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Trade and Investment Dynamics in South Africa: Implications for Environmental Sustainability

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ABSTRACT

With climate change and environmental pollution worsening each year, especially developing countries are seeking to attract environmentally friendly foreign direct investment (FDI) while reducing dependence on imported energy. In countries like South Africa that rely heavily on coal and other fossil fuels, environmental pollution is increasing, sustainable development is being hampered and the importance of renewable energy sources is becoming more and more recognized. This study examines the relationships between renewable energy consumption, ecological footprint (EF), trade balance and FDI in South Africa over the period 1990-2021 using ARDL bounds test and finds that there is a long run cointegration relationship between these variables. The Toda-Yamamoto causality test results show that the variables affect each other in the long run; FDI, renewable energy consumption and trade balance affect EF, while EF and trade balance affect FDI. An increase in renewable energy consumption contributes to environmental improvement, while an improvement in the trade balance can reduce South Africa's EF. The study also suggests that the use of renewable energy can positively affect the trade balance and provides policy recommendations, constraints and suggestions for future research.

Güney Afrika’da Ticaret ve Yatırım Dinamikleri: Çevresel Sürdürülebilirliğe Etkileri

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ÖZET

İklim değişikliği ve çevre kirliliğinin her geçen yıl daha da kötüleşmesiyle birlikte, özellikle gelişmekte olan ülkeler ithal enerjiye olan bağımlılıklarını azaltırken çevre dostu doğrudan yabancı yatırımları (DYY) çekmeye çalışmaktadırlar. Güney Afrika gibi büyük ölçüde kömür ve diğer fosil yakıtlara dayanan ülkelerde çevre kirliliği artmakta, sürdürülebilir kalkınma engellenmekte ve yenilenebilir enerji kaynaklarının önemi giderek daha fazla kabul görmektedir. Bu çalışma, Güney Afrika'da 1990-2021 döneminde yenilenebilir enerji tüketimi, ekolojik ayak izi (EA), ticaret dengesi ve DYY’ler arasındaki ilişkileri ARDL sınır testi kullanarak incelemekte ve bu değişkenler arasında uzun dönemli bir eşbütünleşme ilişkisi olduğunu tespit etmektedir. Toda-Yamamoto nedensellik testi sonuçları, değişkenlerin uzun vadede birbirlerini etkilediğini gösterirken; DYY, yenilenebilir enerji tüketimi ve ticaret dengesi EA'yı etkilerken, EA ve ticaret dengesi DYY'yi etkilemektedir. Yenilenebilir enerji tüketimindeki bir artış çevresel iyileşmeye katkıda bulunurken, ticaret dengesindeki bir iyileşme Güney Afrika'nın EA'sını azaltabilmektedir.

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INTRODUCTION

In recent decades, advancements in information and communication technologies have significantly reduced transaction costs, thereby facilitating increased cross-border trade and investment in goods and services (Buckley & Strange, 2015). In today's globalized world, foreign direct investment (FDI) has emerged as a crucial driver of economic growth, particularly in developing countries (Mert & Caglar, 2020). However, the globalizing world is also struggling with climate change and the resulting global warming, droughts and excessive rainfall, which create social and economic problems for countries (Prince et al., 2023; Sazcha et al., 2020). Therefore, while countries continue their economic growth through globalization and FDIs, they also need to cope with the ever-increasing environmental problems.

FDIs contribute to productivity growth, job creation and technology transfer in countries, and they have been one of the important factors in boosting economic growth (Ghauri et al., 2021). In the global economy, FDI inflows to developing countries increased significantly, reaching USD 867 billion in 2023, compared to USD 194 billion in 2003 and USD 608 billion in 2010, indicating a notable upward trend (UNCTAD, 2024). On the other hand, growing economies through FDI have also been associated with environmental degradation such as pollution, resource depletion (Shahbaz et al., 2015), putting increasing pressure on developing countries to balance economic growth with sustainable development. Moreover, in rapidly growing economies, increased energy demand often leads to increased consumption of fossil fuels, causing environmental degradation by increasing pollution, especially CO_2 emissions (Caglar et al., 2022). However, the use of renewable energy can help reduce over-reliance on fossil fuels, both reducing environmental degradation and improving trade balances over time in energy importing countries. The use of renewable energy also contributes to reducing countries' ecological footprint (EF). While numerous works have examined the environmental impacts of the trade and its relationship with energy consumption in developing countries, the specific interactions between FDI, trade balance, EF and renewable energy consumption in South Africa have not been extensively investigated.

As a BRICS member and one of the largest economies on the African continent, South Africa has significant biomass, wind, and solar energy potential; however, 94% of its domestic energy production is still derived from coal, which adversely affects environmental quality (IEA, 2024). South Africa's increasing investments in renewable energy offer the potential to decrease its reliance on coal and can be an example for other countries, particularly in the region. On the other hand, the country faces a dilemma of ensuring economic growth through traditional coal-based industries and reducing environmental degradation by shifting to cleaner energy sources (Joshua & Alola, 2020).

