A new look at the pollution halo hypothesis: The role of environmental policy stringency*

Una nueva mirada a la hipótesis del halo de contaminación: El papel del rigor de la política ambiental

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Abstract

The effect of Foreign Direct Investments (FDIs) on greenhouse gas (GHG) emissions, has attracted the attention of researchers in recent years. However, the indirect effects of environmental policies in the process were not sufficiently considered. This study uses a panel threshold methodology to examine the non-linear impact of environmental policy stringency on the relationship between FDIs and GHG emissions in 25 OECD countries. Our results show a negative relationship between FDIs and GHG emissions if the countries have environmental policy stringency index above a threshold level of (2.22). The results are also supported by the fixed effects model, which indicates a threshold effect of (2.88). The threshold effect is mostly due to the stringency of nonmarket-based environmental policies.

Key words: *Climate change, environmental taxes, public policy.*

JEL Classification: *Q50, Q53, Q58.*

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Resumen

El efecto de las Inversiones Extranjeras Directas (IED) sobre las emisiones de gas de efecto invernadero (GEI) ha llamado la atención de los investigadores en los últimos años. Sin embargo, los efectos indirectos de las políticas ambientales en el proceso no fueron suficientemente considerados. Este estudio utiliza una metodología de umbral de panel para examinar el impacto no lineal del rigor de la política ambiental en la relación entre las IED y las emisiones de GEI en 25 países de la OCDE. Nuestros resultados muestran una relación negativa entre las IED y las emisiones de GEI si los países tienen un índice de rigor de la política ambiental por encima de un nivel de umbral de (2.22). Los resultados también están respaldados por el modelo de efectos fijos, que indica un efecto de umbral de (2.88). El efecto de umbral se debe principalmente a la rigurosidad de las políticas ambientales no basadas en el mercado.

Palabras clave: *Cambio climático, impuestos ambientales, política pública.*

Clasificación JEL: *Q50, Q53, Q58.*

1. Introduction

The Intergovernmental Panel on Climate Change (IPCC) reports that global warming is one of the most critical problems of our age that concerns both current and future generations. While combating climate change is determined as one of the Sustainable Development Goals (SDGs), the Paris Agreement, which entered into force in November 2016, aims to limit the average global temperature rise to 2°C above pre-industrial levels. Based on the widespread view that greenhouse gas (GHG) emissions from non-renewable energy sources are one of the leading causes of climate change, it is essential to eliminate these emissions through different policies. Although many factors affect GHG emissions, empirical analyses of economic variables' effects have only been made in recent years. In the literature, foreign direct investment (FDI) inflows draw attention as an important economic factor affecting this process.

FDIs are seen as an important tool in ensuring economic growth and employment. Therefore, host countries are trying to attract FDIs to their countries with different strategies. There is essentially no consensus on the impact of FDI inflows on the GHG emissions in the host country, and the debate is based on two main arguments. The first argument was developed by Walter and Ugelow (1979) and Pethig (1976) and called the Pollution Haven Hypothesis (PHAH). This view argues that FDIs, particularly from pollution-intensive industries, tend toward countries with less environmental stringency, thereby increasing the level of pollution in the host country. The second argument, called the Pollution Halo Hypothesis (PHH), argues that FDIs from more developed countries help improve environmental standards in developing countries due to high production standards and clean technology transfer. Both findings support the PHAH (e.g., Blanco *et al.*, 2013; Kivyiro and Arminen, 2014; Gokmenoglu and Taspinar, 2016; Bae *et al.*, 2017; Hanif *et al.*, 2019) and support PHH (e.g. Pao and Tsai, 2011; Kivyiro and Arminen, 2014; Hao and Liu, 2015; Mert and Boluk, 2016; Rafindadi *et al.*, 2018; Balsalobre-Lorente *et al.*, 2019; Mert and Caglar, 2020; Neves *et al.*, 2020).

Although attention has been drawn to the role of environmental policies in the effect of FDI on GHG emissions[1], it has been observed that this relationship has neither been analysed in detail nor empirically tested. However, the strictness of environmental policies implemented in host countries can impact the decisions about what type of FDI will be directed to the relevant country[2]. And this effect may differ depending on the type of policy implemented.

OECD considers environmental policies under three headings: market-based policies, nonmarket-based policies, and technology support policies. Market-based approaches try to eliminate negative externality by changing price signals. Emission tax and marketable permit system are among the most widely used market-based policies. Nonmarket-based policies impose direct controls on pollutants while removing negative externalities. The command-and-control system directly limiting emissions is an excellent example of non-market-based policy instruments. Technology support policies include upstream support such as low-carbon R&D expenditures and adoption support about solar and wind-based energy systems.

In general, FDI inflows are expected to positively impact environmental quality in economies with sufficiently stringent environmental policies. In market-based policies, this effect will work through corrected price signals. As Nobel Prize-winning economist Nordhaus (2013: 19) points out, for policies to combat climate change to be effective, the market prices of GHG emissions must increase. Such an increase in prices will serve four different targets. First, it will signal to consumers which goods and services are pollution-intensive, thus ensuring that they are consumed less. Second, it will show producers which inputs are less pollution-intensive, enabling them to be used more in the production process. Third, it will encourage entrepreneurs and investment bankers to make production technologies more environmentally friendly. Finally, the GHG price lowers the amount of information one needs to know to do all this. The positive effect of the corrective tax policy on regulating price signals may ensure that the efficiency of FDIs comes to the fore. Thus, in countries with sufficiently strict market-based environmental regulations, FDI inflows are relatively likely to serve ecological quality. On the other hand, in nonmarket-based policies, there will be a direct impact that is considered in the decision-making process

[1] The fact that some countries lower their environmental regulations to attract FDI creates a separate factor that triggers environmental degradation.

