

Investigating The Pollution Haven Hypothesis in Türkiye: An ARDL Approach

Djallel Aimar ^{1*}

¹ Karadeniz Technical University, Social Sciences Institute, Economics Department, Trabzon, Türkiye, djallelaimar@ktu.edu.tr

Received: 1/13/2026

Accepted: 4/2/2026

Published: 4/23/2026

Abstract:

This study examines the validity of the Pollution Haven Hypothesis (PHH) in Türkiye for the period 1990–2022. Using annual data, carbon dioxide (CO₂) emissions per capita are analysed in relation to foreign direct investment (FDI), economic growth, energy consumption, renewable energy, trade openness, and economic freedom. The Autoregressive Distributed Lag (ARDL) bounds testing approach is employed to estimate short-run and long-run relationships. Structural changes are controlled for using the Zivot–Andrews unit root test and a structural break dummy for 2003. The results reject the Pollution Haven Hypothesis, as FDI does not significantly affect CO₂ emissions. In contrast, economic growth and energy consumption significantly increase emissions, while renewable energy does not yet mitigate environmental degradation. These findings indicate that energy transition and efficiency-oriented policies are more effective than restricting foreign investment.

Keywords: Pollution Haven Hypothesis, CO₂ Emissions, Foreign Direct Investment, Economic Growth, Energy Consumption.

JEL Classification Codes : Q53; F21

* : *Corresponding author.*

1. INTRODUCTION

Balancing economic growth with environmental sustainability has become a central policy challenge for many emerging and middle-income economies. Rapid industrialisation, expanding energy demand, and deeper integration into global markets have significantly increased environmental pressures, particularly through rising CO₂ emissions. As energy consumption remains a key driver of economic activity, understanding the interaction between growth, energy use, and environmental degradation is essential for designing effective energy and environmental policies.

One of the most influential frameworks linking globalisation to environmental outcomes is the Pollution Haven Hypothesis (PHH). The PHH posits that pollution-intensive production activities may relocate from countries with strict environmental regulations to countries with relatively lax standards, thereby increasing environmental degradation in host economies. This hypothesis has been extensively discussed in the theoretical literature, most notably by Copeland and Taylor (2004), who emphasise the role of regulatory differences and trade liberalisation in shaping pollution patterns. However, empirical evidence on the PHH remains mixed, particularly for developing and emerging economies, where institutional quality, energy structures, and income levels differ substantially from those of advanced economies (Eskeland and Harrison, 2003; Cole et al., 2008).

Türkiye provides a particularly relevant case for examining the validity of the PHH. Over the past three decades, the country has experienced sustained economic growth, increasing trade openness, and rising inflows of FDI, alongside a sharp increase in energy consumption. Despite recent policy efforts to promote renewable energy, Türkiye's energy mix continues to be dominated by fossil fuels, raising concerns about the environmental sustainability of its growth trajectory. These structural characteristics make Türkiye an appropriate case for assessing whether environmental degradation is driven primarily by foreign investment and openness or by domestic growth and energy consumption dynamics.

Empirical studies focusing on Türkiye offer no clear consensus regarding the environmental effects of economic liberalisation. While some studies suggest that FDI and trade openness contribute to environmental degradation, others reject the PHH and argue that income growth and energy consumption are the dominant drivers of CO₂ emissions. For example, Ozturk and Acaravci (2013) find a strong relationship between economic growth, energy consumption, and emissions in Türkiye, while Dogan and Turkekul (2016) highlight the role of energy structure and income dynamics rather than trade openness alone. These divergent findings indicate that the environmental consequences of globalisation in Türkiye remain an open empirical question.

Against this background, this study investigates the validity of the Pollution Haven Hypothesis in Türkiye by analysing the relationship between CO₂ emissions per capita and key economic and energy-related variables over the period 1990–2022. The analysis incorporates real FDI per capita, real GDP per capita and its squared term, total energy consumption, renewable energy consumption, economic freedom, and trade openness. The ARDL bounds testing approach is employed to capture both short-run and long-run relationships while allowing for variables integrated at different orders. In addition, potential structural breaks are

addressed using the Zivot–Andrews unit root test, enhancing the robustness of the empirical analysis.