This study intends to develop a comprehensive understanding of the issue by examining the relationship between renewable energy consumption, FDI, trade balance and EF in South Africa from 1990 to 2021. To achieve this objective, the study employs time series analysis and unit root tests to assess the stationarity of the variables. In addition to the traditional Phillips-Perron (PP) unit root test, the KPSS test is also used. To examine the long-run relationships between the variables, a more recent autoregressive distributed lag (ARDL) bound testing approach was chosen to identify the long-run relationship between the variables (Karataş & Ergül, 2023, p. 226). In addition, instead of the widely used Granger causality test, the Toda-Yamamoto causality test is preferred since it does not require considering the order of stationarity of the variables.

The results of the study are expected to offer valuable insights into the development of sustainable development strategies for developing countries. Specifically, the results could guide policymakers in addressing the challenges faced by fossil fuel-dependent economies as they transition to renewable energy sources, particularly in relation to FDI and trade balances, while reducing the EF of their countries. Consequently, the study could have practical applications not only for South Africa but also for other developing nations with similar economic structures. This analysis aims to inform future policy recommendations by exploring the interactions between renewable energy consumption and key economic indicators from the perspective of sustainable economic development and environmental sustainability.

The structure of this study is organized as follows: In the literature review, the interaction between FDIs, trade balance, and renewable energy consumption in shaping countries' economic development and environmental sustainability is discussed, with a focus on ecological footprint and environmental policies in the context of developing countries. In the third section, the data sources and methodology employed in the analysis are presented, followed by the findings. In the conclusion, the results are interpreted for South Africa, compared with the existing literature, the policy implications are outlined, the limitations are discussed, and recommendations for future research are provided.

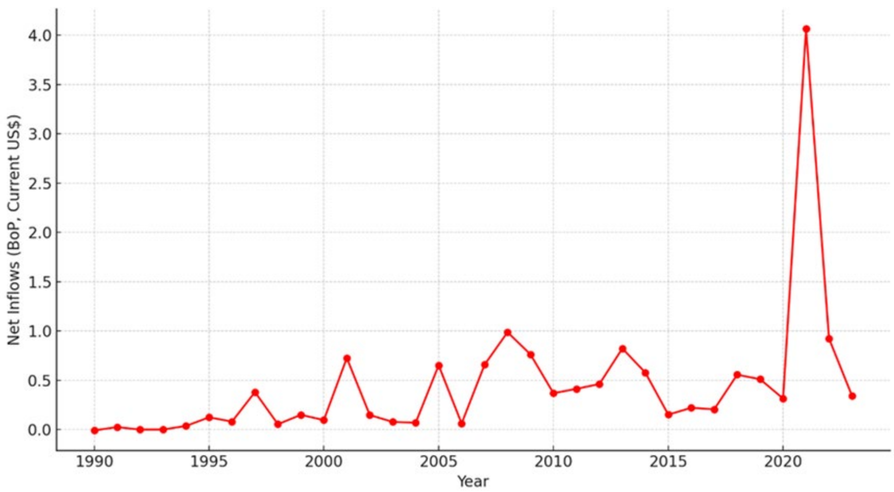
LITERATURE REVIEW

South Africa, as a leading economy in Africa, has seen recovery in employment and GDP post-pandemic but continues to face structural challenges including high unemployment, inequality, and infrastructure bottlenecks that hinder its development (World Bank, 2024d). Factors like FDI inflows and trade balance significantly shape its economic landscape, while environmental conditions are influenced by renewable energy consumption and EF.

South Africa has been a significant recipient of FDI, largely due to its advanced financial and communication sectors, abundant natural resources, and its strategic location as a gateway to Sub-Saharan Africa (PwC, 2024). Figure 1 illustrates that South Africa's FDI inflows from 1990 to 2023 were initially modest, with occasional spikes between 1990 and 2010. These increases can be attributed to various government reforms, including trade liberalization, the easing of exchange controls, and efforts to foster regional integration, all aimed at integrating the South African economy into the global market (Musakwa & Odhiambo, 2019). Post-2010, FDI inflows stabilized until 2021, when they surged to over $40 billion, driven by significant corporate restructurings (UNCTAD, 2023). FDI levels returned to normal levels by 2023, impacted by market adjustments and global uncertainties stemming from regional conflicts, such as the Ukrainian Russian war, and the post-COVID period.

Figure 1

FDI Net Inflows (BoP, Billion US$) In South Africa (1990-2023)



Source: World Bank, 2024b.