[2] Weak environmental policies in the host countries may give the high-income economies a comparative advantage in pollution-intensive goods (Sapkota & Bastola, 2017: 206).

of investments. Therefore, foreign investments that do not meet the defined standards will not be directed to the host country. Countries with sufficiently stringent standards will tend to attract clean investments. In the case of technology support programs, the government bears the costs, so foreign investments can be expected to have a negative impact on the environment in countries where the support is not sufficient. In sum, in addition to the direct effects of reducing pollution, environmental policies can also be considered to have positive effects on environmental quality by serving to attract clean foreign investments.

Based on these discussions, this study aims to test the relationship between FDI inflows and GHG emissions, considering the moderating role of environmental regulations. In this context, the main hypothesis of the study was determined as follows:

H_0: In economies where, environmental policy stringency is above a certain threshold, FDI inflows have a negative effect on GHG emissions.

H_1: The stringency of environmental policies does not affect the relationship between FDI inflows and GHG emissions.

To test these hypotheses, we wanted to benefit from a large dataset, so we preferred to focus on OECD countries. The OECD countries generally consist of developed countries and their GHG emissions are 9.15 tonnes per capita as of 2019. Australia, Canada and the US have the highest emission values with 24.14, 20.70 and 17.54 tonnes per capita, respectively. And, these values are well above the world average of 6.45 tonnes per capita (OurWorldInData, 2022). Therefore, it is noteworthy to examine the effects on GHG emissions in the OECD countries.

It is expected that the findings obtained from this study will contribute to the literature in some respects. Firstly, the study will contribute to creating policy recommendations for reducing GHG emissions in the sample countries and will reveal that the pollution halo hypothesis will become more likely if any policy is implemented. Secondly, we test the relationship in the panel framework. In this way, we benefit from the advantage of the increased number of observations and include the country-specific effects. Thirdly, we use updated environmental policy stringency index of OECD which is a comprehensive measure of environmental policies and thereby, we provide substantial information by using recent data obtained from new methodology. We also had the opportunity to compare the effects of different types of policies: market-based, nonmarket-based and technology support policies. And last, we check our findings by comparing them with the findings obtained from fixed effects regressions.

The rest of the paper is organised as follows. Section 2 presents a literature review. Section 3 presents the methodology. Section 4 sets out the data and description. Section 5 presents empirical analysis, results, and their discussion. Section 6 concludes the paper and offers policy recommendations.

2. Literature Review

Although economies are trying to attract FDI inflows to their countries, the impact of these investments on the environmental quality of the host country is uncertain. In studies examining how FDIs will affect GHG emissions, it is observed that the discussions are divided into two basic views. According to the PHAH, multinational enterprises gain a cost advantage by directing their pollution-intensive industries to countries with weak environmental regulations, thus increasing the volume of pollution in the host country. According to the PHH, multinational companies transfer high production standards and clean technologies, thereby reduce the volume of pollution in the host country.

There are many studies in the literature supporting the PHAH. It is noteworthy that these studies have addressed quite different countries and groups of countries: e.g., Asian countries (Hanif *et al.* 2019), BRIC (Pao and Tsai, 2011), China (Zhou *et al.*, 2018), developed and developing countries (Essandoh *et al.*, 2020; Singhania and Saini, 2021) Latin American countries (Blanco *et al.*, 2013; Sabkota and Bastola, 2017), OECD countries (Caetano *et al.*, 2022), PIIGS countries (Balsalobre-Lorente *et al.* 2022), Sub-Saharan African countries (Kivyiro and Arminen, 2014), and Post-Soviet countries (Bae *et al.*, 2017).

Similarly, there are also studies supporting the PHH. However, it is noteworthy that these studies mostly dealt with the Asian sample: e.g., China (Zhang and Zou, 2016; Sung *et al.* 2018), Korea (Hille *et al.* 2019), and Southeast Asian countries (Zhu *et al.*, 2016). Accordingly, it can be argued that the foreign investments directed to the Asian countries under consideration have effects on reducing emissions by supporting environmentally friendly production technologies instead of increasing carbon emissions. There also studies supporting PHH by considering non-Asian countries: e.g., BRIC (Pao and Tsai, 2011) and Sub-Saharan countries (Kivyiro and Arminen, 2014; Opoku *et al.*, 2021). Table 1 summarizes these studies.

Nevertheless, studies given in Table 1 have set out from the assumption of a linear relationship between the variables in question while testing the effects of FDIs on environmental quality. However, FDIs can have non-linear impacts on GHG emissions. These effects may occur through FDIs themselves or third variables. Among the studies in which the square and cube of FDIs were included in the analysis, Pazienza *et al.* (2019) focused on 30 OECD economies. In the study using fixed-effects and random-effects models, the effect of FDIs in the manufacturing sector on carbon emissions was found to be positive. At the same time, the coefficient of the square of the variable was found to be negative. In other words, FDIs increase carbon emissions, but this increase is gradually decreasing. Another study considering the nonlinear relationship belongs to Sarkodie and Strazov (2019). The FDI variable with its square and cube was included in the analysis for five developing countries, including Asian countries such as China and Indonesia. According to the findings of the study, while the FDI variable and its cube have a positive relationship with carbon emissions, the relationship between the square of the variable and carbon emissions is negative.