This study contributes to the existing literature in several ways. First, it provides updated evidence on the PHH for Türkiye using an extended dataset that includes recent economic and energy developments. Second, it jointly examines traditional PHH variables alongside energy consumption and institutional indicators, offering a more comprehensive assessment of the determinants of environmental degradation. Third, by employing multiple model specifications, the analysis ensures that the results are not driven by a particular model choice.

The findings of this study have important implications for energy and environmental policy in Türkiye. By clarifying whether environmental degradation is primarily associated with foreign investment, economic growth, or energy consumption patterns, the paper provides insights relevant for the design of sustainable growth strategies and energy transition policies. Understanding these dynamics is crucial for policymakers seeking to reconcile economic development objectives with environmental sustainability.

The remainder of the paper is organised as follows. Section 2 reviews the relevant literature on the Pollution Haven Hypothesis and related empirical studies. Section 3 presents the data and methodology. Section 4 discusses the empirical results, and Section 5 concludes with policy implications.

2. Literature Review

The relationship between globalisation and environmental quality has been extensively examined through the lens of the Pollution Haven Hypothesis (PHH). The PHH posits that pollution-intensive activities may relocate from countries with stringent environmental regulations to countries with relatively lax regulatory frameworks, thereby increasing environmental degradation in host economies. Theoretical foundations of the PHH are formalised by Copeland and Taylor (2004), who demonstrate how trade liberalisation, differences in environmental regulation, and factor endowments jointly influence pollution patterns across countries.

Empirical evidence on the PHH remains mixed. Early studies such as Eskeland and Harrison (2003) find limited but context-dependent support for the hypothesis, suggesting that FDI can contribute to higher pollution levels in host countries under certain regulatory and institutional conditions. Similarly, Cole, Elliott, and Shimamoto (2008) show that environmental regulation stringency and factor intensities influence the international location of pollution-intensive industries. These studies provide partial support for the PHH, particularly in developing and emerging economies.

In contrast, a substantial body of literature rejects the PHH and argues that FDI may instead improve environmental quality through technology transfer, cleaner production processes, and improved management practices—a mechanism often referred to as the “pollution halo” effect. This strand of the literature highlights the heterogeneity of FDI effects and emphasises the importance of host-country characteristics, such as income level, energy structure, and institutional quality, in shaping environmental outcomes. As a result, the environmental impact of FDI is increasingly viewed as an empirical question rather than a universal outcome of globalisation.

Economic growth and energy consumption are widely recognised as key drivers of CO₂

emissions. The Environmental Kuznets Curve (EKC) hypothesis suggests an inverted U-shaped relationship between income and environmental degradation, implying that emissions initially rise with income growth but decline beyond a certain income threshold. While the EKC hypothesis has been extensively tested, empirical findings remain inconclusive across countries and pollutants.

A large number of studies emphasise the dominant role of energy consumption in driving emissions, particularly in economies where fossil fuels constitute the primary energy source. Halicioglu (2009) provides early evidence for Türkiye, showing that energy consumption and income growth significantly increase CO₂ emissions, while the role of foreign trade is more ambiguous. Similarly, Acaravci and Ozturk (2010) find that economic growth and energy consumption are major contributors to emissions dynamics in European economies, with limited evidence supporting the EKC hypothesis.

Ozturk and Acaravci (2013) report a strong long-run relationship between energy consumption, economic growth, and CO₂ emissions in Türkiye, while evidence for an inverted U-shaped EKC relationship remains weak. Shahbaz, Lean, and Shabbir (2012), as well as Shahbaz et al. (2013), similarly argue that scale effects associated with economic growth and rising energy demand often dominate potential technique effects in emerging economies, leading to persistent increases in emissions. These findings suggest that controlling for both income and energy consumption is essential when analysing environmental degradation. Failure to account for energy demand may lead to biased inference regarding the role of globalisation-related variables such as FDI and trade openness.

Dogan and Seker (2016) show that the impact of renewable energy on emissions depends critically on whether renewables replace fossil fuels or merely complement growing energy demand. In rapidly growing economies, renewable energy expansion may coexist with increasing fossil fuel consumption, resulting in a positive association between renewable energy use and CO₂ emissions. This perspective highlights the importance of scale effects and transitional dynamics in interpreting renewable energy–emissions relationships. These findings imply that renewable energy alone may not be sufficient to reduce emissions unless accompanied by structural changes in energy consumption patterns. Consequently, empirical models that include renewable energy consumption alongside total energy use provide a more comprehensive assessment of emissions dynamics.