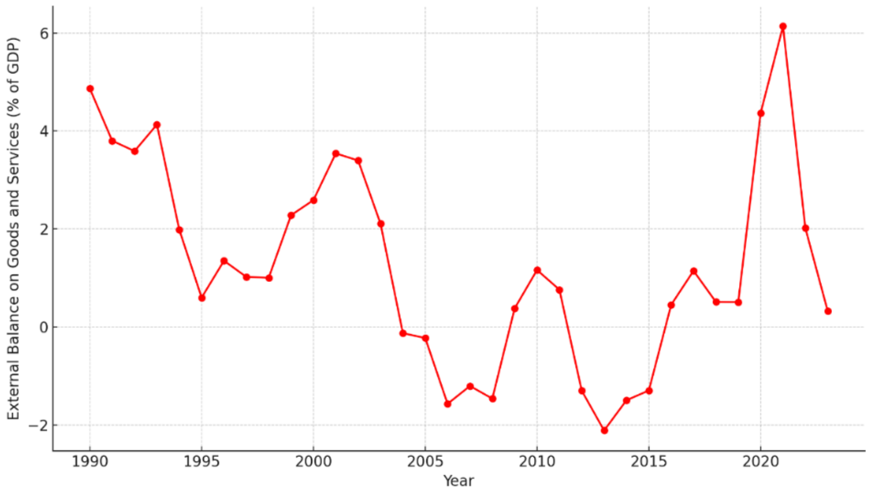
Although FDIs are one of the main factors driving economic growth in developing countries, their environmental impacts are mixed and have been widely debated in the literature. There are two competing theories concerning the relationship between environmental impacts and FDI inflows: The Pollution Haven Hypothesis (PHH) and The Pollution Halo Hypothesis. The pollution halo hypothesis argues that FDIs can improve environmental quality in the host country by introducing greener technologies (Caglar et al., 2022). This perspective suggests that multinational enterprises (MNEs), typically based in countries with strict environmental laws, introduce more sophisticated and less polluting technologies along with superior environmental practices to the host countries (Kisswani & Zaitouni, 2021). On the other hand, PHH notes that FDI can further deteriorate environmental conditions in host countries, as MNEs may shift production to countries with generally weaker environmental standards in order to reduce costs and take advantage of cheaper labor (Mert & Caglar, 2020). Hence, these companies may lead to further environmental degradation in the host country, as serious sanctions cannot be imposed.

Existing studies in the literature on FDIs and their environmental impacts analyze the relationship between CO_2 emissions and environmental degradation in developing countries. Dhrifi et al. (2020) examine 98 developing countries from the years 1995 to 2017 and reveal that FDI has a significant harmful impact on CO_2 emissions in African countries, while in Asian countries it has an inverted U-shaped nexus. In a similar vein, Khan et al (2020) underscore that FDI inflows exacerbate CO_2 emissions in BRICS countries while investigating the interplay between CO_2 emissions, remittances, income, energy consumption, and FDIs. In contrast, some studies report an insignificant or opposite relationship between FDI inflows and increased CO_2 levels, providing evidence in favor of the Pollution Halo Hypothesis in developing countries. Shao et al. (2019) found that FDI inflows lead to pollution reduction in host countries and subsequent improvements in environmental conditions further attract additional investments, pointing out that the PHH does not apply to BRICS and MINT countries and supporting the Pollution Halo Hypothesis. Caglar et al. (2022) analyze the link between renewable energy consumption, natural resources and CO_2 emissions in BRICS countries and find that a 1% increase in FDI leads to a 0.027% decrease in CO_2 emissions, supporting the Pollution Halo Hypothesis. This is due to the fact that MNCs contribute to the improvement of environmental quality through the transfer of clean technologies. In this respect, it can be argued that FDI has the potential to promote sustainable development when it is directed towards sectors such as green technologies and renewable energy. By making investments in natural resources, the mutual benefits of reduced dependence on fossil fuels, the creation of jobs and reduction of EF can be achieved, benefiting both the economy and the environment (Caglar et al., 2022).

In the case of South Africa, the evidence suggests that the impact of FDI inflows has been mixed, with both benefits and challenges. While FDI inflows have led to environmental degradation due to increased reliance on coal and other non-renewable resources (Shahbaz et al., 2015), the contribution of FDI inflows to reducing CO_2 emissions has been modest and it has been recommended that FDI should prioritize the transition to renewable energy sources (Joshua & Alola, 2020). Thus, if South Africa places a greater emphasis on sustainability rather than short-term economic returns, FDI can play a more proactive role in fostering both economic and environmental sustainability. Given that exports and imports are often the main drivers of economic growth in developing countries growth (Bakari & Mabrouki, 2017; Saaed & Hussain, 2015), it can be argued that trade, as a key macroeconomic indicator, plays an important role in a country's economic stability and hence its environmental implications. Figure 2 shows South Africa's trade balance in goods and services from 1990 to 2023, based on World Bank data.