TABLE 1
A SUMMARY OF RELEVANT STUDIES

Study	Sample	Methodology	Supporting Hypothesis
Pao & Tsai (2011)	BRIC (1992-2007)	PECM (Panel)	PHH and PHAH
Blanco *et al.* (2013)	18 Latin American Countries (1980-2007)	Granger Causality (Panel)	PHAH
Kivyiro & Arminen (2014)	6 Sub-Saharan African Countries (1971-2006)	ARDL (Time Series)	PHAH-in 6 countries PHH-in DRC and S. Africa
Zhang & Zou (2016)	China (3 regions) (1995-2010)	Fixed-effects, GLS (Panel)	PHH
Zhu *et al.* (2016)	5 Southeast Asian Countries (1981-2011)	Quantile Regression (Panel)	PHH
Bae *et al.* (2017)	115 Post-Soviet Countries (2000-2011)	GMM (Panel)	PHAH
Sabkota & Bastola (2017)	14 Latin American Countries (1980-2014)	Fixed-effects, Random effects (Panel)	PHAH
Sung *et al.* (2018)	China (28 subsectors) (2002-2015)	GMM (Panel)	PHH
Zhou *et al.* (2018)	China (285 cities) (2003-2015)	GMM (Panel)	PHAH
Hanif *et al.* (2019)	15 Asian Countries (1990-2013)	ARDL (Panel)	PHAH
Hille *et al.* (2019)	Korea (16 provinces) (2000-2011)	Simultaneous equations (Panel)	PHH
Essandoh *et al.* (2020)	52 countries (1991-2014)	ARDL (Panel)	PHAH in developing countries PHH in developed countries
Opoku *et al.* (2021)	22 Sub-Saharan Countries (1995-2014)	GMM (Panel)	PHH
Singhania & Saini (2021)	21 countries with high carbon emissions (1990-2016)	GMM (Panel)	PHAH
Balsalobre-Lorente *et al.* (2022)	PIIGS (1990-2019)	Dynamic OLS (Panel)	PHAH
Caetano *et al.* (2022)	15 OECD Countries (2005-2018)	ARDL (Panel)	PHAH

While considering the nonlinear relationship between FDI and emissions, some studies handle the effect of a third variable on the process. The first of these studies belongs to Liobikiene and Butkus (2019). The authors examined the interaction with the third variables by including the product of FDI and industrial sector value-added, efficiency in energy use, and renewable energy consumption variables in the analysis with the data of 147 countries for the period 1990-2012. However, the analysis findings were statistically insignificant for the coefficients related to the interaction terms. A later study by Xie *et al.* (2020) examined the impact of FDIs on emissions through the economic growth channel. It has been confirmed that FDIs increase emissions in developing countries, but this effect turns negative through the economic growth channel.

To summarise, few studies consider the effects of third variables in testing the relationship between FDIs and emissions. Although, there are many recent studies in the literature emphasising the impact of environmental policies on emissions (e.g. Wang & Shao, 2019; Ahmed, 2020; Neves *et al.*, 2020; Wang *et al.*, 2020; Wolde-Rufael & Weldemeskel, 2020, 2021; Zhang *et al.*, 2020), the role of environmental policies on the relationship between FDIs and emissions are not taken into account. However, strict environmental policies can have an impact on production costs by requiring certain equipment, decreasing waste disposal capacity, and prohibiting certain factor inputs or outputs (Xing and Kolstad, 2002). Therefore, they can also have an impact on companies' investment decisions. As Copeland and Taylor (2004) stated, large-scale enterprises with the capacity to invest directly may prefer to direct their investments towards countries with less strict environmental policies that offer cost advantages by considering ecological costs while making investment decisions. List and Co (2000) and List *et al.* (2003) also confirmed that heterogenous regulations across regions alter the choices regarding FDIs.

Based on the discussions, the strictness of the environmental policies implemented in the host country will have an important role in the ecological effects of foreign capital directed to the country. In other words, it is expected that foreign capital to be required to countries with sufficient strictness in environmental regulations will be relatively environment-friendly and have a reducing effect rather than increasing pollution. Examining the hypothesis above with a sample based on OECD countries and supporting the discussion with empirical findings constitute the primary motivation for this study.

3. Methodology

There are some reasons for choosing the panel threshold regression model of Hansen (1999) as the methodology in the study. First, the method in question eliminates the multicollinearity problem that may arise when the variables' squares, cubes, or multiplications are used in the non-linear analysis. Secondly, a specific threshold value will be found for the variable considered as the threshold variable due to the analysis. Thus, concrete policy recommendations can be made depending on whether it is below or above the threshold value for each country. In addition, since the method is based on panel data, the number of observations and the degree of independence will increase accordingly, making the estimation results more reliable.

A single-threshold model of Hansen (1999) that tests whether there are regime-switching effects can be constructed as follows:

$$y_{it} = \mu_i + \alpha X_{it} + \beta FDI_{it} + e_{it}\ ,\ e_{it} \sim iid\left(0,\sigma^2\right)$$

(1)
$$y_{it} = \begin{cases} \mu_i + \alpha X_{it} + \beta_1 FDI_{it} + e_{it}, P_{it} \le \lambda \\ \mu_i + \alpha X_{it} + \beta_2 FDI_{it} + e_{it}, P_{it} > \lambda \end{cases}$$

$$\alpha = \left(\alpha_1,\ \alpha_2,\ \alpha_3,\ \alpha_4\right)'$$

$$e_{it} \approx N\left(0,\sigma^2\right)$$

where P_{it} indicates relevant environmental policy stringency as the threshold variable, λ indicates threshold value, FDI_{it} indicates FDI variable, X_{it} indicates explanatory variables other than FDI, μ_i indicates fixed effects and e_{it} indicates error term.

