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# Pollution Havens Hypothesis: Smooth Quantile Evidence from BRICS

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## Abstract

Pollution, like everything else, can be carried along with globalization. This approach, which refers to the pollution carried by the capital, is the pollution haven hypothesis. This study investigates the effects of foreign direct investment (FDI) on carbon dioxide (CO<sub>2</sub>) emissions from 1995 to 2021 in BRICS countries. We employed the instrumental variables smooth quantile regression (SIV-QR) method, which is novel in panel econometry. Our findings indicate the negative effects of FDI flows on CO<sub>2</sub> in low quantiles and the positive effects of economic growth. However, FDI flow plot estimates of the instrumental variables' smooth quantile regression show that this effect turns positive. This can help uncover possible relationships between the routes of money and carbon dioxide emissions.

**Key Words:** Pollutions havens, carbon dioxide emission, smooth quantile regression

## Introduction

Global warming and the resulting climate crisis are leading global problems in the 21<sup>st</sup> century. One of the mother-lode feedings in the climate crisis is greenhouse gas and carbon dioxide emissions. Carbon dioxide emissions, which are closely related to the consumption of fossil fuels, are also the subject of trade between regions and countries. It is a cap-and-trade system or an emissions trading system. On the one hand, economic growth is of core importance for the markets. Environmental measures implemented by countries or regional associations can also determine the route of carbon emissions. Globalization has not only mobilized capital but also activated carbon emissions.

One of the issues emphasized in recent years is economic growth, energy consumption, and pollution (Muhammad, 2019; Chang and Li, 2018). While most studies focus on economic growth, energy consumption, and pollution, the effects of foreign direct investment flow on pollution have been relatively less researched (Bakhsh et al., 2017). To fill this gap, our study aimed to discover the relationship between foreign direct investment, CO<sub>2</sub>, and economic growth.

“Increased” environmental awareness in developed countries may affect the location or amount of production geographically. Environmentally friendly policies of developed countries or clean production (Cole, 2004) affect the profitability of production processes more or less through various factors. One of the ways to prevent a possible decline in profit rates may be to shift production centers to developing countries with relatively weak environmental policies (Cole, 2004). Apart from this, costs per unit can be reduced with

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environmentally friendly technologies, and for this, developing environmentally friendly production relations with intensive technology is among the possibilities. The second possibility emphasizes the reducing effects of investments in technology on pollution. In other words, this effect is an approach known as the technological effect in which direct foreign investment flows reduce pollution (Chang and Li, 2018). The first possibility is referred to as the pollution havens hypothesis or the race to the bottom concept (Dean et al., 2009; Khan and Öztürk, 2020). While both can be observed in modern economies, this study focuses on the first possibility.

While foreign direct investment increases economic growth, it can also increase environmental pollution through industrial activity (Aslan et al., 2021; Khan and Öztürk, 2020; Koçak and Şarkgüneşi, 2018). Foreign direct investment (FDI) flow, which is currently considered one of the driving forces of economic growth, can also be the driving force of an insidious result. Among mainstream approaches, studies such as French (1998), Cole (2004), and Dean et al. (2009), Pao and Tsai (2011), and Omri et al. (2014) are pioneering studies that draw attention to the effects of foreign direct investments on pollution.

Today, as in the past (Pao and Tsai, 2011), BRICS countries are pioneers of investment destinations in the world. These countries also have a large share of the world economy in terms of economic growth, energy exports, technology exports, and trade. In addition, since 2006, China has surpassed the USA in terms of CO<sub>2</sub> from fossil fuels and industry (OWD, 2023a).

Based on these explanations, this study examines the effects of FDI flows on carbon emissions in BRICS countries. We employed the instrumental variable smooth quantile regression method developed by Kaplan and Sun (2017), which can be considered a novel method in panel econometrics. This method smooths the tool function rather than the goal, thereby increasing its reliability relative to other instrumental methods. While our findings indicate the negative effects of FDI flows on CO<sub>2</sub> in low quantiles, the quantile plot estimates show that this effect turns positive.

This manuscript is organized as follows: Section 2 presents the most recent studies. Section 3 provides information on the dataset, method, and model. Section 4 concludes and provides policy recommendations after presenting a robustness check of the main findings.