Figure 2

External Balance on Goods and Services (% of GDP) (1990-2023) of South Africa



Source: World Bank, 2024a.

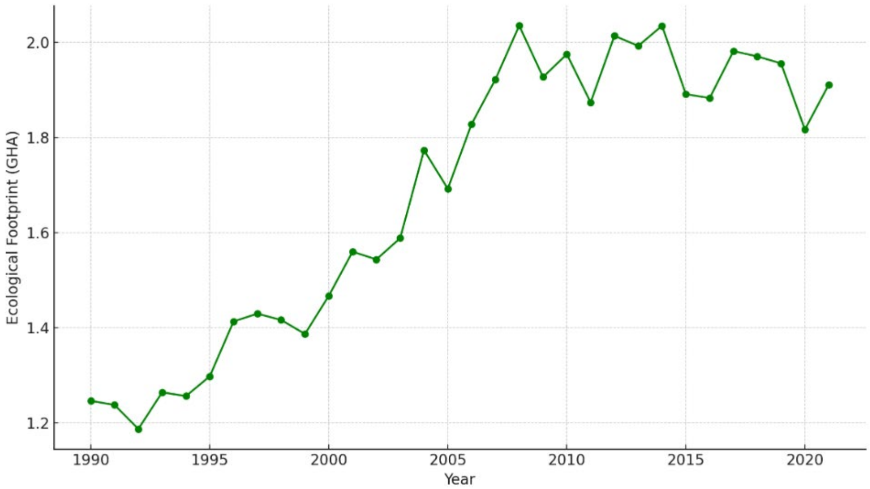
The above figure shows that South Africa's trade balance declined in the early 1990s during economic transitions, recovered in the mid-1990s, peaked in the early 2000s, and fell during the global financial crisis. From 2010 to 2020, there was a moderate post-crisis recovery with fluctuations, including a significant improvement in 2015, possibly driven by increased export demand. Following a surge in 2021, driven by high global demand in the post-COVID period, South Africa's trade balance sharply declined, ultimately stabilizing with the external balance at 0.3% of GDP in more recent years. However, international trade often drives increased natural resource extraction in developing nations, leading to environmental degradation through groundwater depletion, deforestation, loss of biodiversity, and pollution as they exploit natural resources to meet global demand (Merem et al., 2021; Sekhri, 2022; Zhang et al., 2020).

The literature presents mixed results regarding the relation between trade and environmental deterioration in developing countries. Jebli et al. (2016) argued that trade and increased use of renewable energy tend to reduce CO2 emissions and highlight the positive relationship between trade and improved environmental conditions. In contrast, some studies emphasize an inverse relationship between trade and environmental degradation in various developing countries. Nathaniel & Khan (2020) analyzed data from 1990 to 2016 and found that economic growth, trade and non-renewable energy consumption contribute to environmental degradation in ASEAN countries. This finding is supported by different developing market contexts by further studies, such as China (Y. Chen et al., 2019) and North African countries (Mahmood et al., 2020). This is also relevant in the African context, where natural resource exports contribute to ecological degradation and reinforce the negative relationship between trade and the environment in South Africa (Udeagha & Ngepah, 2022). Given that South Africa's trade balance is heavily influenced by natural resource extraction on the export side, while petroleum products are the main driver of imports (WITS, 2024), a shift towards renewable energy could increase the sustainability of the South African economy by reducing dependence on fossil fuels and mitigating associated environmental and economic risks. In this regard, the literature emphasizes that shifting to cleaner energy sources contributes positively to countries' environmental sustainability (Ansari et al., 2022; Sahoo & Sethi, 2021; Xue et al., 2021).

Since South Africa's significant ecological challenges are primarily due to its reliance on coal and other non-renewable energy sources, understanding the use of EF and renewable energy is key to addressing environmental issues and climate change challenges in the country. EF, a relatively new concept in the field of sustainability, can be defined as the measurement of biological resources required to support an economic system (Wackernagel & Monfreda, 2004). It measures the natural resources required to sustain the system, while also considering its capacity to absorb the waste produced (Sahoo & Sethi, 2021). In recent years, EF has been a growing concern in countries like South Africa, especially in those heavily relying on fossil fuels, due to their significant impact on greenhouse gas emissions and the environmental challenges that is one of the biggest challenges hindering progress towards sustainability goals (B. Chen et al., 2007). Figure 3 shows that EF in South Africa increased continuously from 1990 to 2008, driven by industrialization and economic growth, reaching 203.5 million Global Hectares (GHA). Due to the 2008 global financial crisis, EF decreased in the country in response to a decline in industrial activity and economic slowdown. Since 2010, EF has been ranging from 181.6 million to 203.4 million GHA, indicating a more balanced but significant environmental impact.

