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İSTANBUL ÜNİVERSİTESİ YAYINEVİ

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RESEARCH ARTICLE / ARAŞTIRMA MAKALESİ

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

**Ali Çelik*** 

**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

* Ali Çelik (Asst. Prof), Istanbul Gelisim University, Faculty of Applied Sciences, Istanbul, Turkiye. E-mail: alcelik@gelisim.edu.tr
ORCID: 0000-0003-3794-7786

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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).

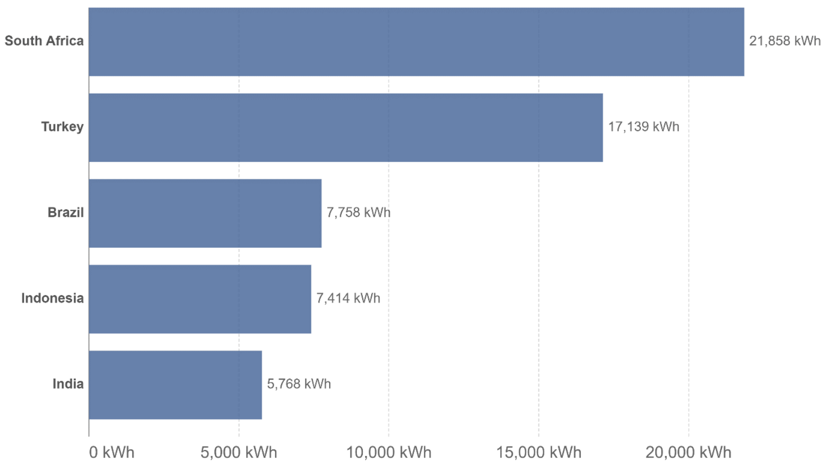


***Figure 1.*** Fossil energy (fuel) consumption per capital in 2020 (Source: Our World in Data).

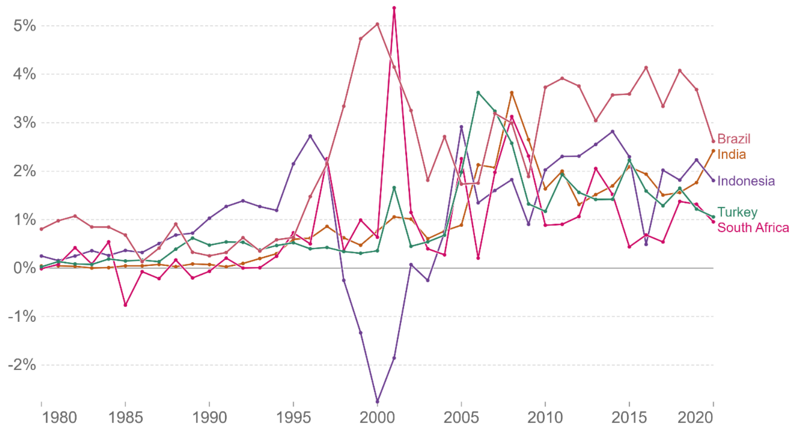


***Figure 2.*** FDI, net inflows as share of GDP, 1980 to 2020 (Source: Our World in Data).

Figure 1 and 2 depict the fossil energy consumption per capital 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 2020, 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; Singhania 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; Kivyori 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 $CO_2$ 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 Insaidoo (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:

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

In Eq. 4, $\varepsilon_t$ is the error term and c represent the threshold value. $\varepsilon_t$~iid (0, σ^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).

$$\Delta y_t = \alpha y_{t-1} + \varepsilon_t \tag{5}$$

Eq.5 is stationary if -2 < $\alpha$< 0. Then, it is determined that if $\alpha$ 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).

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

In this context, the Eq.6 model means globally stationary if -2 <∅< 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:

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

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.

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

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

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

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

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

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

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

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

Where $\eta_t$ 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):

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

Accordingly, the null hypothesis ($H_o$:θ=0) states that there is no cointegration relationship while the alternative hypothesis $H_1$:θ>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):

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

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

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

Within the framework of Eq. 15, the null hypothesis ($H_0$: δ=0) states that there is no cointegration relation between the variables, and the alternative hypothesis ($H_1$: δ<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:

$$T_n(\varepsilon) = \frac{(n-1)}{n(n-1)} \sum_i \left( \hat{f}_{X,Y,Z}(X_i, Y_i, Z_i) \hat{f}_Y \middle| (Y_i) - \hat{f}_{X,Y}(X_i, Y_i) \hat{f}_{Y,Z}(Y_i, Z_i) \right) \tag{16}$$

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

$$\sqrt{n} \frac{(T_n(\varepsilon_n) - q)}{S_n} \underset{\rightarrow}{d} N(0,1) \tag{17}$$

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 $\beta_1$ 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** | | |
|---|---|---|---|
| **Panel A: Brazil** | **None** | **Intercept** | **Trend and Intercept** |
| 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 | ΔFDI≠>ΔLNEC | 1.43 | 0.25 |
| | ΔLNEC≠>ΔFDI | 1.11 | 0.33 |
| Indonesia | ΔFDI≠>ΔLNEC | 0.09 | 0.76 |
| | ΔLNEC≠>ΔFDI | 0.12 | 0.72 |
| India | ΔFDI≠>ΔLNEC | 1.30 | 0.26 |
| | ΔLNEC≠>ΔFDI | 0.00 | 0.98 |
| Turkey | ΔFDI≠>ΔLNEC | 4.12 | 0.04* |
| | ΔLNEC≠>ΔFDI | 0.01 | 0.90 |
| South Africa | ΔFDI≠>ΔLNEC | 0.33 | 0.56 |
| | ΔLNEC≠>ΔFDI | 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** | | **ΔFDI≠>ΔLNEC** | | **ΔLNEC≠>ΔFDI** | |
|---|---|---|---|---|---|
| | | **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 dimenson= 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 Insaidoo (2021) examines different countries or country groups, the results we obtained are in line with these results.

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