



Testing Linear and Nonlinear Relationships Between Foreign Direct Investment and Fossil Energy Consumption in Fragile Five Countries

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Abstract

The global warming and climate change problem is causing severe threats for the present and the future. The excessive utilization of fossil energy resources, especially on the production side, has contributed greatly to global warming by producing the greenhouse effect. In this respect, it is essential to assess the impact of foreign direct investment (FDI), which is expected to increase the production and employment of countries, on the utilization of fossil fuels. In this study, we investigate the relationship between FDI and fossil energy consumption (EC) utilizing such tests as: Johansen linear cointegration, Kapetanios, Shin, and Snell (2006) nonlinear cointegration, the linear Error Correction Model (ECM), Exponential Smooth Autoregressive (ESTAR) ECM, Granger (1969) linear causality, and Diks and Panchenko (2006) nonlinear causality. In this context, annual data covering the period between 1980 and 2020 are employed for the "Fragile Five" countries, which are: Brazil, Indonesia, India, Turkey, and South Africa. By applying the Augmented Dickey-Fuller (ADF) linear unit root test, we found that the series became stationary after taking the first difference. Following the unit root test results, Johansen's (1988) linear cointegration test results indicated that there existed a cointegration relationship from FDI to EC for Turkey and South Africa, while Kapetanios, Shin, and Snell's (2006) nonlinear cointegration test results revealed that there existed a cointegration relationship from FDI to EC in South Africa. In addition, the linear error correction model was proven to be valid for Turkey and South Africa, while the ESTAR nonlinear error correction model is valid only for Turkey. Finally, Granger's (1969) causality test results proved that there was a causal relationship from FDI to EC in Turkey. Dicks and Panchenko (2006) stated that there was no causal relationship between the variables.

Keywords

Foreign Direct Investment, Fossil Energy Consumption, Exponential Smooth Transition Autoregressive

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Introduction

For the last half-century, the environmental and ecological problems caused by global warming and climate change have led to an increased attention on this issue. Therefore, the concept of “sustainability” has begun to be discussed across many disciplines and fields. Because an environment that minimizes ecosystem damage and is environmentally friendly is the most basic need for the continuity of life on this planet, in this respect, the importance of the relationship between the environment and economy increases considerably. The “race to the bottom,” “race to the top,” and “pollution haven” hypotheses come to the fore in relation to foreign direct investment (FDI). Foreign direct investments, which are believed to have a feature that can boost economic growth and employment, are important for countries with a lack of savings and capital. The “Race to the bottom” hypothesis describes countries’ competition to attract FDI to their countries. In this context, there is a desire to produce the conditions for FDI to come to a country by lowering environmental standards and regulations. Thus, privileges are granted to practices of foreign capital that will pollute the environment. Rules that weaken the environmental standards in developing countries to attract FDI encourage a similar approach for developing countries that want to prevent capital outflow (Konisky, 2007; Dong et al., 2012). Unlike the race to the bottom, the “Race to the top” hypothesis believes that local governments do not have to set environmental standards and regulations to attract foreign direct investment. In addition, FDI will prevent ecological problems when they apply technologies that can develop environmentally friendly and renewable energy sources for the host country. In other words, higher income is associated with better environmental quality (Yandle, 2004: 211).

Moreover, “The pollution haven hypothesis” is based on the mentality that dirty industries will settle in countries with weak environmental policies, the latter typically being lower-income, less developed countries (Sheldon, 2006). Therefore, multinational companies will prefer countries where production costs will decrease due to weak environmental regulations (Neumayer, 2000). In particular, the competition to attract FDI to support the economic growth of developing economies results in the stretching of environmental policy practices and the shifting of assets, which are subject to relatively stricter environmental standards in developed countries, and therefore ecological problems towards these regions. The rising energy demand with increased production rates and the environmental issues that arise as a natural result of this threaten the ecology, with the potential costs hoped to be incurred to eliminate these problems endangering the growth and welfare of the economies. The relationship between FDI and fossil energy use is also the subject of many studies (Amri, 2016; Mavikela and Khobia, 2018; Wang and Jiayu, 2019; Bujari and Martinez, 2021; Islam et al., 2021).

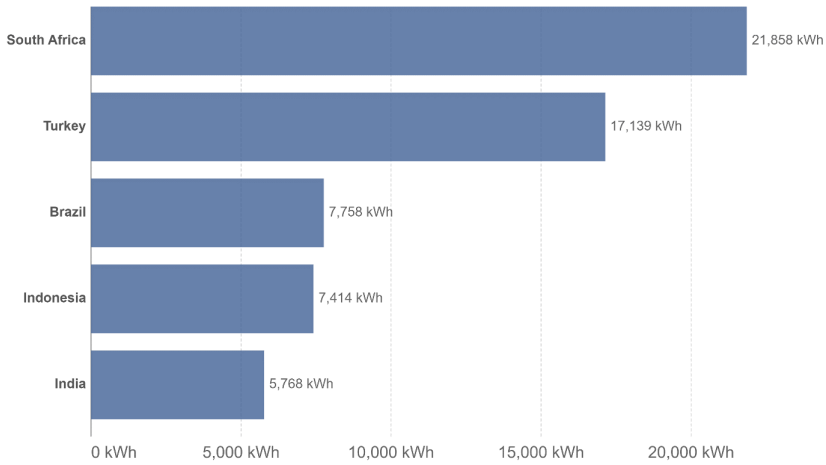


Figure 1. Fossil energy (fuel) consumption per capita in 2020 (Source: Our World in Data).