Figure 3

EF (GHA) of South Africa (1990-2023)



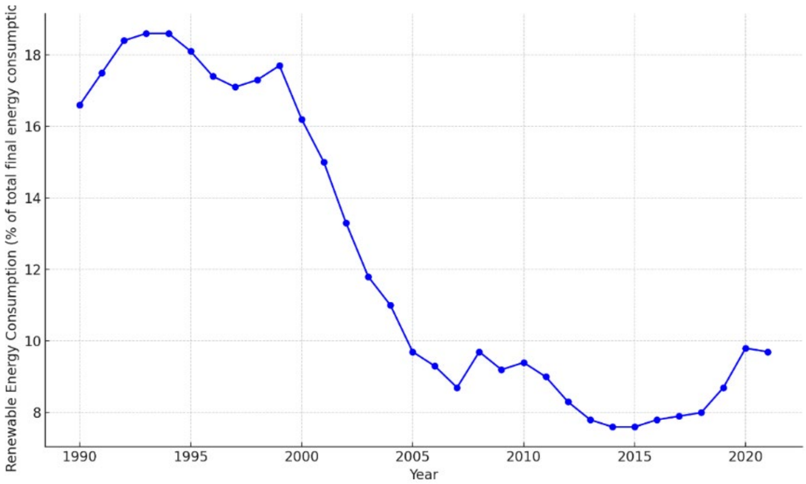
Source: Footprintnetwork, 2024.

While increased economic activity leads to higher energy consumption and CO2 emissions, this reliance on energy consumption is a key driver of ecological degradation, further intensifying climate change (Iqbal et al., 2023; Noorymotlagh & Çiftçioğlu, 2023; Pata et al., 2023). In the literature, studies have demonstrated the adverse effects of non-renewable energy usage on EF. Destek & Sinha (2020) investigated the EF in 24 OECD countries from 1980 to 2014, finding that increased renewable energy use reduces the EF, while higher non-renewable energy consumption leads to greater environmental degradation. In examining the relationship between disaggregated energy sources and institutional quality on the EF of 29 OECD countries, it has been found that economic growth and non-renewable energy sources are detrimental to the environment, whereas institutional quality positively impacts ecological sustainability (Christoforidis & Katrakilidis, 2021). Various studies in the context of developing countries also confirm that the use of non-renewable energy increases EF, while renewable energy is recognized to lower EF by reducing environmental degradation in these countries (Idroes et al., 2024; Nathaniel & Iheonu, 2019; S. Nathaniel & Khan, 2020; Sahoo & Sethi, 2021; Usman et al., 2021). In this context, it can be argued that increasing the use of renewable energy can significantly reduce EF by reducing CO2 emissions and minimizing environmental degradation, while at the same time promoting more sustainable economic development in these countries.

In South Africa, as in all other countries, the use of renewable energy is becoming increasingly vital for reducing environmental degradation and tackling climate change (Ayamolowo et al., 2022). Although South Africa has implemented policies aimed at increasing the share of renewable energy in the energy mix (Akinbami et al., 2021), which can be an important factor to reduceCO2 emissions and thus the country's EF, the slow transition away from coal and the high initial costs of renewable technologies are two major challenges for the country, as discussed in the literature (Caglar et al., 2022; Saqib et al., 2023). Figure 4 depicts the trend of renewable energy consumption in South Africa for the years between 1990-2021, showing a decline from 1990 to 2008. Post-2008, there has been a modest recovery, with the share of renewable energy stabilizing at around 8–9% from 2010 onwards, together with the country's energy mix policies. However, a temporary dip below this range was observed in 2014–2015, likely due to short-term policy shifts and unfavorable market conditions. Moreover, the correlation between South Africa's renewable energy consumption and its EF also reveals a negative relationship and demonstrates how the country's dependence on non-renewable energy sources has led to increased environmental degradation.

Figure 3

Renewable Energy Consumption (% of total final energy consumption) of South Africa (1990-2021)



Source: World Bank, 2024c.

DATA AND METHODOLOGY

Model and Dataset

In this study, the model described below is used to examine the relationship between the EF, FDI, renewable energy consumption, and trade balance in South Africa for the period 1990–2021:

$$ecolo_t = \alpha_0 + \alpha_1 foreign_t + renewable_t + balance_t + e_t$$

In light of current developments, EF data is used as a proxy for environmental pollution in this analysis. The variables employed in the study, along with their sources, are presented in Table 1.