Equation (1) can be written as equation (2) or (3) if I(.) denotes an indicator function:

$$y_{it} = \mu_i + \alpha X_{it} + \beta_1 FDI_{it} I\left(P_{it} \le \lambda\right) + \beta_2 FDI_t I\left(P_{it} > \lambda\right) + e_{it}$$

(2)
$$y_{it} = \mu_i + \alpha' X_{it} + \beta' FDI_{it}\left(\lambda\right) + e_{it} \beta = \left(\beta_1, \beta_2\right)'$$

$$y_{it} = \mu_i + \left[\alpha', \beta'\right] \begin{bmatrix} X_{it} \\ FDI_{it}\left(\lambda\right) \end{bmatrix} + e_{it}$$

$$y_{it} = \mu_i + \theta' h_{it}\left(\lambda\right) + e_{it}$$

(3)
$$FDI_{it}\left(\lambda\right) = \begin{bmatrix} FDI_{it} I\left(P_{it} \le \lambda\right) \\ FDI_{it} I\left(P_{it} > \lambda\right) \end{bmatrix},$$

where $\theta = \left(\alpha', \beta'\right)'$ and $h_{it} = \left(X_{it}{}', FDI_{it}\left(\lambda\right)'\right)'$.

Accordingly, the regression divides the observations into two regimes depending on whether the threshold variable (P_{it}) is smaller or larger than the threshold (λ). Differing regression slopes distinguish the regimes $\left(\beta_1, \beta_2\right)$.

Taking averages of equation (2) over the time index will give:

(4)
$$\overline{y}_i = \mu_i + \theta' \overline{h}_i\left(\lambda\right) + \overline{e}_i,$$

where:

$$\overline{y}_i = T^{-1} \sum_{t=1}^{T} y_{it},\ h_i = T^{-1} \sum_{t=1}^{T} \overline{h}_{it},\ \overline{e}_i = T^{-1} \sum_{t=1}^{T} e_{it}$$

Taking the difference between equations (2) and (4) yields

$$y_{it}^{*} = \theta' h_{it}^{*}(\lambda) + e_{it}^{*} \tag{5}$$

where:

$$y_{it}^{*} = y_{it} - \overline{y}_i \;, h_{it}^{*}(\lambda) = h_{it}(\lambda) - \overline{h}_i(\lambda), e_{it}^{*} = e_{it} - \overline{e}_i.$$

If

$$y_i^{*} = \begin{bmatrix} y_{i2}^{*} \\ . \\ . \\ . \\ y_{iT}^{*} \end{bmatrix}, h_i^{*}(\gamma) = \begin{bmatrix} h_{i2}^{*}(\lambda) \\ . \\ . \\ . \\ h_{iT}^{*}(\lambda) \end{bmatrix}, e_i^{*} = \begin{bmatrix} e_{i2}^{*} \\ . \\ . \\ . \\ e_{iT}^{*} \end{bmatrix}, \text{ and}$$

$$Y^{*} = \begin{bmatrix} y_1^{*} \\ . \\ . \\ . \\ y_n^{*} \end{bmatrix}, H^{*}(\lambda) = \begin{bmatrix} h_1^{*}(\lambda) \\ . \\ . \\ . \\ h_{it}^{*}(\lambda) \end{bmatrix}, e^{*} = \begin{bmatrix} e_1^{*} \\ . \\ . \\ . \\ e_n^{*} \end{bmatrix};$$

Equation (5) can be re-written as follows:

$$Y_{it}^{*} = \theta' H_{it}^{*}(\lambda) + e_{it}{}^{*} \tag{6}$$

The slope coefficient will be calculated with the OLS estimator as follows:

$$\hat{\theta}(\lambda) = \left(H^{*}(\lambda)' H^{*}(\lambda)\right)^{-1} H^{*}(\lambda)' Y^{*} \tag{7}$$

The residual vector will be as in equation (8):

$$\hat{e}^{*}(\lambda) = Y^{*} - H(\lambda)\hat{\theta}(\lambda) \tag{8}$$

The sum of squared errors will be as in equation (9):

$$SSE_1(\lambda) = \hat{e}^{*}(\lambda)\hat{e}^{*}(\lambda)' = Y^{*'}(I - H^{*}(\lambda)' \left(H^{*}(\lambda)' H^{*}(\lambda)\right)^{-1} H^{*}(\lambda)')Y^{*} \tag{9}$$

In this case, λ; can be calculated by minimizing the concentrated sum of squared errors. Therefore, the least-square estimator is:

(10) $$\hat{\lambda} = \underset{\lambda}{\operatorname{argmin}}\, SSE_1(\lambda)$$

When calculating the slope coefficient and the residual vector based on λ, the estimator of the residual variance will be as follows $\left(\widehat{\theta} = \hat{\theta}(\lambda),\ \hat{e}^* = \hat{e}^*(\lambda)\right)$:

(11) $$\hat{\sigma}^2 = \frac{1}{n(T-1)}\hat{e}^{*\prime}\hat{e}^* = \frac{1}{n(T-1)}SSE_1\left(\hat{\lambda}\right)$$

Here n is the number of countries in the sample, where T represents the number of years. Finally, it is necessary to test whether the threshold effect is statistically significant. By testing the null hypothesis that the coefficients are equal to each other, if the probability value is below the critical value, the null hypothesis is rejected, and it is concluded that the threshold effect is statistically significant.

4. Data and description

4.1. Dependent Variable: *ghg*

In the literature, previous studies used different GHGs such as CO_x, NO_x, SO_x, and PM_x (e.g. Narayan and Narayan, 2010; Luo *et al.*, 2014; Hao and Liu, 2016; Wang *et al.*, 2016; Sinha and Bhattacharya, 2016; Aye and Edoja, 2017; Wei *et al.*, 2018; Zhang *et al.*, 2018; Hasmi and Alam, 2019; Ouyang *et al.*, 2019; Neves *et al.*, 2020; Demiral *et al.*, 2021). However, we used GHG emissions as a whole, which are seen as the main cause of climate change, as the dependent variable. The fact that the current environmental policies are directed towards different GHG emissions also played role in our choice. The relevant data is extracted from OECD (2022) database. The *ghg* variable measures GHG emissions in tonnes per capita.

