The effect of trade openness and foreign direct investment on environmental degradation in the context of Saudi Arabia

أثر الإنفتاح التجاري والإستثمارات الأجنبية المباشرة على التدهور البيئي في المملكة العربية السعودية

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Abstract

The present study considers two important determinants of environmental quality using comprehensive and holistic measure of environmental degradation: ecological footprint. It scrutinizes the effect of trade openness on ecological footprint, and verifies the pollution haven hypothesis (PHH) by evaluating the environmental impact of foreign direct investment (FDI). It considers the oil-intensive of Saudi economy between 1981 and 2017. Empirical estimates using the autoregressive distributed lag (ARDL) model identify how trade openness degrades the environment by increasing the ecological footprint both long and short term. However, FDI has also been found to improve environmental quality long-term by transferring eco-friendly technology, implying the PHH hypothesis is not applicable within the country. The findings of this study emphasize the importance of delivering 2030 vision goals in terms of environmental and energy sustainability, using both green technology and renewable energy. Thus, harmful environmental consequences, resulting from trade openness, and benefits proceeding from foreign firms that raise environmental performance must be taken into consideration by policymakers responsible for developing environmental policies as a way to fulfil sustainable development goals (SDGs).

Key Words:

Environmental degradation; ecological footprint; sustainability; renewable energy; Saudi economy.

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ملخص:

تبحث هذه الدراسة محددين أساسيين من محددات الجودة البيئية باستخدام مؤشرشامل يقيس مستوى التدهور البيئي متمثلاً في البصمة البيئية. تختبر الدراسة على وجة الخصوص أثر الانفتاح التجاري على البصمة البيئية، بالإضافة إلى التحقق من فرضية ملاجئ التلوث من خلال تحليل الأثر البيئي للإستثمارات الأجنبية المباشرة. يركز البحث على المملكة العربية السعودية كحالة للدراسة باعتبارها دولة نامية وغنية بالثروات النفطية في الفترة الزمنية من عام 1981وحتى عام 2017. تشير النتائج التجريبية المقدّرة من نموذج الانحدار الذاتي للإبطاءات الموزعه (ARDL) بإن الانفتاح التجاري يؤدي إلى التدهور البيئي من خلال زيادة البصمة البيئية في الأجلين الطويل والقصير. على خلاف ذلك، خلُصت النتائج إلى أن الاستثمار الأجنبي المباشر يحسّن من الجودة البيئية في الأجل الطويل فقط من خلال نقل التنكولوجيا الصديقة للبيئة، مما يعني ذلك عدم تحقق فرضية ملاجئ التلوث في الدولة محل الدراسة. تؤكد نتائج الدراسة أهمية تحقيق أهداف رؤية 2030 فيما يخص إستدامة البيئة والطاقة في الاعتماد على الطاقة المتجددة والتكنولوجيا الخضراء. كذلك توصي الدراسة بأهمية الأخذ بالاعتبار الآثار البيئية السلبيه الناجمة عن الانفتاح التجاري، والفوائد المكتسبة من الشركات الأجنبية لرفع مستوى الأداء البيئي في تطوير السياسات البيئية من قبل صانعي القرار في المملكة العربية السعودية لتحقيق أهداف التنمية المستدامة (SDGs).

الكلمات المفتاحية: التدهور البيئي، البصمة البيئية، الاستدامة البيئية، الطاقة المتجددة، الاقتصاد السعودي.

1. Introduction

The importance of combating further damage to the ecosystem is increasingly being emphasized at the international level by governments, scientists, and policymakers. In particular, developing nations with diverse economies are currently contributing substantially to both economic growth and environmental pollution (Jahanger *et al*., 2022). According to Hanif *et al*. (2019), growing concerns about the environment require policymakers in developing nations to ensure “sustainable economic growth” in contrast to “plain economic growth”. The environmental dimension is among the United Nations Sustainability Development Goals (SDGs), specifically SDG 7 (Affordable and clean energy) and SDG 13 (Climate Action). However, promoting economic growth, in an environmentally healthy way represents a significant challenge for national governments. It is therefore of the utmost importance to address this issue on a global scale, and a number of prior studies have investigated the determinants of environmental quality to understand their potential effects and magnitudes more fully.

1.1 Research objectives

The aim of this study is to analyze two critical economic determinants of environmental quality in the context of Saud Arabia over the long and short term. Thus, the study has two main objectives:

1.2.1 Examining the effect of trade openness on environmental degradation as measured by ecological footprint.

1.2.2 Verifying the pollution haven hypothesis (PHH) by exploring the environmental impact of foreign direct investment (FDI).