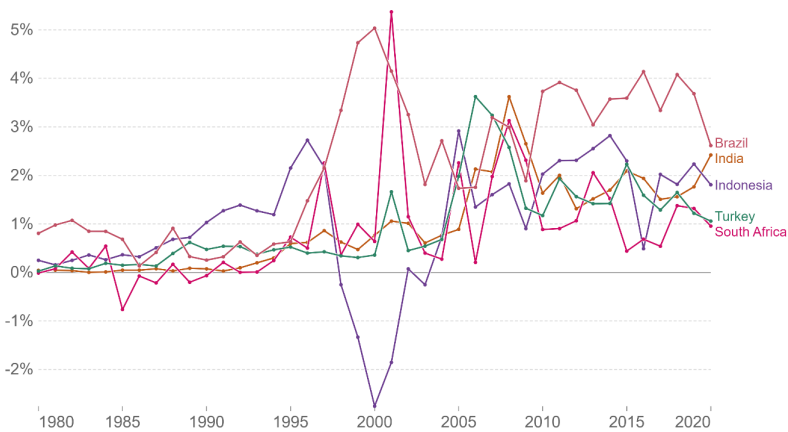


Figure 2. FDI, net inflows as share of GDP, 1980 to 2020 (Source: Our World in Data).

Figure 1 and 2 depict the fossil energy consumption per capita in 2020 and the FDI, net inflows as share of GDP from 1980 to 2020, respectively. Among the Fragile Five countries, South Africa and Turkey were the countries with the highest fossil energy consumption in 2020. In addition, it has been determined that South Africa and Turkey have similar tendencies in terms of foreign direct investment and net inflows as shares of GDP.

This paper investigates the relationship between FDI and EC for the Fragile Five countries (Brazil, Indonesia, India, Turkey, and South Africa) between the years 1980 and 2020, employing linear and non-linear time series methodologies. Following the literature review, the paper discusses the econometric methodology, the dataset, and the results of the analysis. The conclusion constitutes the last part of the paper.

Literature Review

Global warming is essentially a natural phenomenon that has occurred since the formation of the atmosphere. However, with the increase in the use of fossil fuels, especially after the industrial revolution, there has been a critical upward structural break in the rate of increase in global warming. In particular, the increase in fossil fuels with high carbon content has increased the emission of greenhouse gases, which has enabled warm air to hold in the atmosphere at a level that could transform the natural environment and climate. In this regard, after the Second World War, several climate summits were held with the aim of drawing attention to the seriousness of the issue and taking some measures. Finally, the twenty-first session of the Conference of the Parties (COP 21) was held in Paris for the first time in 2015, with all countries involved committing to reducing greenhouse gas emissions on a global scale. In addition, companies in countries that strictly implement the measures brought by these climate agreements can shift their production in the form of FDI to countries that implement the measures relatively more minor, especially within the framework of the “pollution haven” hypothesis and “race to the bottom” argument (Dong et al., 2012; Yoon and Heshmati, 2017; Singhanian and Saini, 2021). In this context, the present study investigates whether there is a non-linear linkage between FDI and EC for the “Fragile Five” countries. In the literature review section, studies examining this relationship were compiled. First, a number of panel econometrics studies that apply the causality linkage between FDI and EC with different variables and econometric methods were reviewed, with most of these studies determining the causality relationship between FDI and EC (Omri and Kahouli, 2014; Kiviyori et al., 2014; Amri, 2016; Behera and Dash, 2017; Muhammad and Khan, 2021).

On the other hand, many studies that examine the linkage between FDI and EC with time series analysis were also examined (Salim et al., 2017, Mavikela and Khobia, 2018; Wang and Jiayu, 2019; Bujari and Martinez, 2021; Islam et al., 2021). Some studies have determined that FDI can reduce EC if the inflow investments are directed to renewable energy sources, thus preventing global warming (Zhang and Zhou, 2016; Sarkodie and Strezov, 2019; Islam et al., 2021; Abbas et al., 2021, Shabir et al., 2022). Other studies argue that if there is an increase in FDI, this situation negatively affects the EC and CO₂ emission volume (Baek and Choi, 2017; Hanif et al., 2019) or vice versa (Shaari et al., 2014; Lorente et al., 2022). In addition, it should be mentioned that several studies have found a cointegration relationship and the Granger causality linkages between FDI and EC for the different countries (Abidin et al., 2015; Latief and Lefen, 2019; Uzar and Eyuboğlu, 2019; Aremo and Ojeyinka, 2019; Udemba et al., 2020).