## **2. Literature Review**

Many empirical studies have been conducted on the direction and magnitude of the relationship between Co2 emissions and macroeconomic variables. In addition to carbon dioxide emissions and foreign direct investment, some studies have focused on variables such as economic growth (Xiong and Xu, 2021), exports (Li et al., 2023), foreign trade (Kander and Lindmark, 2006), imports, and debt (Boly et al., 2022). Some studies on the relationship between FDI flows and CO2 emissions are listed in Table 1.

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**Table 1. Literature Review**

Author/s	Sample	Variables	Methods	Findings
Keho (2015)	12 ECOWAS Countries 1970-2010	CO <sub>2</sub> , FDI, Pop, pGDP	ARDL	FDI, + and – effects on CO <sub>2</sub>
2 Tang and Tan (2015)	Vietnam 1976-2009	CO <sub>2</sub> , EU, FDI, Eg	VECM, Granger causality	FDI, – effects on CO <sub>2</sub>
2 Peng et al. (2016)	Provinces of China 1985-2012	CO <sub>2</sub> , FDI, Eg	OLS, panel VAR	6 FDI, + and – effects on CO <sub>2</sub>
2 Ali et al. (2017)	Malaysia 1971-2012	CO <sub>2</sub> , Eu, pGDP, FDI, Tr, Fd	ARDL	FDI, + and – effects on CO <sub>2</sub>
Bakhsh et al. (2017)	Pakistan 1980-2014	FDI, CO <sub>2</sub> , Ec	3SLS	FDI, + effects on CO <sub>2</sub>
2 Behera and Dash (2017)	17 South and Southeast Asian Countries 1980-2012	CO <sub>2</sub> , FDI, Eu, Ub	FMOLS, DOLS	FDI, + effects on CO <sub>2</sub>
10 Sapkota and Bastola (2017)	14 Latin America Countries 1980-2010	FDI, Eg, CO <sub>2</sub>	FE, RE	FDI, + effects on CO <sub>2</sub>
6 Chang and Li (2018)	84 Countries 1996-2005	FDI, CO <sub>2</sub>	Threshold Effects	FDI, + effects on CO <sub>2</sub>
6 Koçak and Şarkgüneşi (2018)	Türkiye 1974-2013	FDI, CO <sub>2</sub>	Causality	FDI, + effects on CO <sub>2</sub>
16 Salahuddin et al. (2018)	Kuwait 1980-2013	FDI, CO <sub>2</sub> , Eg, Eu, Fd	ARDL, VECM	FDI, + effects on CO <sub>2</sub>
Haug and Ucal (2019)	1 Türkiye 1974-2014	Foreign trade, FDI, CO <sub>2</sub>	ARDL	FDI has no statistically significant effects.
Muhammad and Khan (2019)	34 Host Countries of Asia and 115 Source Countries 2001-2012	FDI, Eu, CO <sub>2</sub> , Eg	GMM	FDI, + effects on CO <sub>2</sub>
21 Esendoh et al. (2020)	52 Countries 1991-2014	Tr, FDI, economic integration, CO <sub>2</sub>	PMG-ARDL	FDI, + effects on CO <sub>2</sub>
Khan and Öztürk (2020)	17 Asia Countries 1980-2014	CO <sub>2</sub> , FDI, Gdp	FMOLS	FDI, + effects on CO <sub>2</sub>
Aslan et al. (2021)	N11 Countries 1980-2018	Air pollution, Eg, Eu, Tr, FDI, Fd	PVAR	FDI, + effects on CO <sub>2</sub>

Notes: CO<sub>2</sub>; CO<sub>2</sub> emissions, FDI; foreign direct investment, Pop; population, Gross domestic per capita; pGDP, Eu; Energy use, Eg; Economic Growth, Tr; Trade, financial development; Fd, Urbanization; Ub, + ; positive, – ; negative.

### 3. Sample, Data and Model and Methodology

18 This study investigates the effects of FDI flow on carbon dioxide emissions in 27 five emerging economies (Brazil, Russia, India, China, and South Africa (BRICS)). BRIC was first introduced by O'Neill (2001), and South Africa was joined in 2011 (Chatterjee and Naka, 2022). We consider three aspects of BRICS when determining the sample. The first was their attitudes towards carbon emissions, the second was their relatively weak environmental

policies compared to Europe, and the last was their stability in foreign direct investment inflows.