1.2 Research problem, importance, and contribution

The problem and importance of this study presented in considerable concerns that arise in relation to climate change, pollution, global warming, resources depletion and other complex issues associated with environmental degradation, all of which seriously threaten the global ecosystem. Notably, Danish *et al*. (2019) mentions that current demand equates to over 50% of the capacity of nature to renew itself; that is, to generate the quantity of natural resources required to sustain the current ecological footprint would require 1.5 Earths. In addition, the COP conferences greatly emphasizes the significance of continued intensive efforts by parties to alleviate environmental hazards. Moreover, the study considers Saud Arabia which is a developing and intensive resource-based economy with oil revenues comprising 53% of government revenues and 70% of all exports (EIA, 2021). Today, Saudi Arabia faces enormous challenges in terms of promoting economic growth through significant economic reforms while implementing mitigation measures to manage any resultant environmental damage. According to the goals set out in vision 2030, the country is seeking to expand its manufacturing industries linked to oil, to benefit from the comparative advantages of oil abundance and the low cost of oil extraction. Such industries are pollution intensive, which raises concerns about environmental degradation.

Against this backdrop, Saudi Vision 2030 aims to increase the contribution of non-oil exports and the private sector, in particular developing industrial production to reduce the reliance on oil exports. This increasing industrialization and diversification of the economy across non-oil sectors requires additional energy consumption. As observed by He *et al*. (2021), it is not possible to achieve sustained economic growth without energy being the basic input of production, particularly in developing economies (Sinha *et al*., 2017). This thereby intensifies environmental damage (Hanif, 2018). Saudi Arabia is currently ranked the second largest energy consumer in the Middle East, and the eleventh largest in the world (EIA, 2022). Moreover, Saudi Arabia aims to be a leader in terms of sustainable energy and has launched a National Renewable Energy Program (NREP) with the aim of expanding the renewable energy potential of Saudi Arabia (Ministry of Energy, 2022) to improve environmental performance. As shown in Figure 1 Ecological footprint per capita is higher than biocapacity per capita, indicating the presence of an ecological deficit. Ecological footprint per capita rose from 2.84 in 1981 to 6.48 in 2017, with an increase of about 3.64, while biocapacity per capita fell from 1 to 0.71 in the same period.

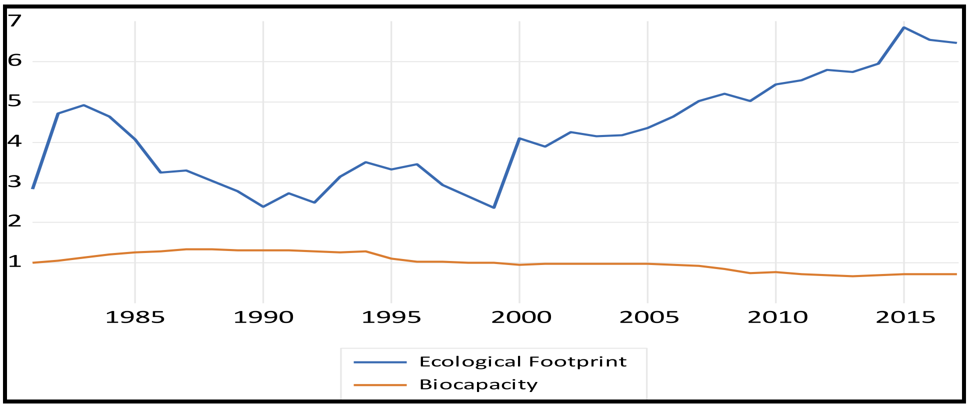

Figure1. Ecological footprint per capita versus biocapacity per capita in Saudi Arabia (1981-2017).

Source: The figure was produced by the author using Global Footprint Network data, (2022).

Moreover, Saudi Arabia's new vision targets a 100% increase in the value of FDI to develop emerging sectors in education, health, retail, and consultant services, as well as attracting investments to the technology sector (Vision 2030, 2021). Among the vision's achievements to date is that the value of FDI has risen significantly, reaching 17,625 billion SR in 2020, compared to just 5.321 billion SR in 2015 prior to launching the vision. Such significant increases in the value of foreign investments are likely to produce different effects on the environment, in either a positive or a negative way.

Thus, question raised by this research include an analysis of the potential environmental effects of both economic factors. It is anticipated that the findings reported here will offer useful information for policy makers concerning the potential environmental impact of trade openness and FDI, taking into consideration environmental and energy policies throughout the country.

This study contributes to existing time series studies covering environmental economics in two main areas. First, as set out above, the study considers the case of Saudi Arabia; second, in contrast to the majority of studies that use CO2 emissions as a proxy to capture environmental degradation, this study instead uses ecological footprint. By definition, "ecological footprint measures the size of an area of biologically productive land and water required by an individual, population or activity to produce all the resources consumed and absorb the generated waste, using prevailing technology and resource management practices" (Global Footprint Network, 2023). In addition, it can be developed to evaluate and manage the utilization of resources within a country (Danish *et al*, 2019). While the CO2 proxy captures just one aspect of environmental damage i.e., air pollution (Ozcan *et al*., 2020), ecological footprint addresses various factors including, cropland, forest, fishing grounds, built-up areas, grazing land, and land used to absorb carbon emissions (York *et al*., 2003). This approach is supported by Strezov *et al*. (2017), who argue that ecological footprint serves as a prime index for sustainable development, thereby expanding the gap between ecological footprint and biocapacity, also indicating any lack of sustainability (Rashid *et al*., 2018).