Table 1

Related literature review

The Author(s)	Country(s)	Sample Period	Empirical Methods	Findings
Kuo et al. (2012)	China	1978-2010	Time series analysis	The results indicate that there is a bidirectional linkage between EC (energy consumption) and FDI.
Li and Qi (2016)	30 Provinces in China	1999-2008	Two-Stage least squares regression analysis and Panel Generalized Method of Moments (GMM)	The results revealed that the overall impact of FDI on Chinese industrial energy consumption is detrimental. Most importantly, the rising trend of foreign capital inflows has adversely impacted the industrial energy consumption. In short, the total effect of FDI increases energy consumption by 0.19%.
Abdouli and Hammami (2017)	MENA Countries	1990-2012	Panel GMM	The results prove that there is a unidirectional causality relationship between EC and FDI inflows for the global panel.
Lin and Benjamin (2018)	MINT Countries	1990-2014	Panel dynamic ordinary least squares	The results reveal that there is a unidirectional causality from FDI to EC for Indonesia and Nigeria. At the same time, there is a bidirectional causality relationship between economic growth, EC, and FDI inflows for Turkey. The results also confirm that there is a unidirectional causality from FDI to EC.
Wang and Jiayu (2019)	Shandong Province in China	2000-2016	Regression and simultaneous equations model	The results revealed that FDI had a negative scale and structural effect on EC, while it was found that there was a positive technical effect on EC in Shandong province. The total impact of these variables was proved to negative directional.
Adom et al. (2019)	27 African countries	2000-2014	Panel GMM	The results revealed that there is a robust concave linkages FDI and EC.
Udemba et al. (2020)	China	1995Q1-2016Q4	Time series analysis	The results displayed a unidirectional causal link between FDI and EC.
Bujari and Martinez (2021)	Mexico	1970-2014	Time series analysis	This paper demonstrates that there is a cointegration nexus between FDI and EC in the long run. In addition, according to the Granger causality test, there is a one-way relationship from FDI to EC in the in the short-term and a two-way relationship in the medium-term.
Amoaka and Insaideo (2021)	Ghana	1981-2014	Time series analysis	The results revealed that there is a cointegration linkages between FDI and EC in the long run when the Johansen multivariate test was conducted.
Lu et al. (2021)	Belt and Road Initiative (BRI) countries	1990-2016	Panel data analysis	Based on DSUR long-run panel estimators, the results showed that if FDI and economic growth increase by 1%, EC will reach to 0.023% and 0.790%, respectively. In addition, according to the Dumitrescu-Hurlin panel causality test, it was found that there existed a bidirectional relationship between EC and FDI for the examined data.

Methodology

To begin with, this study investigates the presence of unit root for series by using the ADF. In this context, we can primarily focus on the methodology of the ADF unit root test. The Dickey-Fuller (DF) is extended to AR (1) and, therefore, can be reached by ADF. In addition, the difference of the dependent variables was added as an independent variable to the model to eliminate the autocorrelation problem of the error term in the ADF test. The ADF test statistic used in this study is as follows:

$$\Delta Y_t = \delta Y_{t-1} + \beta_i \sum_{i=1}^m \Delta Y_{t-i} + u_t \tag{1}$$

$$\Delta Y_t = a_0 + \delta Y_{t-1} + \beta_i \sum_{i=1}^m \Delta Y_{t-i} + u_t \tag{2}$$

$$\Delta Y_t = a_0 + a_1 t + \delta Y_{t-1} + \beta_i \sum_{i=1}^m \Delta Y_{t-i} + u_t \tag{3}$$

In these equations, u_t and a_0 denote the error and the intercept term, respectively. Eq. 1 represents the models without any constant (a_0 and trend (t)). Eq. 2 has a constant and without any trend, while Eq. 3 has constant and trend. The null hypothesis suggests the presence of unit root ($H_0: \delta = 0$) whilst the alternative hypothesis assumes the nonexistence of unit root ($H_1: \delta < 0$) for each variable. In time series analyses, the examination of nonlinear series in a linear way leads to erroneous results, therefore it is crucial to test whether the series is linear. Hence, a nonlinearity analysis based on variance was conducted using ARCH and GARCH (Hentschel, 1995) to examine the nonlinearity of variance. Nonlinearity tests are based on mean and include numerous models, such as: the Nonlinear Autoregressive (NLAR) Model, Generalized Autoregressive (GAR) Model, Threshold AR (TAR) Models, Soft Transition AR (STAR) Models, BAND-TAR Model, and Markov Regime Change (MSA) Model (Tong, 2007).

Terasvirta (1994) noted that nonlinear time series models, such as smooth transition autoregressive models (STAR), gained much importance in modeling economic and analyzing financial data. In addition, Kruse (2011) highlighted that the exponential smooth transition autoregressive model (ESTAR) and its derived tests ESTAR process could be expressed as follows:

$$\Delta y_t = \alpha y_{t-1} + \phi y_{t-1} (1 - \exp\{-\gamma(y_{t-1} - c)^2\}) + \varepsilon_t \tag{4}$$

In Eq. 4, ε_t is the error term and c represent the threshold value. $\varepsilon_t \sim iid(0, \sigma^2)$, if the smoothing parameter (γ) is close to zero, ESTAR model fits into a linear AR (1) model which is shown as follows (Kruse, 2011).

$$\Delta y_t = \alpha y_{t-1} + \varepsilon_t \quad (5)$$

Eq.5 is stationary if $-2 < \alpha < 0$. Then, it is determined that if α equals to zero, it signifies that the ESTAR model has a random walk if γ equals to zero. The ESTAR model under the restriction $\alpha = 0$ is shown as follows (Kapetanios et. al., 2003).

$$\Delta y_t = \phi y_{t-1}(1 - \exp\{-\gamma(y_{t-1} - c)^2\}) + \varepsilon_t \quad (6)$$

In this context, the Eq.6 model means globally stationary if $-2 < \phi < 0$ is true, even though it is locally nonstationary regarding having a partial unit root while $y_{t-1} = c$ holds (Kruse, 2011: 73). On the other hand, we employ Kapetanios et. al. (KSS, 2006) nonlinear cointegration test in this study. For this test, the null hypothesis suggests the nonexistence of a cointegration relationship, while the alternative hypothesis assumes the presence of a nonlinear relationship between the variables. Kapetanios et al. (2006) aimed to develop new alternatives to the error correction model under the alternative hypothesis. For this purpose, the general model is considered:

$$\Delta u_t = F(u_{t-1}) + \varepsilon_t \quad (7)$$

In Eq. 7, multiple functional form of F can be analyzed. Kapetanios et. al. (2006) concentrate on a particular case in which F pursues the exponential smooth transition autoregressive (ESTAR) function form.