Table 1

Definitions and Sources of Variables

Variable Name	Source
Ecological Footprint ($ecolo$)	Global Footprint Network
Foreign Direct Investment ($foreign$)	World Bank
Renewable Energy Consumption ($renewable$)	World Bank
Trade Balance ($balance$)	World Bank

Method

In this paper, unit root tests are conducted to determine the stationarity of the variables and the cointegration relationship between the variables is analyzed by ARDL bounds test. In the ARDL bounds test approach, there is no need to determine whether the variables are I ($_0$) or I ($_1$) and therefore, there is no need to examine the stationarity levels before the test is performed. However, since the critical values provided are tabulated according to whether the variables are I ($_0$) or I($_1$), it is important to ensure that none of the variables are I ($_2$). Moreover, in this study, as opposed to the existing literature, Toda-Yamamoto causality analysis is preferred to identify causal relationships. This is because the Toda-Yamamoto causality test does not consider the order of stationarity of the variables.

Empirical Findings

Unit Root Test

The Kwiatkowski-Phillips-Schmidt-Shin (KPSS) test (Kwiatkowski et al., 1992), differs from the Augmented Dickey-Fuller (ADF) test in terms of its hypothesis structure. While the null hypothesis (H_0) tests for the presence of a unit root, meaning that the series is non-stationary in the ADF test, the null hypothesis (H_0) tests for stationarity in the series in the KPSS test.

The hypotheses for the KPSS test are as follows (Sarıkovanlık et al., 2019, p. 22):

•**H_0:** Variables are stationary.

•**H_1:** Variables have a unit root.

The Phillips-Perron (PP) unit root test (Phillips & Perron, 1988), involves nonparametric corrections to account for autocorrelation in the calculation of the test statistic. This ensures that autocorrelation does not affect the asymptotic distribution of the test statistic. In the PP test, the null hypothesis assumes that the series has a unit root. The hypotheses for the PP test are as follows (Çağlayan & Saçaklı, 2006, p. 124):

•**H_2:** Variables have a unit root.

•**H_3:** Variables are stationary.

According to the KPSS test critical values presented in Table 2, the null hypothesis (H_0) is accepted for the FDI variable, indicating that the series is stationary at the level values. For the other variables, the H_0 hypothesis is rejected, meaning that these series contain a unit root at their level values. In the case of the PP test, the probability values indicate that the H_0 hypothesis is rejected for the FDI variable, confirming that the series is stationary at level values. For the other variables, the H_0 hypothesis is accepted, indicating that they contain a unit root at their level values. While the KPSS test does not allow for further testing at the first difference level, the PP test demonstrates that the variables become stationary when the first differences of those containing a unit root at the level values are taken, thus allowing the unit root test to continue.

Table 2
KPSS and PP Unit Root Test Results

Variables	Lag Length	Critical Value and Significance Level	t-Statistic	Probability Value
KPSS Test				
foreign	0	Test critical value:	0.084237	
		5% level	0.146000	
renewable	0	Test critical value:	0.548224	
		5% level	0.463000	
lnecolo	0	Test critical value:	0.172049	
		5% level	0.146000	
balance	0	Test critical value:	0.150163	
		5% level	0.146000	
Phillips Perron Test				
foreign	0	Adjusted t-statistic value	-2.928828	0.0535
		5% level	-2.960411	
renewable	0	Adjusted t-statistic value	-1.206798	0.8915
		5% level	-3.562882	
renewable	1	Adjusted t-statistic value	-2.890202	0.0053
		5% level	-1.952473	
lnecolo	0	Adjusted t-statistic value	-1.046558	0.9221
		5% level	-3.562882	
lnecolo	1	Adjusted t-statistic value	-6.206877	0.0000
		5% level	-1.952473	
balance	0	Adjusted t-statistic value	-0.655594	0.9678
		5% level	-3.562882	
balance	1	Adjusted t-statistic value	-3.744693	0.0005
		5% level	-1.952473	

ARDL Bounds Test Approach

The Engle & Granger (1987) and Johansen & Juselius (1990) cointegration tests assess the long-run relationship between variables but require that all variables included in the analysis be stationary at the same level. If the series have different orders of integration, these cointegration tests cannot be applied and to overcome this limitation, a bounds test approach to cointegration analysis was introduced (Pesaran et al., 2001; Pesaran & Pesaran, 1997). The ARDL bounds testing approach is applicable when some variables are integrated of order $I(_0)$ and others of order $I(_1)$. Hence, the ARDL model is used in this paper to identify short-run and long-run relationships between variables with different levels of stationarity. The appropriate lag length for the variables in the model was determined using the relevant lag criteria and the ARDL model was tested in this framework (Koç et al., 2023, p. 213)

It is important to determine the maximum lag length for the Vector Error Correction Model (VECM) while using the ARDL bounds testing approach. The optimal lag length is determined according to Schwarz and Hannan-Quinn information criteria and the lag with the highest number of stars is chosen. As presented in Table 3, according to these criteria, the appropriate lag length for each level was found to be 1.