Therefore, ecological footprint is a more comprehensive and informative measure than CO2 emissions for assessing environmental degradation allowing more valid estimates to sufficiently inform policy.

Furthermore, to the best of our knowledge, this is the first study of this type to explore the environmental impact of these important economic factors in the context of Saudi Arabia, employing ecological footprint to measure environmental degradation inclusively.

The paper is organized as follows. The literature review is shown in Section 2. Section 3 offers the methodology with sub-section (3.1) setting out the empirical model and estimation strategy and (3.2) describing the data. Section 4 reveals the empirical findings. Finally, Section (5) presents the conclusions and policy implications.

2. Literature review

This section briefly reviews the literature pertaining to trade openness and FDI and their relationship to environmental considerations. Therefore, this section is divided into two sub-sections as follows:

2.1 Ecological footprint and trade openness

Trade openness is considered in the literature as one of the most important determinants of environmental quality. Although opening up to the world is crucial, bringing great benefits to all countries without exception, trade openness worldwide can potentially damage the environment. In their research, Destek and Sinha (2020) argue that the impact of trade openness on environmental performance can be determined by the level of development and industrialization within a country. In other words, in the early stages of development, countries typically focus on fuelling economic growth at the expenses of environmental quality by importing technologies that are polluting and unfriendly to the environment for use in the production process. In contrast, developed countries aim to import greener more advanced technologies that will improve environmental health over time. Their results confirm their hypothesis that trade openness relates negatively to ecological footprint in 24 OECD economies, implying that trade openness yields advantages to raise environmental quality in developed nations (Destek and Sinha, 2020).

In the Environmental Kuznets Curve (EKC) framework Grossman and Krueger (1991) postulate that trade openness has three different effects upon environmental degradation: scale effect, composition effect, and technique effect (cited in Aydin and Turan, 2020). With regard to the first effect, increased openness to trade degrades the environment as economic growth demands greater energy consumption subsequently. The second effect is associated with the expansion of production in sectors that have a competitive advantage, leading to greater demand for conventional energy, causing further harmful effects on the environment. In addition, Shahbaz *et al*. (2018) state that composition effect is represented in the structural transfer of countries from the agricultural sector to the industrial sector, and from the latter to the third sector; i.e., services. A final effect that can improve environmental performance involves transferring clean technology to the host country via foreign firms.

Empirically, several studies have explored the impact of trade openness on ecological footprint, examples of cross-sectional studies, in the MENA region, Al-Mulali and Ozturk (2015) have scrutinized the connections between ecological footprint and trade openness in addition to other economic and social determinants that include urbanization, political stability, and industrial output in the period 1996-2012. The results from FMOLS estimates reveal that trade openness, energy consumption, urbanization and industrial output increase a nation's ecological footprint, whereas political stability reduces it. According to recent studies using panel data for 13 Asian economies to assess the period between 1973 and 2014, Lu's (2020) empirical findings showed that openness relates negatively to ecological footprint, and that there is bidirectional causality between these two variables. A study by Cutcu *et al*. (2023) explored the impact of foreign trade on ecological footprint when selecting the 10 top developing countries and found that exports have a negative effect on ecological footprint. In contrast, in the case of the G-7 economies, the results from the CS-ARDL model uncovered the extent to which trade openness improves environmental quality, as evidenced by Wang *et al*. (2022).

Examining time-series studies on developing economies in particular, as will be the case here, Kongbuamai *et al*. (2020) employed the ARDL model and found that trade openness in addition to economic growth and energy consumption enhanced ecological footprint over the long-term in Thailand. In agreement with this finding, when examining the case of Qatar, utilizing the Markov Switching Equilibrium Correction Model for the period 1970-2015, Charfeddine (2017) discovered the empirical findings positively identified the nexus between ecological footprint and trade openness. In more recent studies, the estimates of ARDL clarified the harmful effect of global trading opportunities on the environment, as well as the presence of a causal relationship between openness and ecological footprint in Nigeria (Dada *et al*., 2022), consistent with empirical findings reported by Liu *et al.* (2022) in reference to Pakistan. However, in the case of Bangladesh, according to the ARDL model, the environmental ecological footprint is improved by trade openness (Islam, 2022). In agreement, in the context of China, trade openness reduces the ecological footprint, as reported by Quantile Regression results (Magazzino, 2023).