$$F(u_{t-1}) = \gamma(1 - \exp(-\theta u_{t-1}^2))u_{t-1} \quad (8)$$

In this case (Eq. 8) becomes as follows (Kapetanios et. al, 2006):

$$\Delta u_t = \gamma(1 - \exp(-\theta u_{t-1}^2))u_{t-1} + \varepsilon_t \quad (9)$$

$$\Delta y_t = \gamma(1 - \exp(-\theta u_{t-1}^2))u_{t-1} + \beta' \Delta x_t + \varepsilon_t \quad (10)$$

Eq. 11 states as the nonlinear STAR error correction model:

$$y_t = \gamma(1 - \exp(-\theta u_{t-1}^2))u_{t-1} + \alpha' \Delta x_t + \varepsilon_t \quad (11)$$

Then, following the case where ε_t is serially correlated, supposing that these serial correlations with lag length p entered the linear autoregressive model.

$$\Delta u_t = \gamma(1 - \exp(-\theta u_{t-1}^2))u_{t-1} + \sum_{j=1}^p \phi_j \Delta y_{t-j} + \eta_t \quad (12)$$

Where η_t denotes *iid* variates with zero mean and finite variance. Finally, the general equation of the ESTAR error correction model is formed by the above equations (Kapetanios et al., 2006):

$$\Delta y_t = \gamma(1 - \exp(-\theta u_{t-1}^2))u_{t-1} + \alpha' \Delta x_t + \sum_{j=1}^p \phi_j \Delta y_{t-j} + \sum_{j=1}^p \lambda_j \Delta x_{t-j} + \varepsilon_t \quad (13)$$

Accordingly, the null hypothesis ($H_0: \theta=0$) states that there is no cointegration relationship while the alternative hypothesis $H_1: \theta > 0$ proposes the presence of a nonlinear ESTAR cointegration relationship between the variables. Since the parameter “ γ ” is not defined under the null hypothesis, this hypothesis cannot be tested directly so that Taylor expansion equation is used (Eq. 14):

$$\Delta u_t = \delta u_{t-1}^3 + \varepsilon_t \quad (14)$$

If the residuals are autocorrelated, the model can be extended as shown in the following model (Kapetanios et. al., 2006):

$$\Delta u_t = \delta u_{t-1}^3 + \sum_{i=1}^p \rho_i \Delta u_{t-i} + \varepsilon_t \quad (15)$$

Within the framework of Eq. 15, the null hypothesis ($H_0: \delta=0$) states that there is no cointegration relation between the variables, and the alternative hypothesis ($H_1: \delta < 0$) proposes the presence of nonlinear ESTAR cointegration (Kapetanios et. al., 2006). Accordingly, if the null hypothesis (H_0) is rejected, it can be said that the presence of cointegration relationship is found. On the other hand, if the null hypothesis is not rejected, it can be said that there is no cointegration relationship between the variables.

We also applied Dicks and Panchenko (2006) nonlinear causality to investigate the casual relationship between variables. The Dicks and Panchenko (2006) test statistics are as follows: $(n-1) \sum_i \left(\hat{f}_{X,Y,Z}(X_i, Y_i, Z_i) \hat{f}_Y(Y_i) - \hat{f}_{X,Y}(X_i, Y_i) \hat{f}_{Y,Z}(Y_i, Z_i) \right)$ (16)

Moreover, Diks and Panchenko (2006) indicates the distribution of the test statistic as follows:

$$\sqrt{n} \frac{(T_n(\varepsilon_n) - q)}{S_n} \xrightarrow{\rightarrow} dN(0,1) \quad (17)$$

The null hypothesis of this test is that there is no non-linear causality relationship between the variables, while the alternative hypothesis is that there is a non-linear causality relationship. In the methodology part of the study, the methodology of nonlinear tests is specifically discussed instead of the methodology of linear conventional tests.

Data and Test Results

This paper investigates the linear and non-linear relationship between EC and FDI for the Fragile Five countries (Brazil, Indonesia, India, Turkey, and South Africa) using annual data from 1980 to 2020. FDI refers to net inflows (% of GDP); fossil energy consumption per capita is measured as average energy consumption from coal, oil and gas per capita. All data are obtained from Our World in Data. The fossil energy consumption variable is used after its logarithmic transformation. When the

EC variable is considered as raw data, it was used after logarithmic transformation since the scale difference and standard deviations of the relevant series are high. The mathematical model for this analysis is presented as:

$$EC = f(FDI) \tag{18}$$

The econometrics model expression for Eq. 18 is provided as:

$$EC_t = \beta_0 + \beta_1 FDI_t + u_t \tag{19}$$

where u_t is the error term, t subscript indicates yearly data from 1980 to 2020, B_0 is the intercept, and β_1 denotes the respective coefficient quantifying the magnitude of nexus between FDI and EC. Table 2 presents Augmented Dickey-Fuller (ADF) unit root test results.