Recent empirical evidence from Algeria also highlights the role of energy consumption and urbanisation in explaining CO₂ emissions, reinforcing the importance of structural and energy-related factors in environmental degradation (Mouhouni, 2022).

Trade openness constitutes another key channel through which globalisation may affect environmental quality. Theoretical frameworks suggest that trade influences emissions through scale, composition, and technique effects. While trade expansion may increase emissions through higher production levels, it can also facilitate access to cleaner technologies and promote efficiency improvements.

Empirical evidence on the environmental effects of trade openness remains inconclusive. Some studies report that openness exacerbates emissions in pollution-intensive economies, while others find neutral or mitigating effects. Halicioglu (2009) and Ozturk and Acaravci (2013) document mixed results for Türkiye, suggesting that trade openness alone does not fully explain

emissions dynamics once energy consumption and income effects are taken into account.

Beyond trade, institutional quality and economic freedom have gained increasing attention in the environmental economics literature. Stronger institutions may enhance environmental regulation enforcement and encourage sustainable production practices, potentially mitigating the adverse environmental effects of growth and liberalisation. Conversely, weak institutional frameworks may amplify pollution pressures associated with economic integration. Incorporating institutional indicators therefore allows for a more nuanced analysis of the determinants of environmental degradation.

Empirical studies focusing on Türkiye provide no clear consensus regarding the validity of the PHH. While some studies suggest that FDI and openness contribute to environmental degradation, many others find that FDI has no statistically significant impact on CO₂ emissions once energy consumption and income growth are controlled for. Instead, economic growth and fossil-fuel-based energy consumption consistently emerge as the primary drivers of emissions.

Türkiye's emissions dynamics are further shaped by its rapidly growing energy demand and fossil-fuel-dominated energy mix. Despite increasing investments in renewable energy, total energy consumption continues to rise, raising concerns about the environmental sustainability of current growth patterns. These characteristics make Türkiye a particularly relevant case for reassessing the PHH using updated data and a framework that jointly considers growth, energy, openness, and institutional factors.

Building on the existing literature, the present study re-examines the Pollution Haven Hypothesis in Türkiye using an extended dataset covering the period 1990–2022. By employing an ARDL bounds testing approach and estimating a baseline specification alongside multiple robustness specifications, the study assesses whether the FDI–emissions relationship is sensitive to alternative energy, trade openness, and institutional controls. This comprehensive approach contributes to the literature by clarifying the relative importance of globalisation-related and domestic factors in shaping environmental outcomes in an emerging economy context.

3. Data and Methodology

3.1 Data Description

This study examines the relationship between environmental degradation, economic growth, energy consumption, and globalisation-related factors in Türkiye over the period 1990–2022. Environmental degradation is proxied by CO₂ emissions per capita, measured in metric tons per capita. CO₂ emissions are widely used in the literature as a comprehensive indicator of environmental pressure associated with energy use and industrial activity.

To test the Pollution Haven Hypothesis (PHH), FDI is included as the primary explanatory variable and measured as real FDI per capita. Economic growth is captured by real GDP per capita, expressed in constant U.S. dollars, along with its squared term to test for the potential presence of a non-linear Environmental Kuznets Curve (EKC) relationship between income and emissions.

Energy-related variables play a central role in the analysis. Total energy consumption per capita, measured in kilograms of oil equivalent, is included to capture the scale effect of energy demand. In addition, renewable energy consumption, measured as a percentage of total final energy consumption, is incorporated to account for changes in energy structure and the role of

cleaner energy sources.

To control for broader economic liberalisation and institutional factors, the analysis includes trade openness, defined as the ratio of total trade (exports plus imports) to GDP, and economic freedom, which reflects the degree of market orientation and regulatory environment in the economy. These variables allow for an assessment of whether openness and institutional quality condition the relationship between globalisation and environmental outcomes.

All variables are transformed into natural logarithms to stabilise variance and allow coefficient estimates to be interpreted as elasticities. A detailed description of the variables and their measurement units is provided in Table 1. The data are obtained from standard international sources commonly used in the energy–environment literature, including the World Development Indicators (World Bank) and the Index of Economic Freedom.