Based on the brief literature above, it is apparent these studies return mixed results in terms of ecological footprint and its relationship to openness, partly as they employ different perspectives, estimation techniques, time periods and countries.

2.2 Ecological footprint and foreign direct investment

According to Bashir (2022), the pollution haven hypothesis (PHH) states that multinational corporations (MNC) implement low level environmental standards in emerging economies, in contrast to developed countries, which set strict environmental standards. Thus, corporations that meet minimal environmental criteria transfer information from industrialized economies to emerging ones at the cost of environmental quality. However, there is second argument in the literature that states foreign investments may promote environmental quality and thereby yield environmental advantages to host countries using more clean and green technology compared to national companies, termed the "pollution haloes hypothesis" (Mert1 and Bölük, 2016).

Empirical studies have sought to evaluate the validity of these two hypotheses by examining FDI and the environmental degradation nexus. The findings presented in the empirical literature are divided into two strands. The first strand suggests that FDI improves environmental quality. For example, Zafar *et al*. (2019) explored the effect of FDI on human capital, energy consumption and natural resources in the US between 1970 and 2015. Their empirical estimates produced by the ARDL model show FDI and others main explanatory variables contribute to a diminishing ecological footprint. In agreement with this, a study on the impact of FDI by Udemba (2021) found it improved environmental performance in the UEA. More recently, selecting 16 European countries, Saqib *et al*. (2023) examined the association between FDI, human capital and energy and ecological footprint from 1990 to 2020 to confirm the presence of the PHH. In addition, the causality test displayed a unidirectional causal relationship between ecological footprint and FDI. Using the ARDL model, Udemba (2020) identified that FDI mitigates the ecological footprint in India, and that there is unidirectional causality directed from FDI towards ecological footprint, which can be demonstrated using the Granger causality test. Focusing on G-11 economies, Sun (2022) proved the PHH to be valid.

However, the second strand confirms the presence of PHH hypothesis. A study by Chowdhury *et al*. (2021) investigated the effect of FDI on environmental degradation measured by ecological footprint and including 92 economies from 2001 to 2016. The estimates for panel quantile regression showed that FDI connects positively with ecological footprint. Recently, Yasmeen *et al*. (2022) found the PHH hypothesis holds true in 52 Belt and Road countries, in that FDI deteriorates the environment by increasing the ecological footprint. Xu *et al*. (2022) searched for connections between natural resources, FDI, renewable energy, technological advance, and ecological footprint in China, to reveal that FDI reinforces ecological footprint as reported by FMOLS, DOLS and CCR estimates.

Our study will contribute further evidence to the environmental economic literature that focuses on time-series analyses, particularly by considering developing and oil-intensive economy of Saudi Arabia, as well as two important determinants of ecological footprint.

3. Methodology

3.1 Empirical model and estimation method

Based on the theoretical and empirical literature discussed in the previous section, and to examine the impact of trade openness and FDI on ecological footprint, we set out the following empirical model:

$$lnEF_t = \beta_0 + \beta_1 lnOPEN_t + \beta_2 FDI_t + \\ +\beta_4 lnX_t + \varepsilon_t \quad (1)$$

Where $lnEF_t$; the dependent variable is the natural logarithm of the ecological footprint per capita, our main explanatory variables include $lnOPEN$, which indicates the natural logarithm for trade openness, FDI_t is foreign direct investment (FDI). Moreover, lnX_t comprises other control variables, while ε is the error term at t. As control variables, we add to our model of ecological footprint GDP per capita (PGDP), energy consumption per capita (EC) and urbanization (URB). These variables are considered important determinants of environmental quality, as suggested in prior studies. Promoting economic growth brings undesirable and adverse effects for the environment by increasing the demand for energy consumption (Hanif, 2018). Several studies have directed great attention towards examining the connection between energy consumption and environmental degradation (e.g., Zaman *et al*., 2016;

Nathaniel and Iheonu, 2019; Lu, 2020). In addition, a number of studies have intensively explored the association between economic development and environmental degradation by examining the Environmental Kuznets Curve (EKC) hypothesis, which assumes the presence of an inverted U-shaped relationship between the two variables. However, there many studies have identified that this hypothesis does not hold true (e.g., Rehman *et al*., 2017; Lind and Mehlum, 2010; Caviglia-Harris *et al*., 2009). In the context of Saudi Arabia, Samargandi (2017) found economic growth has a linear effect on environmental degradation as measured by carbon emissions. For this, PGDP was entered into the model linearly[1].

With regard to urbanization, Ahmed *et al*. (2020) argue that urbanization causes population growth, increasing demand for resources such as food, water, energy, transportation, and housing. This generates environmental challenges such as pollution, climate change and the rapid depletion of resources. Some additional studies support this perspective (e.g., Luo *et al*., 2018; Ahmed *et al*. 2020). Conversely, however, Danish and Wang (2019) contest this view, suggesting urbanization may lower the ecological footprint as when purchase power increases urban residents typically demand clean energy.