Table 3
Determination of Common Lag Lengths Among Variables

Lag Number	AIC	SC	HQ
0	9.970703	10.15753	10.03047
1	6.153429	7.087561*	6.452266*
2	5.916864*	7.598301	6.454770

* The optimal lag length that minimizes the information criterion

After the lag length is determined in the ARDL bounds test, the cointegrated link between variables is evaluated by using the F-test. The calculated F-values, together with the lower and upper critical values, are shown in Table 4 for sample sizes of 30 and 35 observations. The F-value is above the upper critical values for both 30 and 35 observations and leads to the rejection of the null hypothesis stating that there is no cointegrated relationship between the variables. This finding confirms the existence of a cointegrated link between renewable energy consumption, EF, trade balance and FDI in South Africa for the period 1990-2021, while suggesting that all variable in this study are interdependent and influence one another over the long term, while highlighting significant long-run dynamics between them in South Africa.

Table 4
ARDL Bounds Test Results

Number of Observations	F-Statistic	Lower Bound	Upper Bound	Significance Level
35	8.839071	4.568	5.795	%5
30	8.839071	4.683	5.98	%5

In the second stage, the ARDL long-run model is developed to analyze the cointegrated relationship between the variables. Table 5 presents the long-run coefficients, with significant results indicating a negative relationship between renewable energy consumption, trade balance, and the EF at a 5% significance level. Specifically, a 1% increase in renewable energy consumption leads to an approximate 0.04% reduction in the EF, while a 1% increase in the trade balance results in a reduction in the EF by around 0.02%.

Table 5
Long-Run Coefficient Estimates

Variable	Coefficient	Standard Error	t-Statistic	p-Value
Foreign	-0.017662	0.030413	0.580747	0.5706
Renewable	-0.042476	0.012329	3.445152	0.0039
Balance	-0.029980	0.008540	-3.510498	0.0035

The results of the ARDL model, based on the error correction model (ECM) to examine the short-run relationship between renewable energy consumption, EF, trade balance, and FDI in South Africa from 1990 to 2021, are presented in Table 6. In the ECM, the desired outcome is for the error correction term to be negative and statistically significant. According to the findings, the error correction term meets this expectation, being both negative and significant. This indicates that any short-term imbalance, with the EF as the dependent variable, will adjust toward equilibrium in the long run. Based on the calculation of 1/0.741500, the short-term imbalance will be corrected after approximately 1.34 periods, meaning that equilibrium will be restored within roughly 1.34 years.

Table 6
Short-Run ARDL Model Estimates

Variable	Coefficient	Standard Error	t-Statistic	p-Value
C	14.54307	2.214613	6.566868	0.0000
@TREND	-0.004726	0.000860	-5.497962	0.0001
D(FOREIGN)	0.013995	0.002733	5.120632	0.0002
D(FOREIGN(-1))	0.019964	0.005080	3.929885	0.0015
D(FOREIGN(-2))	0.014257	0.005055	2.820315	0.0136
D(FOREIGN(-3))	0.017731	0.004229	4.192706	0.0009
D(BALANCE)	-0.005002	0.004335	-1.153765	0.2679
D(BALANCE(-1))	0.017907	0.005245	3.413879	0.0042
D(BALANCE(-2))	0.005120	0.005420	0.944627	0.3609
D(BALANCE(-3))	0.025649	0.005035	5.093873	0.0002
CointEq(-1)*	-0.741500	0.113166	-6.552300	0.0000

Toda-Yamamoto Causality Analysis

The Toda-Yamamoto causality test is used to identify the causality relationship between variables (Toda & Yamamoto, 1995). Unlike other tests, the Toda-Yamamoto method can be applied even when the variables are stationary at different integration orders. To apply this test, the maximum degree of integration (dmax) and the optimal lag length (p) for the variables in the analysis are first determined, and then a VAR model with (p+dmax) lags is estimated. The Toda-Yamamoto causality test is conducted using the level values of the variables (Özşahin & Şahin, 2023, p. 66). In this case, the lag length recommended by the Schwarz and Hannan-Quinn information criteria is determined to be 1. Since both the optimal lag length and the maximum degree of integration were identified as 1, a VAR model with 2 lags was created according to the (p+dmax) condition. The Wald test was then applied to the coefficients of the model to identify the causality relationship between the variables. Toda and Yamamoto introduced the chi-squared value calculated in their 1995 study as the modified Wald test (MWALD) (Kızılgöl & Öndes, 2021, p. 210). However, it is noted that when comparing the chi-square table value, the test statistic should be compared with the table value that has p degrees of freedom. In the EViews software, the probability value is given according to two degrees of freedom under the p+dmax condition. Therefore, the probability value directly provided cannot be used, and instead, the probability value based on the table with p degrees of freedom, as suggested by Toda and Yamamoto, was calculated by us, with the results presented.