Table 2
ADF Linear Unit Root Test Results

Variables	ADF		
	None	Intercept	Trend and Intercept
Panel A: Brazil			
EC	-0.92 (0.90)	-0.97 (0.75)	-1.14 (0.90)
FDI	-0.62 (0.43)	-1.71 (0.41)	-2.29 (0.42)
ΔEC	-4.84 (0.00)*	-4.94 (0.00)*	-4.97 (0.00)*
ΔFDI	-6.03 (0.00)*	-5.96 (0.00)*	-5.88 (0.00)*
Panel B: Indonesia			
EC	-4.66 (1.00)	-2.36 (0.15)	-0.02 (0.99)
FDI	-1.62 (0.09)	-2.39 (0.15)	-2.64 (0.26)
ΔEC	-3.67 (0.00)*	-4.76 (0.00)*	-3.29 (0.08)*
ΔFDI	-3.40 (0.00)*	-6.02 (0.00)*	-5.94 (0.00)*
Panel C: India			
EC	-7.36 (1.00)	-1.92 (0.31)	-0.96 (0.93)
FDI	-0.30 (0.57)	-1.32 (0.60)	-3.09 (0.12)
ΔEC	-2.58 (0.01)*	-4.02 (0.00)*	-4.20 (0.00)*
ΔFDI	-6.85 (0.00)*	-6.90 (0.00)*	-6.81 (0.00)*
Panel D: Turkey			
EC	-3.81 (0.99)	-1.82 (0.36)	-1.34 (0.86)
FDI	-1.23 (0.19)	-2.21 (0.20)	-2.72 (0.23)
ΔEC	-4.57 (0.00)*	-6.24 (0.00)*	-6.85 (0.00)*
ΔFDI	-5.92 (0.00)*	-5.85 (0.00)*	-5.80 (0.00)*
Panel E: South Africa			
EC	-0.11 (0.63)	-2.45 (0.13)	-3.20 (0.09)
FDI	-0.70 (0.40)	-1.59 (0.47)	-5.50 (0.00)*
ΔEC	-7.36 (0.00)*	-7.26 (0.00)*	-7.67 (0.00)*
ΔFDI	-8.02 (0.00)*	-7.93 (0.00)*	-7.84 (0.00)*

The critical values are obtained from MacKinnon (1996), * indicates rejection of null hypothesis at 5% significance levels and Δ denotes the first difference of a time series. Expressions in parentheses () and square brackets [] state probability values and lag length, respectively, while those not in parentheses indicate t statistics. In addition, Schwarz Info Criterion is used for unit root test.

The ADF unit root test results in Table 2 are given for none, constant, constant, and trend data. For all countries, it was determined that the EC and FDI series are stationary after taking the first difference for none, constant, and trend data. This result also shows that it is possible to conduct a long-term cointegration analysis. Table 3 presents Kruse (2011) nonlinear unit root test results.

Table 3

Kruse (2011) Nonlinear Unit Root Test Results

	Case 1	Case 2	Case 3
	Test Stat.	Test Stat.	Test Stat.
Panel A: Brazil			
EC	3.38 (2)	5.13 (2)	3.16 (2)
FDI	3.83 (0)	2.56 (0)	4.61 (0)
Panel B: Indonesia			
EC	34.13 (0)*	2.54 (1)	2.10 (0)
FDI	7.26 (0)	7.06 (2)	6.24 (2)
Panel C: India			
EC	67.17 (1)*	6.76 (2)	1.86 (0)
FDI	10.03 (0)*	6.92 (0)	8.15 (0)
Panel D: Turkey			
EC	19.94 (0)*	5.80 (0)	3.93 (0)
FDI	3.47 (0)	2.99 (0)	2.59 (0)
Panel E: South Africa			
EC	5.98 (0)	16.80 (0)*	15.80 (0)*
FDI	18.44 (0)*	3.85 (2)	4.10 (0)
Kruse (2011) Critical Values	5%	9.53	10.17
			12.82

* indicates rejection of null hypothesis at 5% significance level. Case 1 and Case 2 represent raw and demeaned data, respectively, while Case 3 represents detrended data.

Table 3 demonstrates the nonlinear unit root test results of the EC and FDI series for the Fragile Five countries. Accordingly, it was proven that the EC series in South Africa is stationary at the level values for Case 2 and Case 3, while the EC series in Indonesia, India, and Turkey are stationary at level values for Case 1. In addition, the FDI in India and South Africa is stationary at level values for Case 1. According to the other results, all series are stationary after taking the first difference. Table 4 presents the Johansen Cointegration test results. This test was applied to examine a linear cointegration relationship.

Table 4
Johansen Cointegration Test Results

Hypothesized No. of CE (s)	Eigenvalue	Trace Statistic	0,05 Critical Value	Prob.***	Max-Eigen Statistic	0,05 Critical Value	Prob.***
Brazil (1)							
None	0.21	12.79	20.26	0.38	9.58	15.89	0.37
At most 1	0.07	3.20	9.16	0.54	3.20	9.16	0.54
Indonesia (1)							
None	0.20	9.04	18.39	0.57	9.04	17.14	0.49
At most 1	1.29	0.00	3.84	0.98	0.00	3.84	0.98
India (1),							
None	0,29	16.37	25.87	0,46	13.43	19,38	0,29
At most 1	0,07	2.94	12,51	0,88	2,94	12,51	0,88
Turkey (2)							
None*	0.26	15.93	15.94	0.04	11.63	14.26	0.12
At most 1*	0.10	4.29	3.84	0.03*	4.29	3.84	0.03*
South Africa (5)							
None *	0.35	19.50	18.39	0.03*	16.94	17.14	0.05**
At most 1	0.06	2.56	3.84	0.10	2.56	3.84	0.10

* and ** indicate rejection of null hypothesis at 5% and 10% significance level, respectively. *** denotes Mackinnon-Haug-Michells (1999) p-values. Values in parentheses adjacent to countries () denote the lag length.

