://doi.org/10.1007/s10818-021-09323-x.

Danish., Hassan, S. T., Baloch, M. A., Mahmood, N., & Zhang, J. (2019). Linking economic growth and ecological footprint through human capital and biocapacity. *Sustainable Cities and Society*, *47*(5), 101516. https://doi.org/10.1016/j.scs.2019.101516.

Dickey, D. A., & Fuller, W. A. (1979). Distribution of the estimators for autoregressive time series with a unit root. *Journal of the American statistical association*, *74* (366a), 427-431. https://doi.org/10. 1080 / 01621459.1979.10482531.

EIA. (2021). *Country Analysis Executive Summary: Saudi Arabia.* https://www.eia.gov/international/content/analysis/countries_long/Saudi_Arabia/saudi_arabia.pdf.

EIA. (2022). *International Energy Statistics*. https://www.eia.gov/international/data/world.

Galli, A., Wiedmann, T., Ercin, E., Knoblauch, D., Ewing, B., & Giljum, S. (2012). Integrating ecological, carbon and water footprint into a "footprint family" of indicators: definition and role in tracking human pressure on the planet. *Ecological indicators*, *16*(5), 100-112. https://doi.org/10.1016/j.ecolind.2011.06.017.

Global Footprint Network. (2022). *Explore Data*. https://data. Footp rint network.org/?_ga=2.205936154.827853424.1701146569-783089861. 1679317533#/ countryTrends?cn=5001& type=BCtot,EFCtot.

Grossman, G. M., & Krueger, A. B. (1991). *Environmental Impacts of a North American Free Trade Agreement* (Working Paper No.3914). National Bureau of Economic Research. https://ssrn.com/abstract=232073.

Hanif, I., Raza, S. M. F., Gago-de-Santos, P., & Abbas, Q. (2019). Fossil fuels, foreign direct investment, and economic growth have triggered CO2 emissions in emerging Asian economies: some empirical evidence. *Energy*, *171*(3), 493-501. https://doi.org/10.1016/j.energy. 2019.01.011.

Harte, J. (2007). Human population as a dynamic factor in environmental degradation. *Population and Environment*, *28*(5), 223-236. https://doi.org /10.1007/s11111-007-0048-3.

Huang, C., Zhang, X., & Liu, K. (2021). Effects of human capital structural evolution on carbon emissions intensity in China: A dual perspective of spatial heterogeneity and nonlinear linkages. *Renewable and Sustainable Energy Reviews*, *135*(1), 110258. https://doi.org/10.1016/j.rser.2020.110258.

Iorember, P. T., Jelilov, G., Usman, O., Işık, A., & Celik, B. (2021). The influence of renewable energy use, human capital, and trade on environmental quality in South Africa: multiple structural breaks cointegration approach. *Environmental Science and Pollution Research*, *28*(3), 13162-13174. https://doi.org/10.1007/s11356-020-11370-2.

Irfan, M., Hao, Y., Ikram, M., Wu, H., Akram, R., & Rauf, A. (2021). Assessment of the public acceptance and utilization of renewable energy in Pakistan. *Sustainable Production and Consumption*, *27*(7), 312-324. https://doi.org/10.1016/j.spc.2020.10.031.

Jahanger, A., Usman, M., Murshed, M., Mahmood, H., & Balsalobre-Lorente, D. (2022). The linkages between natural resources, human capital, globalization, economic growth, financial development, and ecological footprint: The moderating role of technological innovations. *Resources Policy*, *76*(6), 102569. https://doi.org/10.1016/j.resourpol.2022.102569.

Johansen, S., & Juselius, K. (1990). Maximum likelihood estimation and inference on cointegration—with appucations to the demand for money. *Oxford Bulletin of Economics and statistics*, *52*(2), 169-210. https://doi.org/10.1111/j.1468-0084.1990.mp52002003.x.

Karakul, A. K. (2016). Educating labour force for a green economy and renewable energy jobs in Turkey: A quantitave approach. *Renewable and Sustainable Energy Reviews*, *63*(9), 568-578. https://doi.org/ 10.1016/ j.rser.2016.05.072.

Kongbuamai, N., Zafar, M. W., Zaidi, S. A. H., & Liu, Y. (2020). Determinants of the ecological footprint in Thailand: the influences of tourism, trade openness, and population density. *Environmental science and pollution research*, *27*(11), 40171-40186. https://doi.org/10.1007/s11356-020-09977-6.

Kumar, P., Sahani, J., Rawat, N., Debele, S., Tiwari, A., Emygdio, A. P. M., ... Pfautsch, S. (2023). Using empirical science education in schools to improve climate change literacy. *Renewable and Sustainable Energy Reviews*, *178*(5), 113232. https://doi.org/10.1016/j.rser.2023.113232.