Table 1. Data

Variable	Meaning	Unit
CE	CO2 Emissions per capita	Metric tons per capita
FDI	Real Foreign Direct Investment per capita	Real FDI per Capita
GDP	Real GDP per capita	Constant USD
GDP²	Real GDP per capita square	Constant USD
EC	Total Energy consumption	kg of oil equivalent per capita
REN	Renewable energy consumption	% of total final energy consumption
ECF	Economic freedom	-
TOP	Trade openness	% of GDP

3.2 Econometric Model Specification

To investigate the determinants of CO₂ emissions and test the Pollution Haven Hypothesis in Türkiye, the study estimates a set of five ARDL specifications, consisting of a baseline model and four robustness specifications. The baseline model captures the core PHH relationship between FDI and emissions while controlling for economic growth and energy consumption. The remaining specifications extend the baseline framework by incorporating alternative energy, trade, and institutional controls to ensure robustness.

The general long-run relationship can be expressed as follows:

$$\ln CE_t = \alpha_0 + \alpha_1 \ln FDI_t + \alpha_2 \ln GDP_t + \alpha_3 \ln GDP_t^2 + \alpha_4 \ln EC_t + \alpha_5 Z_t + \varepsilon_t$$

where CE denotes CO₂ emissions per capita, FDI represents foreign direct investment per capita, GDP is real GDP per capita, GDP² captures potential non-linear income effects, EC denotes total energy consumption per capita, and Z is a vector of additional control variables including renewable energy consumption, trade openness, and economic freedom depending on the model specification.

3.3 Unit Root Tests and Structural Breaks

Prior to estimation, the time-series properties of the variables are examined to avoid spurious regression. Standard unit root tests, namely the Augmented Dickey–Fuller (ADF) and Phillips–Perron (PP) tests, are applied to determine the order of integration of each variable. The results indicate that the variables are integrated of order zero or one, I(0) or I(1), but none is integrated of order two, I(2).

Given the long sample period and the presence of major macroeconomic and policy

changes in Türkiye, the Zivot–Andrews (ZA) unit root test is employed to allow for one endogenous structural break in the intercept and/or trend. The ZA results, reported in Table 4, confirm that all variables are integrated of order one, $I(1)$, after accounting for a single structural break. Importantly, the test identifies 2003 as a dominant breakpoint for several key variables, including CO₂ emissions, energy consumption, FDI and income-related series.

The year 2003 represents a major structural shift in Türkiye’s economic and policy framework, coinciding with the post-2001 crisis stabilisation period, the implementation of IMF-backed structural reforms, large-scale financial and institutional restructuring, and the initiation of European Union accession negotiations. These developments significantly altered growth dynamics, capital inflows, trade orientation, and energy demand patterns. To account for this regime change and ensure stable long-run estimation, a structural break dummy for 2003 is incorporated into the ARDL specifications.

3.4 ARDL Bounds Testing Approach

To examine the existence of a long-run relationship among the variables, the study employs the ARDL bounds testing approach developed by Pesaran, Shin, and Smith. The ARDL methodology offers several advantages: it can be applied regardless of whether the regressors are $I(0)$ or $I(1)$, it performs well in small samples, and it allows for simultaneous estimation of short-run and long-run dynamics.

The ARDL error-correction representation is specified as:

$$\Delta \ln CE_t = \beta_0 + \sum_{i=1}^p \beta_i \Delta \ln CE_{t-i} + \sum_{j=0}^q \gamma_j \Delta X_{t-j} + \lambda ECT_{t-1} + \mu_t$$

where Δ denotes the first difference operator, X is a vector of explanatory variables, and ECT_{t-1} represents the error-correction term derived from the long-run cointegrating relationship. The coefficient of the error-correction term is expected to be negative and statistically significant, indicating convergence towards long-run equilibrium following short-run shocks.

The bounds F-statistic is used to test the null hypothesis of no cointegration. If the computed F-statistic exceeds the upper critical bound, the null hypothesis is rejected, confirming the existence of a long-run relationship.

3.5 Diagnostic and Stability Tests

To ensure the reliability of the estimated ARDL models, a series of diagnostic tests is conducted. These include tests for serial correlation, heteroskedasticity, normality of residuals, and functional form misspecification. In addition, the stability of the estimated coefficients is examined using the CUSUM and CUSUM of squares tests. Empirical evidence shows that the estimated models are stable over the sample period and free from major econometric problems.