To achieve the aim of study, we use the Autoregressive Distributed Lag bounds test (ARDL) approach to cointegration (Pesaran *et al*., 2001). This technique requires, as a condition, that there is no variable stationary at *I*(2). However, use of the ARDL technique is widespread in the literature, as it is more flexible than other cointegration approaches (e.g., Engle *et al*., 1989; Johansen *et al*., 1990) allowing a mixed order of integration at level *I*(0) or first difference *I*(1). According to Equation 1, the ARDL model is as follows:

$$\begin{aligned}\Delta lnEF_t = {} & \beta_0 + \beta_1 lnEF_{t-1} + \beta_2 lnOPEN_{t-1} + \beta_3 FDI_{t-1} + \beta_4 URB_{t-1} + \beta_5 lnPGDP_{t-1} \\ & + \beta_6 lnEC_{t-1} + \sum_{i=1}^{p} \gamma_i \Delta lnEF_{t-i} + \sum_{j=1}^{q} \delta_j \Delta lnOPEN_{t-j} + \sum_{l=1}^{q} \vartheta_l \Delta FDI_{t-l} \\ & + \sum_{m=1}^{q} \mu_m \Delta URB_{t-m} + \sum_{s=1}^{q} \pi_s \Delta lnPGDP_{t-s} + \sum_{h=1}^{q} \theta_h \Delta lnEC_{t-h} + \varepsilon_t\end{aligned} \quad (2)$$

To implement the ARDL bounds testing, this study estimates equation 2 using F-testing. The null hypothesis, H*0* (cointegration relationship between study variables does not exist) is examined against the alternate hypothesis, H*1* (the presence of a long-term association between these variables). To specify the

[1] In addition, the author estimated the model with considering the non-linear effect of income on ecological footprint, but the results was not accord to the EKC hypothesis. This result confirms the findings delivered by the study of (Samargandi, 2017) in Saudi Arabia.

existence of cointegration relation, according to statistical outcomes, we compare calculated-F with the two asymptotic critical bounds proposed by (Pesaran *et al*. ,2001)[2].

When the cointegration relation among variables is identified, the long-run and short run relationship for the ARDL model is estimated as the following equations (3-4) respectively:

$$lnEF_t = \beta_0 + \sum_{i=1}^{p} \gamma_i \, \Delta lnEF_{t-i} + \sum_{j=1}^{q} \delta_j \Delta \, lnOPEN_{t-j} + \sum_{l=1}^{q} \vartheta_l \Delta \, FDI_{t-l} + \sum_{m=1}^{q} \mu_m \Delta \, URB_{t-m} + \sum_{s=1}^{q} л_s \Delta \, lnPGDP_{t-s} + \sum_{h=1}^{q} \theta_h \Delta \, lnEC_{t-h} + \varepsilon_t \quad (3)$$

$$\Delta lnEF_t = \beta_0 + \sum_{i=1}^{p} \gamma_i \, \Delta lnEF_{t-i} + \sum_{j=1}^{q} \delta_j \Delta \, lnOPEN_{t-j} + \sum_{l=1}^{q} \vartheta_l \Delta \, FDI_{t-l} + \sum_{m=1}^{q} \mu_m \Delta \, URB_{t-m} + \sum_{s=1}^{q} л_s \Delta \, lnPGDP_{t-s} + \sum_{h=1}^{q} \theta_h \Delta \, lnEC_{t-h} + \varepsilon_t \quad (4)$$

After estimating the model, it is necessary to check the adequacy of the model to confirm the reliability of model estimates. To achieve this, we employed several diagnostic tests, including serial correlation (LM), Heteroskedasticity (Breusch-Pagan-Godfrey), and functional Form (REMSAY). Furthermore, to determine whether the estimated coefficients are stable, the author employs the cumulative sum of recursive residuals (CUMSUM) and the cumulative sum of squares for the recursive residuals (CUMSUMSQ).

3.2 The data

The study uses time series data from 1981 to 2017. The dependent variable (EF) was calculated as the total of built up-land, carbon, cropland, fishing grounds, forest products, and grazing land per capita. The data for ecological footprint per capita was gathered from the Global Footprint Network (2022). The database for the main explanatory variables of the study including trade openness (OPEN) and FDI was derived from World Bank (2022). OPEN is the sum of exports and imports of goods and services as a share of GDP, while FDI is the percentage of FDI net inflows in GDP. Regarding the additional

[2] If the result shows that the computed F-statistic is less 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.

control variables, (PGDP) is measured by GDP per capita in constant 2015 US dollars, urbanization (URB) denotes people living in urban areas; both collected from World Bank (2022). In addition, (EC) is primary energy consumption per capita, the data for which was obtained from EIA (2022).