Kwauk, C., & Braga, A. (2017, September). *Three platforms for girls' education in climate strategies*. Global Economy and Development at Brookings. https://www.researchgate.net/profile/Amanda-Braga-4/ publication /319964141_Three_platforms_for_girls'_education_in_climate_strategies/links/59c3ccf7aca27298d9e25f7a/Three-platforms-for-girls- education-in-climate-strategies.pdf.

Lan, J., & Munro, A. (2013). Environmental compliance and human capital: Evidence from Chinese industrial firms. *Resource and energy economics*, *35*(4), 534-557. https://doi.org/10.1016/j.reseneeco.2013.05.003.

Langnel, Z., Amegavi, G. B., Donkor, P., & Mensah, J. K. (2021). Income inequality, human capital, natural resource abundance, and ecological footprint in ECOWAS member countries. *Resources Policy*, *74*(12), 102255. https://doi.org/10.1016/j.resourpol.2021.102255.

Lee, D. S., Fahey, D. W., Skowron, A., Allen, M. R., Burkhardt, U., Chen, Q., ... Wilcox, L. J. (2021). The contribution of global aviation to anthropogenic climate forcing for 2000 to 2018. *Atmospheric Environment*, *244*(1), 117834. https://doi.org/10.1016/ j.atmosenv.2020.117834.

Lind, J. T., & Mehlum, H. (2010). With or without U? The appropriate test for a U-shaped relationship. *Oxford bulletin of economics and statistics*, *72*(1), 109-118. https://doi.org/10.1111/j.1468-0084.2009.00569.x.

Liu, Y., Sadiq, F., Ali, W., & Kumail, T. (2022). Does tourism development, energy consumption, trade openness and economic growth matters for ecological footprint: Testing the Environmental Kuznets Curve and pollution haven hypothesis for Pakistan. *Energy*, *245*(4), 123208. https://doi.org/10.1016/j.energy.2022.123208.

Mahmood, H., Alkhateeb, T. T. Y., & Furqan, M. (2020). Industrialization, urbanization and CO2 emissions in Saudi Arabia: Asymmetry analysis. *Energy Reports*, *6*(11), 1553-1560. https://doi.org/10.1016 /j. egyr.2020.06.004.

Mehrara, M., Rezaei, S., & Razi, D. H. (2015). Determinants of renewable energy consumption among ECO countries; based on Bayesian model averaging and weighted-average least square. *International Letters of Social and Humanistic Sciences*, *54*(6), 96-109. https://10.18052/www.scipress.com /ILSHS.54.96.

Meyer, A. (2015). Does education increase pro-environmental behavior? Evidence from Europe. *Ecological economics*, *116*(8), 108-121. https://doi.morg/10.1016/j.ecolecon.2015.04.018.

Murshed, M., Rahman, M. A., Alam, M. S., Ahmad, P., & Dagar, V. (2021). The nexus between environmental regulations, economic growth, and environmental sustainability: linking environmental patents to ecological footprint reduction in South Asia. *Environmental Science and Pollution Research*, *28*(36), 49967-49988. https://doi.org/10.1007/s11356-021-13381-z.

Naseer, S., Song, H., Chupradit, S., Maqbool, A., Hashim, N. A. A. N., & Vu, H. M. (2022). Does educated labor force is managing the green economy in BRCS? Fresh evidence from NARDL-PMG approach. *Environmental Science and Pollution Research*, *29*(3), 1-9. https://doi.org/10.1007/s11356-021-16834-7.

Nathaniel, S., Nwodo, O., Adediran, A., Sharma, G., Shah, M., & Adeleye, N. (2019). Ecological footprint, urbanization, and energy consumption in South Africa: including the excluded. *Environmental Science and Pollution Research*, *26*(9), 27168-27179. https://doi.org/10.1007/s11356-019-05924-2.

Nathaniel, S. P., Yalçiner, K., & Bekun, F. V. (2021). Assessing the environmental sustainability corridor: Linking natural resources, renewable energy, human capital, and ecological footprint in BRICS. *Resources Policy*, *70*(3), 101924. https://doi.org/10.1016/j.resourpol.2020.101924.

Ozcan, B., Tzeremes, P. G., & Tzeremes, N. G. (2020). Energy consumption, economic growth and environmental degradation in OECD countries. *Economic Modelling*, *84*(1), 203-213. https://doi.org/10.1016/j.econmod.2019.04.010.

Pata, U. K., & Caglar, A. E. (2021). Investigating the EKC hypothesis with renewable energy consumption, human capital, globalization and trade openness for China: evidence from augmented ARDL approach with a structural break. *Energy*, *216*(1), 119220. https://doi.org/10.1016/ j.energy .2020.119220.

Perron, P. (1989). The great crash, the oil price shock, and the unit root hypothesis. *Econometrica: journal of the Econometric Society*, *57*(11), 1361-1401. https://doi.org/10.2307/1913712.

Pesaran, M. H., Shin, Y., & Smith, R. J. (2001). Bounds testing approaches to the analysis of level relationships. *Journal of applied econometrics*, *16*(3), 289-326. https://doi.org/10.1002/jae.616.