According to the Toda-Yamamoto test probability values shown in Table 7, a causality relationship was identified from FDI and renewable energy consumption to the EF at a 5% significance level, and from the trade balance to the EF at an 8% significance level. Additionally, causality was found from both the EF and trade balance to FDI, from the EF to renewable energy consumption at a 10% significance level, and from renewable energy consumption to the trade balance during the period 1990–2021 in South Africa.

Table 7
Toda-Yamamoto Causality Test Results

Direction of Causality	Lag	Chi-Square	p-Value
Foreign Direct Investments → Ecological Footprint	1	4.123030	0.042303
Renewable Energy → Ecological Footprint	1	23.94088	0.000000
Trade Balance → Ecological Footprint	1	3.182076	0.074450
Ecological Footprint → Foreign Direct Investments	1	6.061003	0.013819
Renewable Energy → Foreign Direct Investments	1	2.286174	0.130531
Trade Balance → Foreign Direct Investments	1	11.17225	0.000830
Ecological Footprint → Renewable Energy	1	2.709994	0.099721
Foreign Direct Investments → Renewable Energy	1	0.220364	0.638762
Trade Balance → Renewable Energy	1	2.090378	0.148229
Ecological Footprint → Trade Balance	1	0.115176	0.734326
Foreign Direct Investments → Trade Balance	1	1.415607	0.234127
Renewable Energy → Trade Balance	1	11.98095	0.000537

CONCLUSION

This study examines the relationship between the EF, FDI, renewable energy consumption, and trade balance in South Africa from 1990 to 2021. The ARDL bounds test revealed a long-term cointegration relationship among the variables, indicating that they move together over time and influence each other in the long run. The Toda-Yamamoto causality analysis identified directional causal relationships, particularly from FDI, renewable energy consumption, and trade balance to the EF; from the EF and trade balance to FDI; from the EF to renewable energy consumption; and from renewable energy consumption to the trade balance.

The results show that renewable energy consumption negatively affects EF, suggesting that increased use of renewable energy can reduce environmental degradation. This finding aligns with the broader consensus in the literature, which emphasizes the environmental benefits of shifting to cleaner energy sources. Despite South Africa's renewable energy potential, its energy supply is still dominated by coal and other non-renewables. Therefore, national-scale policies are needed to support the expansion of renewable energy. Some of these policies may include promoting investment-friendly environments for renewable energy, enhancing waste management systems for biomass, and increasing the deployment of solar technologies. Human capital development also plays a critical role in creating sustainable urban environments, promoting clean energy use, and conserving biodiversity. Based on the findings, the following policy recommendations are offered for South Africa and other developing countries with similar economic characteristics:

- Government incentives should be expanded, institutional reforms implemented, and energy efficiency improvements prioritized to increase renewable energy investments and encourage technological innovation.
- Public awareness campaigns, tax and financial incentives for renewable energy use, R&D investments to reduce costs and improve efficiency, and support for human capital development are key to reducing environmental pollution and achieving sustainability targets.

The study also highlights that FDI and renewable energy consumption causally affect EF, underlining the importance of clean energy investments in minimizing environmental harm. FDI directed toward green technologies and sustainable sectors can play a central role, while governments should adopt environmentally sound regulations to guide such investments. In this regard, a targeted incentive framework to attract green FDI should be established, including tax breaks, R&D and employment incentives, investment credits, and SME support mechanisms. Additionally, the trade balance was found to be negatively related to EF, indicating that trade improvements can reduce environmental pressure. Reducing reliance on imported fossil fuels and increasing the domestic use of renewable energy can enhance the trade balance and environmental outcomes simultaneously. Based on these findings, the following policy recommendations can be made:

- Designing foreign trade policies that discourage imports of fossil fuel-intensive products and support clean energy production aligned with environmental standards.
- Promoting trade in environmentally friendly products to reduce environmental degradation and foster sustainable trade practices.

Finally, the bidirectional causality between EF and trade balance to FDI highlights the role of environmental quality and trade performance in attracting FDI. A lower EF may appeal to environmentally conscious investors, while a strong trade balance can improve investor confidence. These findings stress the need for harmonized environmental and economic policies as sustainability becomes a key consideration for MNEs. This study has several limitations. First, it covers data only up to 2021, potentially missing recent developments in the post-COVID era. Future research could incorporate more recent data. Second, the focus on South Africa limits generalizability, so comparative studies across other developing or BRICS countries would be beneficial. Third, external shocks such as global crises were not explicitly included, though they may affect the studied relationships. Future research could expand the model with additional variables such as GDP growth, urbanization, and various pollution indicators, using advanced econometric techniques like VAR or SEM to gain deeper insights.

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