4.2. Regime-Dependent Variable: *fdi*

FDI inflow is an economic variable that is thought to significantly affect GHG emissions (e.g. Blanco *et al.*, 2013; Gokmenoglu and Taspinar, 2016; Bae *et al.*, 2017; Balsalobre-Lorente *et al.*, 2022; Caetano *et al.*, 2022). The *fdi* variable measures FDI net inflows (% of GDP). The relevant data is extracted from World Bank WDI (2022) database.

4.3. Threshold Variables: *eps, meps, nmeps, tsp*

In the next section, the impact of FDI inflows on GHG emissions will be tested by considering the role of environmental policies in the process. Botta and Kozluk (2014) pioneered the creation of a comprehensive index of environmental policy stringency. This index published by the OECD has been used in some recent studies (e.g. Ahmed & Ahmed, 2018; Ahmed, 2020; Demiral *et al.*, 2021; Ouyang *et al.*, 2019; Wolde-Rufael & Weldemeskel, 2020, 2021; Zhang *et al.*, 2020). Utilising selected policy tools on climate and air pollution, the index is considered the implicit or explicit cost of polluting or environmentally harmful behaviour.[3] The index ranges from 0 (not stringent) to 6 (highest degree of stringency) and shows relatively high and significant correlations with its alternatives used in the literature (Botta & Kozluk, 2014). Since the index is created based on a dual distinction between market-based and non-market-based policies, it also allows to empirically test the effects of different policies.

Later, Kruse *et al.* (2022) have developed this index by handling with a triple distinction to include technology support policies (*tsp*) in addition to market-based (*meps*) and nonmarket-based (*nmeps*) environmental policies. Accordingly, market-based policies consist of certificates and taxes, while nonmarket-based policies consist of emission limits. Technology support policies include clean R&D expenditures and support for adaptation to solar and wind-based energy systems.

With the new methodology, the previous index data were also recalculated and the data set was expanded to include the year 2020. Thus, in our study, data from 25 OECD countries (Australia, Austria, Belgium, Canada, Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Italy, Japan, Korea, Netherlands, Norway, Poland, Portugal, Slovak Republic, Spain, Sweden, Switzerland, Turkiye, United Kingdom and United States) were used for the 1998-2020 period, considering the maximum data availability. The effects of each of the three policy types are examined separately.

4.4. Control Variables: *gdppc, primen, poplr, ren*

We used GDP per capita (*gdppc*), primary energy consumption per capita (*primen*), population in the largest city (*poplr*), the share of renewable energy consumption in total energy consumption (*ren*) as the control variables. The data of *gdppc* and *poplr* variables were used in the logarithmic form. These variables are frequently used in the literature as determinants of GHG emissions. It is expected that increases in population and primary energy consumption will increase GHG emissions, while increases in the renewable energy use will decrease. How GDP per capita will affect is controversial in the literature. Detailed descriptions of all variables used in the analysis are reported in Table 2, and Table A1 in Appendix 1 shows descriptive statistics of all the variables in the model.

[3] Detailed information about the index is available in the study of Botta and Kozluk (2014).

TABLE 2
DESCRIPTION AND SOURCES

Variable	Definition	Source
ghg	GHG emissions (tonnes/capita)	OECD.stat (2022)
gdppc	GDP per capita (constant 2015 USD)	World Bank, WDI (2022)
primen	Primary energy consumption per capita (kWh/person)	Our World in Data, GCP (2022)
poplr	Population in the largest city (% of urban population)	World Bank, WDI (2022)
ren	Renewable energy consumption (% of total final energy consumption)	World Bank, WDI (2022)
fdi	Foreign direct investments, net inflows (% of GDP)	World Bank, WDI (2022)
eps	EPS index	OECD.stat (2022)
meps	EPS index (market-based policies)	OECD.stat (2022)
nmeps	EPS index (nonmarket-based policies)	OECD.stat (2022)
tsp	EPS index (technology support policies)	OECD.stat (2022)

5. Empirical analysis

In the first step, we tested for cross-sectional dependency of residuals to choose appropriate panel unit root test. We benefited from three different tests: Breusch-Pagan (1980) Lagrange Multiplier (LM) test, the Pesaran, Ullah, and Yamagata (2008), bias-adjusted LM test, and the Pesaran (2004) Cross-Sectional Dependence (CD) test. The results of the tests are given in Table 3.

The null hypothesis of no covariance between the residuals of cross-sections have been rejected in all models according to LM and the CD tests. Therefore, in the next stage, all variables were tested for stationarity using the second-generation panel unit root test of the Cross-Sectionally Augmented Dickey-Fuller (CADF) test of Pesaran (2007). This test gives more robust results than the first-generation unit root tests in case of cross-sectional dependence. The results

TABLE 3
RESIDUAL CROSS-SECTIONAL DEPENDENCE

	LM		LM Adj.		LM CD	
Policy Variable	Stat.	p-value	Stat.	p-value	Stat.	p-value
eps	397	0.0001	1.85	0.0643	5.944	0.0000
meps	367.4	0.0047	-0.1892	0.8499	5.711	0.0000
nmeps	405.6	0.0000	2.856	0.0043	5.954	0.0000
tsp	404.6	0.0001	5.954	0.0100	5.769	0.0000