4 Empirical results

4.1 The findings of unit root tests

As a prerequisite to implementing the ARDL bounds testing approach to cointegration, checking the order of integration for the study variables is essential. To do this end we used two different unit root tests to evidence no variable is stationary at $I(2)$. These unit root tests included Augmented Dickey–Fuller (1979) denoted by (ADF) and Phillips and Perron (1989) abbreviated as (PP), and the findings are displayed in Tables 1 and 2. The empirical outcomes generated from all the tests emphasize that the order of integration for the variables of interest is mixed at $I(0)$ and $I(1)$. All the study variables are stationary at first difference $I(1)$ except for GDP per capita and urbanization, which are stationary at level $I(0)$.

Table 1. The findings of Augmented Dicky-Fuller (ADF) unit root test

Variable	level				1st difference			
	With constant		With constant & trend		With constant		With concept & trend	
	t-statistics	Prob.	t-statistics	Prob.	t-statistics	Prob.	t-statistics	Prob.
$lnEF_t$	-1.361	0.590	-2.064	0.548	-7.124	0.000	-7.292	0.000
$lnOPEN_t$	-2.516	0.120	-2.666	0.256	-4.475	0.001	-4.417	0.007
FDI_t	-2.188	0.214	8-2.18	20.48	-6.431	0.000	-6.395	0.000
URB_t	-1.711	0.417	-12.953	0.000	-	-	-	-
$lnPGDP_t$	-2.618	0.099	-3.439	0.063	-5.255	0.000	-5.213	0.001
$lnEC_t$	-0.379	0.902	-2.781	0.213	-8.261	0.000	-8.109	0.000

*, ** and *** denote the significance at 1%, 5% and 10% levels, respectively.
Source*:* It was estimated by the author, using EViews -12.

Table 2. The findings of Philips - Perrion (PP) unit root test

Variabl e	level				1st difference			
	With constant		With constant & trend		With constant		With concept & trend	
	t-statistics	Prob.	t-statistics	Prob.	t-statistics	Prob.	t-statistics	Prob.
$lnEF_t$	-1.361	0.590	-2.112	0.522	-7.177	0.000	-9.009	0.000
$lnOPEN_t$	-2.139	0.231	-2.049	0.556	-4.383	0.001	-4.322	0.008
FDI_t	-2.308	0.175	-2.297	0.425	-6.391	0.000	-6.356	0.000

URB_t	-9.062	0.000	-10.867	0.000	-	-	-	-
$lnPGDP_t$	-4.964	0.000	-7.245	0.000	-	-	-	-
$lnEC_t$	-0.359	0.906	-2.799	0.207	-8.261	0.000	-8.186	0.000

*, ** and *** denote the significance at 1%, 5% and 10% levels, respectively.
Source: It was estimated by the author, using EViews -12.

4.2 The results of ARDL model and discussion

Based on the findings reported from the above unit root tests, it seems that there is no variable was stationary at $I(2)$, which allowed employment of the ARDL model. To estimate the long-term relationship using equation 2, the proper lag length is set by the Schwarz information criterion (SIC), using a maximum lag order of 3. The null hypothesis (H_0) is examined versus the alternative one (H_1) using the F-test. The empirical results for the ARDL bounds testing are displayed in Table 3. The computed F-statistic for F_{EF} is 7.594, whereas the ecological footprint per capita (EF) was normalized as the dependent variable. The calculated F-statistic is greater than the upper critical bound $I(1)$ at the 10%, 5%, and 1% significance levels3. This implies the presence of a long-term relationship between these variables in the period from 1981-2017.

Table 3. The ARDL bounds testing.

Dependent variable is normalized to ecological footprint per capita (*EF).* ARDL specification is (1,3,1,0,3,0)			
F-statistics	**p-value**	***I(0)***	***I(1)***
7.594	10%	2.08	3
	5%	2.39	3.38
	1%	3.06	4.15

*, ** and *** are significance level at 10%, 5% and 1% respectively.
Source: It was estimated by the author, using EViews -12.

The empirical findings are demonstrated in (Table 4 - Panel A). The results shown suggest trade openness relates positively to ecological footprint in the long-term, as trade openness degrades the environment, indicating that an increase in trade openness of 1% increases the ecological footprint by 0.914%. Our results are in line with other studies that consider individual developing countries for example, Charfeddine (2017) for Qatar, Kongbuamai *et al*. (2020) for Thailand, Dada *et al*. (2022) for Nigeria and Liu *et al*. (2022) for Pakistan. To interpret this result, as discussed through the paper in section 2, trade openness exerts three different effects on environment: the size effect, the composition effect, and the technical effect, as proposed by Grossman and Krueger (1991). In the case of Saudi Arabia, the adverse impact of trade openness transits into the environment through the size effect and the composition effect.

Table 4. The findings of long- and short-term ARDL estimates.