We were inspired by the model developed by Omir <sup>4</sup> et al. (2014), Shahbaz et al. (2019), and Salahuddin et al. (2018). We adopted the Bakhsh et al. (2017) time-series model for the panel estimation. The functional definition is as follows and Equation 2:

$$CO_2 = f(GDP, FDI) \tag{1}$$

$$\ln CO_{2it} = a_0 + \beta_1 \ln gdp_{it} + \beta_2 \ln fdi_{it} + \varepsilon_{it} \tag{2}$$

Equation 2 is a double-log model and where <sup>1</sup>  $CO_2$  is carbon dioxide emissions per capita,  $GDP$  is gross domestic product per capita,  $FDI$  is foreign direct investment, net inflow (% of GDP), and  $\varepsilon$  is the error term in Equation 2. In addition, we added two control variables (electricity consumption <sup>13</sup> and population density) to our model. The definitions, abbreviations, and sources of variables are listed in Table 2.

**Table 2.** Data Information

Variable	Definition	Unit	<sup>17</sup> Data source
<b>CO<sub>2</sub></b>	Carbon dioxide emissions	CO <sub>2</sub> per capita	OWD, 2023a
<b>Eu</b>	Energy consumptions	Primary energy consumption per capita (Wh/person)	OWD, 2023b
<b>GDP</b>	Gross Domestic Product	GDP per capita (constant 2015 US\$)	WDI, 2023
<b>FDI</b>	<sup>7</sup> foreign direct investment	Foreign direct investment, net inflows (% of GDP)	
<b>Pop</b>	Population density	Population density (people per sq. km of land area)	

In the economic approach, one of the main issues in creating a model is the use of exogenous and instrumental variables. In a model, some variables can be explained by other variables while some variables cannot be explained by other variables. To take this into account, we assume our model to be GDP endogenous and FDI exogenous. Considering that GDP can be explained by different variables, instrumental variables are also included in the model. These are Energy consumption and population density.

<sup>20</sup> In the current study, which is based on foreign direct investments and economic growth, we used an effective method that theoretically considers endogenous and exogenous. For this purpose, we prefer a novel method developed recently in panel econometrics. Kaplan and Sun (2017) developed smoothed quantile estimating equations, a quantile method that allows the use of instrumental data. In this method, instrumental variables quantile regression was added, and the authors developed it to smooth the indicator function (namely, SIV-QR).

SIV-QR has some advantages as a kernel-based nonparametric conditional quantile estimator. i) This method can be easily calculated using a standard iterative algorithm that requires smoothness; ii) owing <sup>5</sup> the smoothing estimator of SIV-QR, the method has high-order properties; iii) SIV-QR is a flexible set of estimators that includes IV/OLS mean regression

estimators and median and quantitative regression estimators; and iv) SIV-QR reduces the mean square error, which creates more powerful tests (see for detail Kaplan and Sun (2017)).

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#### 4. Empirical Findings and Robustness Check

Table 3 presents descriptive statistics. Eu and GDP means are higher than others respectively. The standard divisions of CO<sub>2</sub> and FDI are lower than the rest. Skewness shows that only GDP is positively skewed, while the others are negatively skewed.

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**Table 3.** Descriptive Statistics

	Mean	Std. Dev.	Min.	Max.	Skewness	Kurtosis
CO <sub>2</sub>	5.52	3.88	.72	13.2	.262	1.50
GDP	5254.0	2923.1	546.4	10358.2	-.16	1.83
FDI	2.11	1.45	.002	6.18	.55	2.42
Pop	120.5	145.2	8.71	469.65	1.25	3.08
Eu	23135.2	17312.9	2812.7	64323.9	.84	2.51

While the kurtosis value belonging to Pop is about mesokurtic (normal distribution), CO<sub>2</sub>, GDP, and Eu are leptokurtic (T-distributions) and platykurtic (uniform distributions). Therefore, most variables did not have a normal distribution. Therefore, nonparametric methods may be more effective for our estimations.