TABLE 4
PESARAN (2007) CADF UNIT ROOT TEST RESULTS

		Z(t-bar)		p-value	
		Without trend	With trend	Without trend	With trend
ghg	level	-1.888	-2.391	0.030	0.008
	1st diff.	-11.548	-9.621	0.000	0.000
gdppc	level	-0.275	0.574	0.391	0.717
	1st diff.	-3.600	-1.485	0.000	0.069
primen	level	-2.622	-3.141	0.004	0.001
	1st diff.	-11.591	-9.503	0.000	0.000
poplr	level	1.190	-5.501	0.883	0.000
	1st diff.	-6.521	-4.201	0.000	0.000
ren	level	-1.107	0.002	0.134	0.501
	1st diff.	-8.458	-7.797	0.000	0.000
fdi	level	-2.947	-0.522	0.002	0.301
	1st diff.	-11.632	-9.937	0.000	0.000
eps	level	-3.756	-3.090	0.000	0.001
	1st diff.	-10.130	-7.276	0.000	0.000
meps	level	-2.345	-0.131	0.010	0.448
	1st diff.	-7.985	-6.388	0.000	0.000
nmeps	level	-3.126	-3.325	0.001	0.000
	1st diff.	-10.125	-6.739	0.000	0.000
tsp	level	-4.974	-2.817	0.000	0.002
	1st diff.	-9.832	-7.253	0.000	0.000

***, **, and * denote statistically significance at 1%, 5%, and 10% levels, respectively.

are displayed in Table 4. The results show that the *gdppc* and *ren* variables are not stationary at the level. For this reason, we took the first differences of them and re-tested for stationarity. The new variables, which we named *dgdppc* and *dren*, were stationary due to the panel stationarity test. Stationary variables are used in the following panel threshold analyses.

We constituted four different models using different policy variables:

$$\text{M1}: ghg_{it} = \mu_i + \alpha_1 dgdppc_{it} + \alpha_2 primen_{it} + \alpha_3 poplr_{it} + \alpha_4 dren_{it} + \beta_1 FDI_{it} I\left(eps_{it} \leq \lambda\right) + \beta_2 FDI_t I\left(eps_{it} > \lambda\right) + e_{it}$$

$$\text{M2}: ghg_{it} = \mu_i + \alpha_1 dgdppc_{it} + \alpha_2 primen_{it} + \alpha_3 poplr_{it} + \alpha_4 dren_{it} + \beta_1 FDI_{it} I\left(meps_{it} \leq \lambda\right) + \beta_2 FDI_t I\left(meps_{it} > \lambda\right) + e_{it}$$

$$\text{M3}: ghg_{it} = \mu_i + \alpha_1 dgdppc_{it} + \alpha_2 primen_{it} + \alpha_3 poplr_{it} + \alpha_4 dren_{it} + \beta_1 FDI_{it} I\left(nmeps_{it} \leq \lambda\right) + \beta_2 FDI_t I\left(nmeps_{it} > \lambda\right) + e_{it}$$

$$M4: ghg_{it} = \mu_i + \alpha_1 dgdppc_{it} + \alpha_2 primen_{it} + \alpha_3 poplr_{it} + \alpha_4 dren_{it} + \beta_1 FDI_{it} I(tsp_{it} \leq \lambda) + \beta_2 FDI_t I(tsp_{it} > \lambda) + e_{it}$$

Each model tests the threshold effect of one of the policy variables. Table 5 shows the results of the threshold tests.

According to Table 5, environmental policy stringency has a threshold effect at a 1% significance level. Therefore, the stringency of environmental policies has been observed to affect the relationship between FDIs and GHG emissions. The threshold value of (2.22) divides the observations into two regimes depending on whether the *eps* variable is smaller or larger than the threshold. In addition, it was observed that *meps* and *tsp* did not have a threshold effect at the 5% significance level, while *nmeps* had a threshold effect. The threshold value of (5.00) divides the observations into two regimes in which FDI has a different effect on GHG emissions. In the low-regime countries that have *nmeps* lower than or equal to (5.00), FDIs increase GHG emissions. On the other hand, in the high-regime countries that have *nmeps* value higher that (5.00), FDIs decrease GHG emissions. The estimated coefficients are given in Table 6.

As Table 6 shows, GDP per capita has a positive significant effect on the level of GHG emissions. Fossil fuels are still the most common source of energy in many of the countries in the sample. Therefore, economic growth and income increase can cause polluting effects. In this context, it can be deduced that

TABLE 5
TESTING THE THRESHOLD EFFECTS OF ENVIRONMENTAL POLICY ON GHG EMISSIONS

Model	Threshold effects	F-stats	P-values	Critical Values			Threshold Values	95% Confidence Interval
				1%	5%	10%		
M1	Single threshold	35.10***	0.0033	31.7113	23.2079	19.5476	2.2222	1.9306-2.2500
M2	Single threshold	10.50	0.2067	46.8715	20.9993	14.7540	2.3333	2.0833-2.500
M3	Single threshold	30.84**	0.0367	35.3468	26.8535	23.5404	5.0000	3.7500-5.2500
M4	Single threshold	20.99*	0.0900	36.6505	26.7731	19.9326	1.500	0.0000-1.7500

Note: (1) Three hundred bootstrap replications are employed for each bootstrap test.
(2) No evidence of second threshold effects was found in any model.
(3) ***, ** and * denote those variables are statistically significant at 1%, 5% and 10% respectively.