Table 2. Descriptive analysis of data

	CE	FDI	GDP 2	GDP	EC	ECF	TOP
Mean	3.748388	9.596834	551360.8	573.1351	16037.39	6.222121	0.444204
Median	3.751129	6.954093	280577.2	529.6954	15884.85	6.320000	0.494293
Maximum	5.205879	32.21008	1961421.	1400.507	22806.30	7.080000	0.541804
Minimum	2.562358	0.098169	1974.607	44.43655	10345.27	5.110000	0.233233
Std. Dev.	0.818288	10.56418	624211.9	479.4182	4027.594	0.668154	0.100827
Skewness	0.132279	0.730285	0.727418	0.257318	0.249622	-0.340968	-0.967812
Kurtosis	1.695774	2.152885	2.114357	1.461342	1.732345	1.878245	2.514198
Jarque-Bera	2.435121	3.919947	3.988755	3.619439	2.552267	2.369633	5.476141
Probability	0.295951	0.140862	0.136098	0.163700	0.279114	0.305802	0.064695
Sum	123.6968	316.6955	18194907	18913.46	529233.9	205.3300	14.65872
Sum Sq. Dev.	21.42703	3571.263	1.25E+13	7354939.	5.19E+08	14.28575	0.325313
Observations	33	33	33	33	33	33	33

Source: Author's calculation using Stata 14 application

Table 2 presents the descriptive statistics for all variables included in the analysis. CO₂ emissions per capita exhibit moderate variability over the sample period, reflecting Türkiye's sustained economic growth and rising energy demand since the early 1990s. Real GDP per capita and energy consumption display considerable dispersion, indicating structural changes in economic activity and energy use over time. FDI per capita shows higher volatility, consistent with fluctuating capital inflows and periods of macroeconomic instability.

Renewable energy consumption exhibits relatively lower variability, suggesting a gradual and stable evolution rather than abrupt structural shifts in the energy mix. Trade openness and economic freedom display moderate dispersion, reflecting Türkiye's progressive integration into the global economy and institutional reforms over the sample period.

Figure 1 illustrates the time-series plots of the variables. CO₂ emissions, GDP per capita, and energy consumption exhibit upward trends, highlighting the close association between economic expansion, energy use, and environmental pressure. These visual patterns underscore the importance of controlling for growth and energy effects when assessing the environmental consequences of foreign investment and economic liberalisation.

Fig.1. Plots of data overview.



Table 3. Conventional Unit Root Test (ADF, PP)

Augmented Dickey Fuller (ADF)									
Null Hypothesis: the variable has a unit root									
At Level		LNCE	LNCEC	LNCECF	LNFDI	LNGDP	LNGDP 2	LNRE N	LNTOP
With Constant	t-Statistic	-1.455	-0.704	-1.909	-1.274	-1.174	-1.174	-0.657	-3.739
	Prob.	0.5558	0.8456	0.3277	0.6409	0.6821	0.6846	0.8575	0.0036
With Constant & Trend	t-Statistic	n0	n0	n0	n0	n0	n0	n0	***
	Prob.	-1.735	-2.635	-0.673	-0.310	0.564	0.564	-1.757	-1.452
Without Constant & Trend	t-Statistic	n0	no	n0	n0	n0	n0	n0	n0
	Prob.	1.464	3.569	0.917	-0.968	-0.050	-0.050	1.409	-3.054
At First Difference		n0	n0	n0	n0	n0	n0	n0	***
With Constant	t-Statistic	d(LNCE)	d(LNCEC)	d(LNCECF)	d(LNFDI)	d(LNGDP)	d(LNGDP P2)	d(LNREN)	d(LNTOP)
	Prob.	-4.125	-4.278	-3.364	-2.585	-2.279	-2.279	-4.261	-2.929
		0.0009	0.0005	0.0122	0.0961	0.1788	0.1788	0.0005	0.0420