Table 4 demonstrates the presence of a cointegration relationship between FDI and EC for Turkey and South Korea. This is because the cointegration test statistics for these countries are less than five percent.

Table 5
Kapetanios, Shin and Snell (2006) Nonlinear Cointegration

Model		Test Statistics	Critical Values (according to 5%) for t_{NEG}
Brazil	KSS _c	-1.80 (0)	-3.28
	KSS _t	-2.09 (2)	3.71
Indonesia	KSS _c	-1.99 (3)	-3.28
	KSS _t	-2.37 (3)	3.71
India	KSS _c	-2.25 (4)	-3.28
	KSS _t	-1.24 (3)	3.71
Turkey	KSS _c	-1.92 (0)	-3.28
	KSS _t	-1.67 (0)	3.71
South Africa	KSS _c	-3.91 (0)*	-3.28
	KSS _t	-4.11 (0)*	3.71

The values in parentheses indicate the lag length, KSS (2006) critical values was used and KSS_c denotes KSS test statistic obtained from demeaned data. KSS_t denotes KSS test statistic obtained from both demeaned and detrended data, * indicates rejection of null hypothesis at 5% significance levels. The lag length (lsm=3) was considered as 2 in the nonlinear cointegration analysis.

In Table 5, the KSS (2006) nonlinear cointegration test statistics were compared to the critical values in the KSS (2006) study. Accordingly, it was concluded that the test statistics values of South Africa are less than the critical values (according to t_{NEG}). Accordingly, the null hypothesis of a non-cointegration relationship between EC and FDI series should be rejected. Therefore, it can be said that these series have cointegration relationships as there is a transition effect from FDI to EC.

Table 6
Linear Error Correction Model

Model	Coefficients	t-Value	Pr(> t)
Brazil	-0.17	-1.41	0.166
Indonesia	-0.31*	-2.59	0.013
India	-0.14	-1.17	0.248
Turkey	-0.23**	-1.95	0.058
South Africa	-0.41*	-3.35	0.001

* and ** indicate rejection of null hypothesis at 5% and 10% significance level, respectively.

Table 6 displays that the linear error correction model test result is statistically significant for Turkey and South Africa in terms of the obtained coefficients and probability values. At the same time, it was stated that these countries have a long-term relationship according to the Johansen (1988) cointegration test. Table 7 presents the values of the probabilities of the error correction terms ($I(u^3)$). The error correction model suggests that the short-term imbalances can be corrected in the long-term.

Table 7
ESTAR Nonlinear Error Correction Model

Model	Coefficients	Estimate	t-Value	Pr(> t)
Brazil	$I(u^3)$	-1.73	-1.349	0.186
Indonesia	$I(u^3)$	-0.09	-1.371	0.179
India	$I(u^3)$	-0.47	-0.522	0.605
Turkey	$I(u^3)$	-0.43*	-1.699	0.098
South Africa	$I(u^3)$	-38.86	-1.751	0.088

$I(u^3)$ denotes for the error correction terms. * Indicates rejection of null hypothesis at 10% significance level.

Table 7 illustrates that the results of the ESTAR error correction model are assumed statistically significant when the value of the coefficient of error correction model $I(u^3)$ is between -2 and 0. Accordingly, the ESTAR error correction model mechanism works for Turkey. In addition, these models are appropriate and prove the existence of a significant long-term causality relationship. Table 8 presents the Granger linear causality test results.

Table 8
Granger Linear Causality Test Results

Countries	Null hypothesis	Statistic	Prob.
Brazil	$\Delta FDI \neq \Delta LNEC$	1.43	0.25
	$\Delta LNEC \neq \Delta FDI$	1.11	0.33
Indonesia	$\Delta FDI \neq \Delta LNEC$	0.09	0.76
	$\Delta LNEC \neq \Delta FDI$	0.12	0.72
India	$\Delta FDI \neq \Delta LNEC$	1.30	0.26
	$\Delta LNEC \neq \Delta FDI$	0.00	0.98
Turkey	$\Delta FDI \neq \Delta LNEC$	4.12	0.04*
	$\Delta LNEC \neq \Delta FDI$	0.01	0.90
South Africa	$\Delta FDI \neq \Delta LNEC$	0.33	0.56
	$\Delta LNEC \neq \Delta FDI$	0.39	0.52

* indicates that the null hypothesis is rejected at 5% significance level. Since cointegration relationship was found between the variables of Turkey and South Africa, the Vector Error Correction Model (VECM) based causality was implemented. For other countries, since there was no cointegration relationship between the variables, the Vector Autoregressive Models (VAR) based causality analysis was executed.

Table 8 demonstrates the existence of a unidirectional causality relationship from FDI to EC. In other words, it was determined that the probability value of the FDI and EC nexus in Turkey is less than 0.05. This result indicates that the null hypothesis is rejected.