TABLE 6
THRESHOLD REGRESSIONS FOR THE STRINGENCY OF ENVIRONMENTAL POLICIES

Dependent variable: *ghg*	M1	M2	M3	M4
Threshold variable	*eps*	*meps*	*nmeps*	*tsp*
dgdppc	4.8844*** (1.6048)	5.9344*** (1.6927)	5.0828*** (1.5745)	5.1870*** (1.6146)
primen	0.0003*** (0.0001)	0.0003*** (0.0001)	0.0003*** (0.0001)	0.0002*** (0.0001)
poplr	-0.3869 (3.2460)	-0.5528 (3.3980)	-0.1968 (3.2867)	-0.5899 (3.3854)
dren	-0.0965*** (0.0281)	-0.1067*** (0.0293)	-0.1151*** (0.0299)	-0.1017*** (0.0277)
fdi((p≤λ)	0.0457*** (0.0125)	0.0028 (0.0047)	0.0290** (0.0113)	0.0346** (0.0123)
fdi(p>λ)	-0.0034 (0.0029)	-0.0361* (0.0176)	-0.0074** (0.0035)	-0.0039 (0.0030)
c	-0.6005 (9.9284)	-0.4767 (10.3707)	-1.1934 (10.0671)	0.0299 (10.3406)
R-square	0.7358	0.7230	0.7346	0.7298
F-stat.	41.10	34.47	37.42	40.56
F-prob.	0.0000	0.0000	0.0000	0.0000

Note: (1) Three hundred bootstrap replications are employed for each bootstrap test.
(2) ***, ** and * denote those variables are statistically significant at 1%, 5% and 10% respectively.
(3) White heteroscedasticity consistent standard errors are in parentheses.
(4) Residuals are stationary according to Pesaran (2007) CADF test (Z(t-bar) value is -3.565).

sample countries are in the ascending part of the environmental Kuznets curve. Primary energy consumption was found to be significant in all models and it has an increasing effect on GHG emissions in line with expectations. Similarly, the increase in the share of renewable energy consumption has a decreasing effect on GHG emissions. This finding is consistent with the work of Bae *et al.* (2017) and Balsalobre-Lorente *et al.* (2022), who draws attention to the importance of using alternative energy sources.

When we focus on the policy variables, according to the results presented in Table 5 and Table 6, the *eps* index has a threshold effect on the FDI-GHG emissions nexus at the 5% significance level. This effect is mainly due to *nmeps*. Accordingly, if the stringency of nonmarket-based environmental policies is under a certain threshold level (5.00 from Table 5), there is a positive relationship between FDIs and GHG emissions. However, if the stringency of nonmarket-based environmental policies is above (5.00), there is a negative relationship between FDIs and GHG emissions. This finding confirms that the pollution halo hypothesis will be valid if sufficiently strict environmental policies are applied in the sample under consideration.

5.1. Robustness Analysis: Fixed-Effects Regression

In the last step, we used fixed effects regression to check the robustness of our previous analyses.

Table 7 summarizes the results obtained from fixed effect regressions with Driscoll-Kraay standard errors which gives robust results in case of heteroscedasticity, autocorrelation and cross-sectional dependence. Each column presents the findings from the model using a different policy variable. Accordingly, *fdi* has a positive effect on the GHG emissions in first three models. However, the interaction terms with *eps*, *meps* and *nmeps* has a moderating role on the level of emissions. More importantly, the coefficients of the interaction terms in which

TABLE 7
FIXED EFFECT REGRESSION RESULTS

Dependent variable: *ghg*	M1	M2	M3	M4
policy variable (*p*)	*eps*	*meps*	*nmeps*	*tsp*
dgdppc	5.2793*	5.7867**	4.9968*	5.6618**
	(2.5751)	(2.6117)	(2.5206)	(2.6368)
primen	0.0003***	0.0003***	0.0002***	0.0003***
	(0.0001)	(0.0001)	(0.0001)	(0.0001)
poplr	-0.3969	-0.6265	-0.3172	-0.4651
	(1.0948)	(1.0727)	(1.1056)	(1.0983)
dren	-0.0964**	-0.1043***	-0.0988**	-0.1035***
	(0.0354)	(0.0354)	(0.0356)	(0.0351)
fdi	0.0634***	0.0196**	0.0695***	0.0140
	(0.0161)	(0.0077)	(0.0225)	(0.0122)
*fdi*p*	-0.0220***	-0.0166***	-0.0136***	-0.0057
	(0.0055)	(0.0051)	(0.0039)	(0.0046)
c	-0.6079	-0.2114	-0.7804	-0.6210
	(2.3109)	(2.2970)	(2.3597)	(2.3213)
Num. of Obs.	550	550	550	550
F-stat.	331.19	382.01	743.32	283.77
R-square	0.7306	0.7222	0.7332	0.7211

Note: (1) ***, ** and * denote those variables are statistically significant at 1%, 5% and 10% respectively.
(2) Driscoll-Kraay consistent standard errors are in parentheses.
(3) The models were estimated with random effects regressions. As the results of the Hausman tests, fixed effects models were preferred.

the *eps* and *nmeps* variables are used (2.88 and 5.11, respectively) provide estimates very close to the findings obtained from the Hansen panel threshold method (2.22 and 5.00, respectively).

Thus, nonmarket-based environmental policy stringency in particular plays an important role in the FDI-GHG emissions nexus. While policy stringency has direct effects on reducing emissions, it also has indirect effects, supporting pollution halo hypothesis.