With Constant & Trend	t-Statistic	*** -4.280	*** -4.222	** -4.056	* -2.819	no -2.660	no -2.660	*** -4.270	** -5.095
	Prob.	0.0034	0.0041	0.0073	0.1901	0.2529	0.2529	0.0035	0.0001
Without Constant & Trend	t-Statistic	*** -3.512	*** -2.758	*** -3.219	no -2.627	no -2.388	no -2.388	** -4.001	*** -2.518
	Prob.								
		***	***	***	**	**	**	***	**

Philips Peron (PP)

Null Hypothesis: the variable has a unit root

At Level									
		LNCE	LNCE	LNCF	LNFDI	LNGDP	LNGDP 2	LNREN	LNTOP
With Constant	t-Statistic	-1.431	-0.609	-1.7995	-1.231	-1.165	-1.165	-0.725	-1.783
	Prob.	0.5671	0.8688	0.3740	0.6600	0.6884	0.6884	0.8401	0.3887
With Constant & Trend	t-Statistic	n0	n0	n0	n0	n0	n0	n0	No
	Prob.	0.6856	0.0654	0.9771	0.9894	0.9969	0.9969	0.5265	0.9826
Without Constant & Trend	t-Statistic	n0	*	n0	n0	n0	n0	n0	n0
	Prob.	1.623	3.659	1.0147	-0.904	-0.040	-0.040	1.313	-1.046
		*	***	n0	n0	n0	n0	n0	N0
At First Difference									
		d(LNCE)	d(LNCE)	d(LNCF)	d(LNFDI)	d(LNGDP)	d(LNGDP2)	d(LNREN)	d(LNTOP)
With Constant	t-Statistic	-5.309	-7.310	-4.674	-4.290	-4.564	-4.564	-6.673	-4.810
	Prob.	0.0000	0.0000	0.0001	0.0005	0.0002	0.0002	0.0000	0.0001
With Constant & Trend	t-Statistic	***	***	***	***	***	***	***	***
	Prob.	0.0000	0.0000	0.0001	0.0016	0.0003	0.0003	0.0000	0.0000
Without Constant & Trend	t-Statistic	***	***	***	***	***	***	***	***
	Prob.	0.0000	0.0000	0.0000	0.0001	0.0000	0.0000	0.0000	0.0001
		***	***	***	***	***	***	***	***

Source: Author's calculation using Stata 14 application

The results of the Augmented Dickey–Fuller (ADF) and Phillips–Perron (PP) unit root tests are reported in Table 3. The findings indicate that all variables are non-stationary in levels but become stationary after first differencing, implying integration of order one, I(1). None of the variables is integrated of order two, satisfying the necessary condition for applying the ARDL bounds testing approach.

Table 4. Unit Root with Breakpoint Zivot Andrews

Variables	ZA Model	Level		First difference		Decision
		ZA Test Statistic	Break Date	ZA Test Statistic	Break Date	
lnCE	A	-2.699 (0)	2006	-5.935*** (0)	2003	I(1)
	B	-2.892 (0)	2017	-6.214*** (0)	2017	
	C	-3.859 (0)	2017	-6.317*** (0)	2016	
lnEC	A	-4.009 (0)	1999	-7.841*** (0)	2003	I(1)
	B	-3.407 (0)	2002	-7.142*** (0)	2000	
	C	-4.330 (0)	1999	-8.013*** (0)	2003	
lnFDI	A	-3.066 (0)	2003	-5.528*** (0)	2000	I(1)
	B	-2.434 (0)	2012	-6.040*** (0)	2005	
	C	-3.615 (0)	2004	-6.983*** (0)	2007	
lnGDP	A	-1.463 (0)	2003	-6.966*** (0)	1999	I(1)
	B	-2.320 (0)	2015	-6.903*** (0)	2005	
	C	-2.291 (0)	2014	-7.123*** (0)	2006	
lnGDP^2	A	-1.463 (0)	2003	-6.966*** (0)	1999	I(1)
	B	-2.320 (0)	2015	-6.903*** (0)	2005	
	C	-2.291 (0)	2014	-7.123*** (0)	2006	
lnTOP	A	-2.699 (0)	1995	-7.057*** (0)	2005	I(1)
	B	-4.242** (0)	2005	-6.880*** (0)	2017	
	C	-4.015 (0)	2003	-7.223*** (0)	1998	
lnECF	A	-2.173 (0)	2017	-6.274*** (0)	2002	I(1)
	B	-3.313 (0)	2013	-5.521*** (0)	1996	
	C	-3.400 (0)	2008	-6.161*** (0)	2002	
lnRen	A	-4.279 (0)	1999	-7.158*** (0)	2009	I(1)
	B	-4.003 (0)	2009	-6.990*** (0)	2000	
	C	-4.186 (0)	1999	-7.802*** (0)	2002	