Table 9
Diks and Panchenko (2006) Nonlinear Causality Test Results

Countries		$\Delta FDI \neq \Delta LNEC$		$\Delta LNEC \neq \Delta FDI$	
		t-stat	p-value	t-stat	p-value
Brazil	2	0.81	0.20	0.04	0.48
Indonesia	2	-1.09	0.86	0.91	0.17
India	2	0.30	0.38	-0.05	0.52
Turkey	2	0.32	0.37	0.23	0.40
South Africa	2	0.72	0.23	0.65	0.25

N= 41, Bandwith=1.0, Embedding dimension= 2

The findings of the Granger causality test in Table 8 demonstrate the existence of a unidirectional causality relationship from FDI to EC in Turkey. Namely, it was found that the probability value of the link between FDI and EC for Turkey is less than 0.05. Therefore, the null hypothesis, which states that there is no causal relationship between the variables, is rejected. Table 9 presents the results of the Dicks and Panchenko (2006) non-linear causality test. The Dicks and Panchenko (2006) test results show that the probability values of all variables are greater than 0.05. Accordingly, the null hypothesis, which states that there is no causal relationship between the variables, is not rejected. In other words, the non-linear causality relationship between FDI and EC could not be detected for all countries.

Conclusion

In today's world, it can be seen that there is a tremendous increase in the frequency of natural events caused by climate change and ecological crises. It has been observed that the tendency to use fossil fuels as an energy source in the production process has increased the severity of global warming due to the greenhouse gas effect. In this respect, countries have taken measures to protect the natural environment with the help of climate agreements. Mainly industrialized countries, which pollute the air relatively more, prefer shifting their production to countries that pollute the air less through multinational companies. This situation is discussed within the framework of the pollution haven hypothesis. This study aims to examine whether FDI affects the amount of EC for the Fragile Five countries. For this purpose, we investigated these linkages between variables by utilizing linear and nonlinear test methods. We concluded that most of the variables were shown to be stationary after taking the first differences according to the linear and nonlinear unit root tests. Following that, it was determined that there existed a cointegration relationship from FDI to EC for Turkey and South Africa by utilizing Johansen's (1988) linear cointegration test, while there existed a cointegration relationship from FDI to EC in South Africa in terms of the KSS (2006) nonlinear cointegration test. Looking at the linear and nonlinear error correction model results, it was determined that the linear error correction model works for Turkey and South Africa, while the ESTAR nonlinear error correction model works only for Turkey. Finally, we concluded that there is a causality nexus from FDI to EC in Turkey based on Granger's (1969) linear causality test results, while the model of Dicks and Panchenko (2006) showed that there was no causality nexus between variables. Although the studies of Kuo et al. (2012), Li and Qi (2016), Lin and Benjamin (2018), Wang and Jiayu (2019), Udemba et al. (2020), Bujari and Martinez (2021), and Amoaka and Insaïdoo (2021) examines different countries or country groups, the results we obtained are in line with these results.

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References

- Abbas, H. S. M., Xu, X., & Sun, C. (2021). Role of foreign direct investment interaction to energy consumption and institutional governance in sustainable GHG emission reduction. *Environmental Science and Pollution Research*, 28(40), 56808-56821.
- Abdoul, M., & Hammami, S. (2017). Exploring links Between FDI Inflows, Energy Consumption, And Economic Growth: Further Evidence From MENA Countries. *Journal of economic development*, 42(1).
- Abidin, I. S. Z., Haseeb, M., Azam, M., & Islam, R. (2015). Foreign direct investment, financial Development, international trade and energy consumption: Panel data evidence from selected ASEAN Countries. *International Journal of Energy Economics and Policy*, 5(3), 841-850.

- Adom, P. K., Opoku, E. E. O., & Yan, I. K. M. (2019). Energy demand–FDI nexus in Africa: do FDI's induce dichotomous paths?. *Energy Economics*, *81*, 928-941.
- Amoako, S., & Insaiddoo, M. (2021). Symmetric impact of FDI on energy consumption: Evidence from Ghana. *Energy*, *223*, 120005.
- Amri, F. (2016). The relationship amongst energy consumption, foreign direct investment and output in developed and developing countries. *Renewable and Sustainable Energy Reviews*, *64*, 694-702.
- Areemo, A. G., & Ojeyinka, T. A. (2018). Foreign direct investment, energy consumption, carbon emissions and economic growth in Nigeria (1970-2014): an aggregate empirical analysis. *International Journal of Green Economics*, *12*(3-4), 209-227.
- Baek, J., & Choi, Y. J. (2017). Does foreign direct investment harm the environment in developing countries? Dynamic panel analysis of Latin American countries. *Economies*, *5*(4), 39.
- Balsalobre-Lorente, D., Driha, O. M., Halkos, G., & Mishra, S. (2022). Influence of growth and urbanization on CO2 emissions: The moderating effect of foreign direct investment on energy use in BRICS. *Sustainable Development*, *30*(1), 227-240.
- Behera, S. R., & Dash, D. P. (2017). The effect of urbanization, energy consumption, and foreign direct investment on the carbon dioxide emission in the SSEA (South and Southeast Asian) region. *Renewable and Sustainable Energy Reviews*, *70*, 96-106.
- Bujari, A., & Venegas-Martínez, F. (2021). On the relationship between foreign direct investment and energy consumption: The Mexican case. *International Journal of Energy Economics and Policy*, *11*(3), 231.
- 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.
- Dong, B., Gong, J., & Zhao, X. (2012). FDI and environmental regulation: pollution haven or a race to the top?. *Journal of Regulatory economics*, *41*(2), 216-237.
- Granger, C. W. (1969). Investing Causal Relations by Econometric Models and Cross-Spectral Methods. *Econometrica: Journal of the Econometric Society*, *37*(3), 424-438.
- 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*, 493-501.
- Hentschel, L. (1995). All in the family nesting symmetric and asymmetric garch models. *Journal of financial economics*, *39*(1), 71-104.
- Islam, M., Khan, M. K., Tareque, M., Jehan, N., & Dagar, V. (2021). Impact of globalization, foreign direct investment, and energy consumption on CO2 emissions in Bangladesh: Does institutional quality matter?. *Environmental Science and Pollution Research*, *28*(35), 48851-48871.
- Johansen, S. (1988). Statistical Analysis of Cointegration Vectors. *Journal of Economic Dynamics and Control*, *12* (2-3), 231-254.
- Kapetanios, G., Shin, Y., & Snell, A. (2003). Testing for a unit root in the nonlinear STAR framework. *Journal of Econometrics*, *112*(2), 359-379.
- Kapetanios, G., Shin, Y., & Snell, A. (2006). Testing for cointegration in nonlinear smooth transition error correction models. *Econometric Theory*, *22*(2), 279-303.
- Kiviyiro, P., & Arminen, H. (2014). Carbon dioxide emissions, energy consumption, economic growth, and foreign direct investment: Causality analysis for Sub-Saharan Africa. *Energy*, *74*, 595-606.