**Table 4.** Partial Correlations of Carbon Dioxide Emission

	Partial Corr.	Semi partial	Partial Corr <sup>2</sup>	Significance Value
lngdp	-0.59	-0.11	0.35	0.0000
lnfdi	-0.17	-0.02	0.03	0.0382
lneu	0.97	0.681	0.95	0.0000
lnpop	0.80	0.208	0.65	0.0000

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While the partial correlation results provide some proof of the effects of GDP and FDI flow on CO<sub>2</sub>, the fact that we received confirmed findings with the semi-partial results provides key information about the explanatory power of the control variables. Graph 2 shows the estimation results of the function in Equation 1 by weighted least-squares regression, with the weighted versions of lnfdi (left) and lngdp (right).

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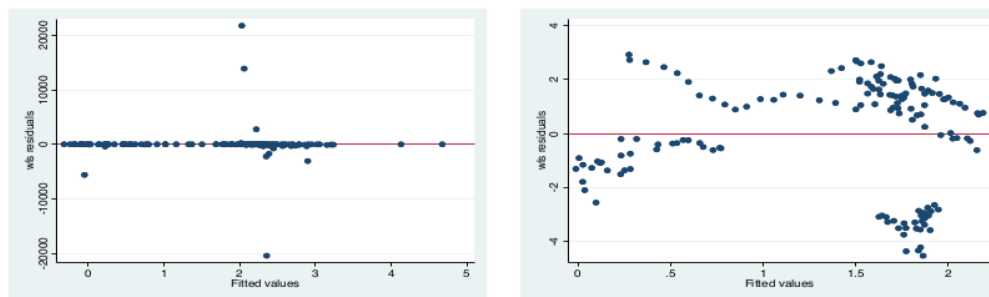


Figure 1. Weighted least squares estimate plots

Accordingly, the correlation between lnfdi (left) and CO<sub>2</sub> appears strong. On the other hand, lngdp (right) indicates a relatively weak and volatile relationship.

**Table 5.** SIV-QR and IV-2SLS results.

	2SLS	SIV-QR			
		Q10	Q25	Q50	Q75
lngdp	1.07 <sup>a</sup>	.68	.96 <sup>a</sup>	1.09 <sup>a</sup>	1.16 <sup>a</sup>
lnfdi	-.17 <sup>a</sup>	-.20	-.16	-.09 <sup>b</sup>	-.09 <sup>a</sup>
Constant	-7.49 <sup>a</sup>	-5.24	-6.74 <sup>a</sup>	-7.45 <sup>a</sup>	-7.79 <sup>a</sup>
R <sup>2</sup>	0.4130	---	---	---	---
Robust score chi2	59.16 [0.0000]	---	---	---	---
Robust regression F	181.32 [0.0000]	---	---	---	---
Endogenous R <sup>2</sup>	0.7630 [0.0000]	---	---	---	---
Score chi2	27.202 [0.0000]	---	---	---	---

Notes: Q indicates quantiles. a, b, and c indicate  $p < 0.05$ , and  $p < 0.01$ , respectively. Employed for each estimator are exogenous regressors: lnfdi, endogenous regressor; lngdp, excluded instruments; lnpop lneu. We also used a robust version of the 2SLS, the VCE version, which confirmed the 2SLS results.

Table 5 presents the estimated coefficients. The SIV-QR findings show that for lngdp, coefficients are interquartiles of 0.96 and 1.16 and positive and significant in the last three quantiles. Therefore, per capita income (lngdp) leads to an increase in lnco2. On the other hand, the lnfdi coefficient is -0.09, which is negative and significant in the last two quantiles, indicating that lnfdi leads to a decrease in lnco2. We used the 2SLS method to check the robustness of the SIV-QR findings. The 2SLS results confirm the SIV-QR findings. We also run several tests to determine the accuracy of our endogenous variables in the model. All the tests yielded similar results, so lngdp is endogenous to the model and is instrumented with lneu and lnpop.

Figure 2 shows the plots for the quantiles. When we move from left to right on the horizontal axis, it can be observed that for higher values. Sivqr1 (SIV-QR) values are shown in red, indicating high values, and when we move toward the right, the graph indicates a transition into increasingly higher values. We can say the same for both the variables.

While lnfdi has a negative effect in low quantiles, this effect is reversed in high quantiles. Therefore, the pollution haven hypothesis is valid for our sample. For the robustness of the SIV-QR graphical representation, we estimated the model again without using instrumental variables with two different quantile techniques and drew graphs for this. This can be observed in Figures 3 and 4. The results confirmed the SIV-QR graphical representation. In other words, the high-quantile coefficients of lnfdi are positive.