Source: Author's calculation using Stata 14 application

Table 4 reports the Zivot–Andrews unit root test results allowing for one endogenous structural break. The findings confirm that all variables become stationary after first differencing once the break is considered. Notably, the estimated break dates cluster around the year 2003, indicating a common regime shift affecting emissions, energy consumption, income, and foreign capital flows.

This breakpoint coincides with a period of profound macroeconomic transformation in Türkiye following the 2001 financial crisis, marked by fiscal consolidation, financial sector reform, market liberalisation, and increased integration with global markets. The ZA evidence therefore provides strong econometric and economic justification for controlling for a 2003 structural break in the subsequent ARDL estimations.

Table 5. Cointegration Test Bound Test

No.	Model Specification	F-stat	lag	Normality	Serial Correlation	Heteroskedasticity ARCH	Ramsey
-----	---------------------	--------	-----	-----------	--------------------	-------------------------	--------

1	LnCE = f(lnFDI, lnGDP, lnEC)	9.861***	(1, 0, 1, 0)	0.9587	0.8059	0.3151	0..3736
2	LnCE = f(lnFDI, lnGDP, lnREN)	3.535**	(1, 1, 1, 0)	0.5111	0.1243	0.2038	0.9033
3	LnCE = f(lnFDI, lnEC, lnGDP ²)	9.861***	(1, 0, 0, 1)	0.9587	0.8059	0.3151	0.3736
4	LnCE = f(lnFDI, lnGDP, ln EC, ln ECF)	9.139***	(1, 0, 1, 0, 0)	0.8907	0.6365	0.5264	0.6634
5	LnCE = f(lnFDI, lnGDP, ln EC, lnTOP)	7.400***	(1, 0, 1, 0, 0)	0.5213	0.9974	0.3243	0.5761

Source: Author's calculation using Stata 14 application

The results of the ARDL bounds cointegration tests are reported in Table 5. For all model specifications, the calculated F-statistics exceed the upper critical bounds at conventional significance levels, leading to rejection of the null hypothesis of no cointegration. This indicates the existence of a stable long-run relationship between CO₂ emissions and the explanatory variables across the baseline and robustness specifications.

Diagnostic test results reported alongside the bounds tests confirm the absence of serial correlation, heteroskedasticity, and functional form misspecification. These results provide confidence in the reliability of the estimated ARDL models and validate the use of long-run and short-run coefficient estimates for interpretation.

Table 6: Long-Run and Short-Run Results

INDEPENDENT VARIABLE	MODEL 1	MODEL 2	MODEL 3	MODEL 4	MODEL 5
LONG-RUN COEFFICIENTS					
LNFDI	-0.0004674 (0.990)	-0.184312 (0.272)	-0.0004674 (0.990)	-.0298025 (0.518)	-0.0123886 (0.775)
LNGDP	0.1356953 (0.053)*	0.6259138 (0.028)**	- -	0.2319974 (0.037)**	0.1564412 (0.049)**
LNEC	1.33876 (0.0000)***	- -	1.33876 (0.000)***	1.132835 (0.013)**	1.082815 (0.102)
LNREN	- -	0.6883814 (0.016)	- -	- -	- -
LNGDP^2	- -	- -	0.678477 (0.053)*	- -	- -
LNECF	- -	- -	- -	0.7663272 (0.252)	- -
LNTOP	- -	- -	- -	- -	0.2671835 (0.440)
DUMMY 2003	1.055086 (0.536)	5.817499 (0.050)	1.055086 (0.536)	0.1302176 (0.959)	-4.425026 (0.591)
TREND	-0.0096782 (0.072)*	0.0087437 (0.138)	-0.0096782 (0.072)*	-0.0120911 (0.026)**	-0.0168258 (0.034)**
CONSTANT	11.02847 (0.214)	-19.29208 (0.091)*	11.02847 (0.240)	17.06142 (0.083)*	27.21277 (0.117)
SHORT-RUN COEFFICIENTS					
LNFDI	-0.0003203 (0.990)	-0.0092696 (0.811)	-0.0003203 (0.990)	-0.0176632 (0.489)	-0.0083058 (0.772)
LNGDP	0.0542467 (0.094)*	0.1542817 (0.004)***	- -	0.0667369 (0.039)**	0.0602093 (0.074)*
LNEC	0.9173886 (0.0000)***	- -	0.9173886 (0.000)	0.6714043 (0.014)**	0.72596429 (0.071)
LNREN	- -	0.2497268 (0.016)**	- -	- -	- -
LNGDP^2	- -	- -	0.0271233 (0.094)*	- -	- -
LNECF	- -	- -	- -	0.4541837 (0.211)	- -
LNTOP	- -	- -	- -	- -	0.1791309 (0.451)