Variable Dependent variable: EF_t	Coefficient	Standard error	t-statistics	p-value
Panel (A): Long - run result				
$lnOPEN_t$	0.914	0.237	3.851	0.001
FDI_t	-0.039	0.012	-3.313	0.004
URB_t	0.201	0.049	4.057	0.000
$lnPGDP_t$	0.130	0.315	0.413	0.684
$lnEC_t$	0.025	0.388	0.065	0.949
Constant	-20.281	3.157	-6.424	0.000
Panel (B): Short-run result				
$\Delta lnOPEN_t$	0.844	0.182	4.645	0.000
ΔFDI_t	-0.003	0.009	-0.382	0.707
ΔURB_t	0.252	0.179	1.406	0.175
$\Delta URB_t(-1)$	0.025	0.231	0.109	0.915
$\Delta URB_t(-2)$	0.724	0.179	4.024	0.001
$\Delta lnPGDP_t$	-0.909	0.291	-3.121	0.005
$\Delta lnPGDP_t$(-1)	-1.615	0.278	-5.816	0.000
$\Delta lnPGDP_t$(-2)	-1.570	0.337	-4.662	0.000
$\Delta lnEC_t$	0.023	0.359	0.065	0.949
ECM_{t-1}	-0.923	0.111	-8.313	0.000
Constant	-18.715	3.613	5.179	0.000
Panel (C): ARDL-VECM model diagnostic tests	**F - statistics**	**P-value**		
χ^2LM-Serial correlation	2.355	0.124		
χ^2 Heteroskedasticity (Breusch-Pagan-Godfrey)	1.397	0.243		
χ^2Functional Form (REMSAY)	2.051	0.054		

*The ARDL specification is (1,3,1,0,3,0).

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

That is, the country aims to increase its share of non-oil exports according to 2030 vision goals necessitating an increase in growth in non-oil sectors, driving greater demand for energy consumption, damaging the environment through the size effect. In addition to develop manufacturing industries in the non-oil sectors, the Saudi economy seeks to expand those industries that are related to natural resources, exploiting competitive advantage, increasing pollution intensive industries and damage to the environment via the composition effect.

Regarding the second interest variable, the findings show FDI contributes to reducing the ecological footprint in the country; as increasing FDI by 1% lowers ecological footprint by 0.039% over the long term. This implies the

PHH does not hold in the country, rather the empirical evidence supports the pollution haloes hypothesis. Although the magnitude coefficient is small, at about 4%, reflecting a meagre effect from FDI on ecological footprint, it can be said that it is a good indicator of how FDI might improve environmental quality in Saudi Arabia over the long term, benefiting from the clean and green technology transferred by foreign firms. These results are also inconsistent with previous studies that utilize time-series data (e.g., Zafar *et al*., 2019; Udemba, 2021; Sun, 2022). Concerning other control variables, urbanization (URB) is associated positively and significantly with ecological footprint. However, the estimated coefficients of GDP per capita (PGDP) and energy consumption per capita (EC) were insignificant contrary to expectations.

The short-term relation was estimated using Equation (4), as shown in (panel B in Table 4). The results reveal trade openness also promotes ecological footprint in the short-term, as the increase of OPEN by 1% gives rise to an increase in EF of 0.844%. Although the impact is significant in the long and short term, it is worth mentioning that the size of the long-term coefficient is slightly larger than that of the short-term coefficient, placing additional emphasis on the long-term importance of the negative environmental role of trade openness. In contrast to these long-term estimates, foreign investments relate negatively but insignificantly with ecological footprint in the short term, meaning the positive effect of foreign investment in improving environmental health is more important over the long-term.

The error correction coefficient ECM shown in (Panel B of Table 4) was negative and highly significant, with a value of − 0.923. This implies approximately 92% of disequilibrium in the short-term is adjusted annually towards long-term equilibrium. We implemented a set of tests including serial correlation, Heteroskedasticity, and functional form, using Ramsey's RESET test to diagnose the adequacy of the ARDL model. The results are shown in (Panel C of Table 4), indicating the model was adequate and there was no evidence of misspecification. In addition, the functional form for the model was found to be specified correctly, as clarified by the Ramsey test. In addition to these diagnostic tests, the study also examined the stability of the estimated coefficients using CUMSUM and CUMSUMQ. The plots, as shown in Figure 2, suggest the estimated coefficients were stable for the period between 1981 and 2017, since the residuals were located within critical bounds at the 5% significance level.