- Konisky, David M. "Regulator attitudes and the environmental race to the bottom argument." *Journal of Public Administration Research and Theory* 18, no. 2 (2008): 321-344.
- Kruse, R. (2011). A new unit root test against ESTAR based on a class of modified statistics. *Statistical Papers*, 52(1), 71-85.
- Kuo, K. C., Chang, C. Y., Chen, M. H., & Chen, W. Y. (2012). In search of causal relationship between FDI, GDP, and energy consumption-Evidence from China. In *Advanced Materials Research* (Vol. 524, pp. 3388-3391). Trans Tech Publications Ltd.
- Latief, R., & Lefen, L. (2019). Foreign direct investment in the power and energy sector, energy consumption, and economic growth: Empirical evidence from Pakistan. *Sustainability*, 11(1), 192.
- Li, K., & Qi, S. (2016). Does FDI increase industrial energy consumption of China? Based on the empirical analysis of Chinese provinces industrial panel data. *Emerging Markets Finance and Trade*, 52(6), 1305-1314.
- Lin, B., & Benjamin, I. N. (2018). Causal relationships between energy consumption, foreign direct investment and economic growth for MINT: Evidence from panel dynamic ordinary least square models. *Journal of Cleaner Production*, 197, 708-720.
- Lu, J., Imran, M., Haseeb, A., Saud, S., Wu, M., Siddiqui, F., & Khan, M. J. (2021). Nexus between financial development, FDI, globalization, energy consumption and environment: evidence from BRI countries. *Frontiers in Energy Research*, 466.
- Mavikela, N., & Khobai, H. (2018). Investigating the Link Between Foreign direct investment, Energy consumption and Economic growth in Argentina.
- Muhammad, B., & Khan, M. K. (2021). Foreign direct investment inflow, economic growth, energy consumption, globalization, and carbon dioxide emission around the world. *Environmental Science and Pollution Research*, 28(39), 55643-55654.
- Neumayer, E. (2000). Pollution havens: Why be afraid of international factor mobility? London School of Economics and Political Science mimeo.
- Omri, A., & Kahouli, B. (2014). Causal relationships between energy consumption, foreign direct investment, and economic growth: Fresh evidence from dynamic simultaneous-equations models. *Energy Policy*, 67, 913-922.
- Salim, R., Yao, Y., Chen, G., & Zhang, L. (2017). Can foreign direct investment harness energy consumption in China? A time series investigation. *Energy Economics*, 66, 43-53.
- Sarkodie, S. A., & Strezov, V. (2019). Effect of foreign direct investments, economic development, and energy consumption on greenhouse gas emissions in developing countries. *Science of the Total Environment*, 646, 862-871.
- Shabir, M., Ali, M., Hashmi, S. H., & Bakhsh, S. (2022). Heterogeneous effects of economic policy uncertainty and foreign direct investment on environmental quality: Cross-country evidence. *Environmental Science and Pollution Research*, 29(2), 2737-2752.
- Sheldon, Ian. "Trade and environmental policy: A race to the bottom?." *Journal of Agricultural Economics* 57, no. 3 (2006): 365-392.
- Singhania, M., & Saini, N. (2021). Demystifying pollution haven hypothesis: Role of FDI. *Journal of Business Research*, 123, 516-528.
- Teräsvirta, T. (1994). Specification, estimation, and evaluation of smooth transition autoregressive models. *Journal of the American Statistical Association*, 89(425), 208-218.
- Tong, H. (2007). Birth of the threshold time series model. *Statistica Sinica*, 17(1), 8-14.

- Udemba, E. N., Magazzino, C., & Bekun, F. V. (2020). Modeling the nexus between pollutant emission, energy consumption, foreign direct investment, and economic growth: new insights from China. *Environmental science and pollution research*, 27(15), 17831-17842.
- Wang, C., & Jiayu, C. (2019). Analyzing on the impact mechanism of foreign direct investment (FDI) to energy consumption. *Energy Procedia*, 159, 515-520.
- Yandle, B. (2004). Environmental turning points, institutions, and the race to the top. *The Independent Review*, 9(2), 211-226.
- Yoon, H., & Heshmati, A. (2017). Do environmental regulations effect FDI decisions? The pollution haven hypothesis revisited.
- Zhang, C., & Zhou, X. (2016). Does foreign direct investment lead to lower CO2 emissions? Evidence from a regional analysis in China. *Renewable and Sustainable Energy Reviews*, 58, 943-951.