Rahman, S. M., Khondaker, A. N., Hasan, M. A., & Reza, I. (2017). Greenhouse gas emissions from road transportation in Saudi Arabia-a challenging frontier. *Renewable and Sustainable Energy Reviews*, *69*(3), 812-821. https://doi.org/10.1016/j.rser.2016.11.047.

Schäfer, A. W., & Waitz, I. A. (2014). Air transportation and the environment. *Transport policy*, *34*(7), 1-4. https://doi.org/10 .1016/j.tranpol.2014.02.012.

Sinha, A., Shahbaz, M., & Balsalobre, D. (2017). Exploring the relationship between energy usage segregation and environmental degradation in N-11 countries. *Journal of cleaner production*, *168*(12), 1217-1229. https://doi.org/10.1016/j.jclepro.2017.09.071.

Udeagha, M. C., & Ngepah, N. (2022). Does trade openness mitigate the environmental degradation in South Africa?. *Environmental Science and Pollution Research*, *29* (3), 19352-19377. https://doi.org/10.1007/s11356-021-17193-z.

Ullah, S., Ozturk, I., Majeed, M. T., & Ahmad, W. (2021). Do technological innovations have symmetric or asymmetric effects on environmental quality? Evidence from Pakistan. *Journal of cleaner production*, *316*(9), 128239. https:// doi.org/10.1016/j.jclepro.2021.128239.

world bank. (2022). *World Development Indicators*. https://databank.worldbank.org/source/world-development-indicators.

Zafar, M. W., Shahbaz, M., Sinha, A., Sengupta, T., & Qin, Q. (2020). How renewable energy consumption contribute to environmental quality? The role of education in OECD countries. *Journal of Cleaner Production*, *268*(9), 122149. https://doi.org/10.1016/j.jclepro.2020.122149.

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* (10), 101428. https://doi.org/10.1016/j.resourpol.2019.101428.

Zhang, L., Godil, D. I., Bibi, M., Khan, M. K., Sarwat, S., & Anser, M. K. (2021). Caring for the environment: How human capital, natural resources, and economic growth interact with environmental degradation in Pakistan? A dynamic ARDL approach. *Science of The Total Environment*, *774*(6), 145553. https://doi.org/10.1016/j.scitotenv.2021.145553.

Zsóka, Á., Szerényi, Z. M., Széchy, A., & Kocsis, T. (2013). Greening due to environmental education? Environmental knowledge, attitudes, consumer behavior and everyday pro-environmental activities of Hungarian high school and university students. *Journal of cleaner production*, *48*(6), 126-138. https://doi.org/10.1016/j.jclepro.2012.11.030.

التأثير غير المتماثل لرأس المال البشري على البصمة البيئية في إطار منحنى كوزنتس البيئي (EKC) في المملكة العربية السعودية

د. نجلاء المطيري

ملخص البحث باللغة العربية

على خلاف الدراسات السابقة التي اختبرت التأثير الخطي لرأس المال البشري على التدهور البيئي، تهدف الدراسة الحالية إلى اختبار العلاقة غير الخطية بين هذين المتغيرين باستخدام منحى كوزنتس البيئي (EKC) خلال الفترة (1986-2017). تناول البحث دراسة المملكة العربية السعودية باعتبارها دولة نامية وغنية بالثروات الطبيعية. وفقاً لتقديرات نموذج الانحدار الذاتي للإبطاءات الموزعه (ARDL) اتضح ارتباط رأس المال البشري والذي تم قياسه بواسطة إجمالي نسبة الالتحاق بالتعليم العالي بعلاقة على شكل مقلوب حرف U مع البصمة البيئية. هذة النتيجة التي خلصت إليها الدراسة تتفق مع فرضيه الدراسة في نموذج منحى كوزنتس البيئي. بمعنى آخر عندما تكون معدلات الالتحاق بالتعليم العالي منخفضة في المراحل الأولى للتنمية الاقتصادية فإن التدهور البيئي يزداد، ولكن عند الوصول إلى نقطة التحول في التعليم، الزيادة في تلك المعدلات تقلّل من مستوى التدهور البيئي. تؤكد النتائج التي توصلت إليها الدراسة مدى الدور الحيوي للتعليم في الحدّ من التدهور البيئي وتحسين كفاءة الطاقة واستدامتها في المملكة العربية السعودية، لذلك توصي الدراسة بدمج الوعي البيئي للأفراد والتعليم البيئي وزيادة المعرفة بشأن الإجراءات المتعلقة بتغير المناخ في تطوير السياسات التي تختص بالجوانب البيئية من قبل صانعي القرار في المملكة العربية السعودية.

الكلمات الدالة: التدهور البيئي، البصمة البيئية، التعليم، رأس المال البشري، التنمية المستدامة، المملكة العربية السعودية.

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