6. Conclusions

Analysing the effects of FDI on the environment would guide policymakers make critical decisions on FDI inflows. As Sapkota and Bastola (2017) suggest, if the effect of FDI on the environment is positive, then the current policy on FDI would be appropriate. However, the conditions under which FDI inflows reduce pollution may depend on currently implemented environmental policies. The findings in this study showed that if the stringency of environmental policy is above a certain threshold value (2.88 and 2.22 according to fixed-effects and panel threshold regressions, respectively), FDIs will reduce GHG emissions. Moreover, the threshold effect is mainly due to nonmarket-based policy stringency. Accordingly, in the low-regime countries that have *nmeps* lower than or equal to the threshold value (5.11 and 5.00 according to fixed-effects and panel threshold regressions, respectively), FDI inflows increase GHG emissions. On the other hand, in the high-regime countries that have *nmeps* value higher than the threshold value, FDI inflows decrease GHG emissions.

Non-market environmental policies have direct impacts in the decision-making process of investments. Enterprises that do not meet the standards set by the host countries will direct their investments to countries with weaker environmental regulations as they will avoid incurring additional costs. Changing production technologies, especially moving to cleaner technologies, is often costly. For this reason, the standards in the host countries play a decisive role when making decisions about where FDIs will be directed. On the other hand, investments that meet the standards set by the host countries are clean investments that already include advanced production technologies. Therefore, they contribute to the transfer of clean technologies to the host country and positively affect the environmental quality.

Of the countries in our sample, none of the countries has a nonmarket-based policy stringency above threshold value during the whole sample period. However, 18 out of 25 countries (Austria, Belgium, Canada, Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Italy, Korea, Netherlands, Poland, Slovak Republic, Spain, Sweden and United Kingdom) have a nonmarket-based policy stringency value higher than (5.00) in 2015 and beyond. Thus, foreign investment entering the country has gained a pollution-reducing nature in recent years, as nonmarket-based environmental policies are sufficiently stringent in these countries. On the other hand, in three of the sample countries (Australia, Norway, and Turkiye), nonmarket-based policy stringency is always below 5 for the period under consideration. Therefore, foreign investments directed to these countries do not contribute to the reduction of pollution. Thus, these countries need to tighten up their environmental regulations.

Additionally, it is worth noting that, fixed effects regression results also indicate a significant threshold effect for market-based environmental policy stringency, which is approximately (0.09). The difference in the findings is perhaps attributable to the multicollinearity problem caused by the interaction term in the fixed effects model. However, it should be kept in mind that market-based policies remain relatively weak in the sample countries (See Figure A1 in Appendix 2) and may limit the polluting effects of FDIs if implemented sufficiently stringent in the future. Future studies can obtain more reliable results with the development of the data set and the use of different methods.

As a result, environmental policies have indirect effects that reduce pollution caused by FDI inflows, as well as direct effects of reducing pollution originating from domestic production. Therefore, policy makers can benefit from environmental policies to avoid the polluting effects of FDI inflows. When environmental policies are implemented stringently enough, they can make the pollution halo hypothesis more likely through the transfer of clean technologies and production techniques. Thus, FDIs deemed necessary for economic growth also serve the environmental quality of the host country. However, these recommendations focus on only one aspect of the fight against climate change. It is also necessary for the government to implement policies to raise awareness about the importance of climate change and to support the expansion of domestic production with environment-friendly technologies.

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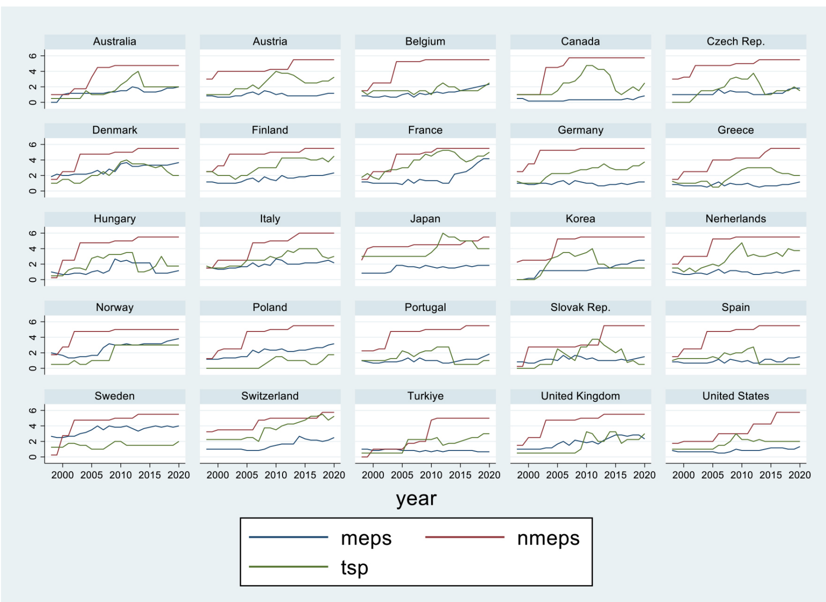
Appendix A1

TABLE A1
SUMMARY STATISTICS

Variables		Obs.	Mean	Std. Dev.	Min.	Max.
ghg	1	575	11.4249	4.9144	4.294	26.011
gdppc	2	575	10.3290	0.6074	8.7121	11.3898
primen	3	575	52122.25	24028.67	12238.71	129020
poplr	4	575	20.7017	9.7316	5.4125	49.0051
ren	4	575	16.2261	13.9238	0.69	62.37
fdi	5	575	4.2787	10.1839	-40.0811	109.3306
eps	6	575	2.6167	0.8895	0.3611	4.8889
meps	7	575	1.4432	0.8489	0	4.1667
nmeps	8	575	4.3087	1.4180	0	6
tsp	9	575	2.0983	1.2393	0	6

Appendix A2

FIGURE A1
THE ENVIRONMENTAL POLICY STRINGENCY IN SELECTED OECD COUNTRIES



Source:The figure was created by the authors using OECD data and STATA software.