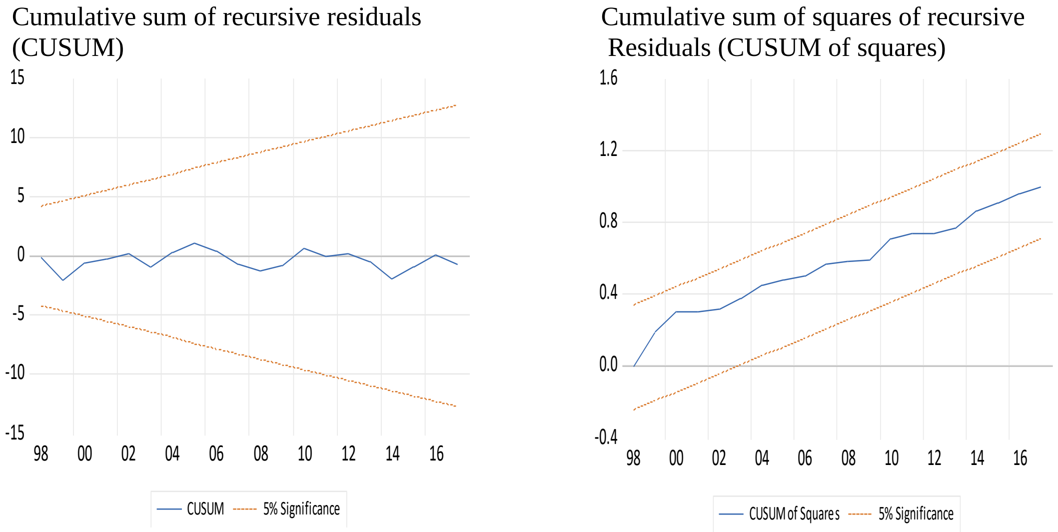

Figure 2. Coefficient stability testing

5 Conclusion and policy implications

The current study examines the environmental impact of trade openness and FDI as critical determinants of environmental quality. To the best of our knowledge, this is the first study of its type to explore the environmental role of these two economic factors in Saudi Arabia employing ecological footprint proxy. This metric is more comprehensive and valid as a measure of environmental degradation than CO2 emissions. Utilizing the ARDL technique, the empirical findings for long-term estimates reveal trade openness increases ecological footprint resulting in damage to the environment. This impedes environmental sustainability in the case of Saudi Arabia through both the size effect and the composition effect. However, FDI was found to contribute to improve environmental health by reducing the ecological footprint as evidenced by the empirical findings. Regarding additional control variables, while urbanization affects ecological footprint positively and significantly, the estimated coefficient of per capita GDP and energy consumption per capita proved to be positive but insignificant. In the short term, our main interest variable is openness, which has a positive and significant impact on ecological footprint that is similar to the long-term analysis. However, direct foreign investment associates negatively and insignificantly with ecological footprint, implying a positive impact from foreign investment, with better environmental performance being more important in the long-term.

The study has important policy implications. First, the empirical findings suggest trade openness is a contributor to environmental deterioration over both the long and short term. Thus, the study directs the attention of policy makers in the country to the significance of considering the adverse environmental consequences of trade openness in terms of environment, along with, especially when promoting economic growth and developing industrial production, which specifically increases demand for conventional energy consumption. According to the objectives of Vision 2030, the Saudi economy has launched several initiatives and projects with the aim of adopting renewable energy to improve environmental quality. This includes, for example, the Saudi green initiative and the Middle East green initiative; establishing the Saudi investment recycling company; the King Salman renewable energy initiative and launching the national environment strategy. Therefore, the findings of this study assert the importance of delivering these objectives by using clean and efficient- energy and green technology in the production process in all productive sectors. This contributes to mitigating the undesirable environmental effects of trade openness. In addition, it is important to regulate imported technology so that it is greener and more environmentally friendly.

Second, our results indicate that the PHH is not applicable to the case of Saudi Arabia, implying that foreign investments may mitigate environmental degradation by utilizing advanced eco-friendly technology transferred from foreign corporations. Thus, foreign investments may help to fulfil Vision 2030 goals in terms of ensuring sustainable energy and preserving the environment while increasing the value of foreign investments. Certainly, the government must impose stringent environmental compliance regulations and standards on foreign firms. Indeed, Saudi Arabia recently established the National Centre for Environmental Compliance (NCEC), to set environmental regulations to implement the national environmental strategy. In addition, FDI may contribute to enhancing renewable energy by attracting investments in renewable projects, with the importance of awarding privileges to foreign companies to help them adopt advanced and green technology as part of their production process. However, balancing economic growth by reaping the advantages of foreign investments and preserving environmental health is vital.

To conclude, the environmental impacts of these two particular economics factors must be involved in the environmental policy and strategy agenda for the environment on one side and development policies on the other, especially in view of the significant economic reforms thus far in Saudi Arabia.

For future research, it would be interesting to analyze these determinants of environmental quality using the ecological footprint measure, due to its comprehensiveness relative to CO2 measures, focusing particularly on developing and resource-based countries. Importantly, this would enrich the literature concerning this crucial issue, and serve to inform policy worldwide as environmental degradation and climate change are global challenges.

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