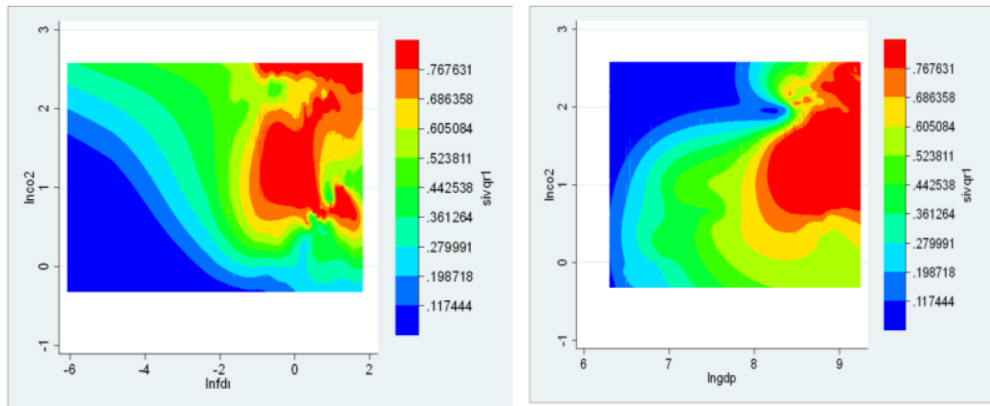


Figure 2. SIV-QR plots

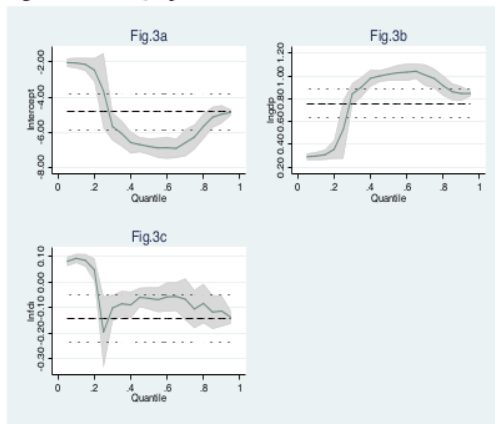


Figure 3. Quantile estimate plots

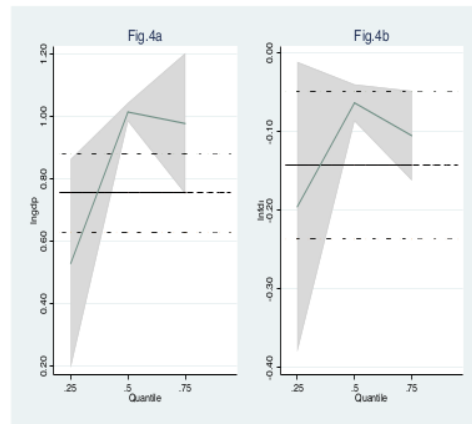


Figure 4. Simultaneous-quantile estimate plots

## Conclusion and Policy Implications

While “increased” environmental awareness in developed countries affects the location or amount of production geographically, the relatively weak environmental policies of developing countries attract pollution from other countries as well as domestically produced pollution. The realization of this process with foreign direct investment flows is expressed by the pollution haven hypothesis. This study investigated the effects of foreign direct investment flows and economic growth on carbon emissions based on 1992-2020 annual data. Population density and electricity consumption were used as the control variables.

As a research method, we used the instrumental variables smooth quantile regression method, which is a novel method in panel econometrics. Our findings indicate the negative effects of FDI flows on CO<sub>2</sub> in low quantiles and the positive effects of economic growth. We validated these findings using the instrumental variables of the two-stage least squares estimation. However, the plot estimates of the instrumental variables’ smooth quantile regression show that the effect of FDI flow becomes positive. These findings show that in BRICS countries,



the technological impact may <sup>28</sup> be negative in the short run, but <sup>12</sup> the pollution havens hypothesis is valid in the long run.

Based on our findings, we make two recommendations: one for policymakers and one for researchers. Policymakers should focus on long-term environmental policies rather than short-term growth plans. Second, our instrumental variables' smooth quantile regression plot findings show a threshold value. Researchers may focus on this threshold value using threshold methods that consider nonparametric and instrumental relationships between the variables.

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