DUMMY 2003	0.791398 (0.486)	2.110437 (0.011)**	0.791398 (0.486)	0.0771768 (0.959)	-2.966721 (0.599)
TREND	-0.0096782 (0.072)***	- (0.072)***	-0.0096782 (0.072)*	-0.120911 (0.026)**	-0.0168258 (0.034)**
CONSTANT	11.02847 (0.240)	-2.547807 (0.003)	11.02847 (0.240)	17.06142 (0.083)*	27.21277 (0.117)
ECT-1	-0.6852524 (0.0000)***	-0.3627739 (0.008)**	-0.6852524 (0.000)***	-0.592676 (0.000)***	-0.6704416 (0.000)***

Source: Author's calculation using Stata 14 application

4. RESULTS AND DISCUSSION

4.1. Long-Run Results

Table 6 reports the estimated long-run coefficients for all five ARDL specifications. Across all models, FDI per capita is statistically insignificant, suggesting that FDI does not exert a meaningful long-run impact on CO₂ emissions in Türkiye. This finding provides no empirical support for the Pollution Haven Hypothesis, indicating that foreign investment inflows are not a primary driver of environmental degradation once economic growth and energy consumption are taken into account. This result is consistent with studies that reject the PHH for emerging economies and emphasise domestic structural factors over globalisation-related channels.

Real GDP per capita exhibits a positive and statistically significant effect on CO₂ emissions in all relevant specifications. Moreover, the squared term of GDP per capita is also positive and significant, implying the absence of an inverted U-shaped Environmental Kuznets Curve. This result suggests that economic growth in Türkiye has been predominantly scale-driven, with increases in income associated with higher emissions even at relatively higher income levels. The failure to observe an EKC relationship aligns with earlier evidence for Türkiye and other emerging economies, where structural and energy-intensive growth patterns dominate potential technological or efficiency gains.

Total energy consumption per capita has a positive and highly significant effect on CO₂ emissions across all specifications in which it is included. This confirms that energy demand constitutes the primary transmission channel through which economic activity affects environmental degradation in Türkiye. Given the country's fossil-fuel-dominated energy mix, increases in energy consumption translate directly into higher emissions.

Interestingly, renewable energy consumption also exhibits a positive and statistically significant long-run relationship with CO₂ emissions. Although this result may appear counterintuitive, it suggests that renewable energy expansion in Türkiye has not yet been sufficient to offset rising fossil fuel consumption. Instead, renewable energy may be complementing overall energy demand rather than substituting for carbon-intensive sources. This finding is consistent with the view that scale effects dominate substitution effects during early stages of energy transition.

Trade openness and economic freedom are found to be statistically insignificant in the long run. These results imply that economic liberalisation, by itself, does not significantly influence environmental outcomes once growth and energy factors are controlled for. This reinforces the conclusion that domestic structural factors, rather than openness or institutional orientation alone, shape Türkiye's emissions trajectory.

4.2. Short-Run Dynamics and Error Correction

The short-run estimates reported in Table 6 largely mirror the long-run results. Changes in GDP per capita and energy consumption exert significant short-run effects on CO₂ emissions, confirming the strong link between economic activity, energy demand, and environmental pressure. In contrast, short-run changes in FDI, trade openness, and economic freedom remain statistically insignificant.

The error-correction terms are negative and statistically significant across all specifications, indicating a stable adjustment process towards long-run equilibrium following short-run shocks. The magnitude of the error-correction coefficients suggests a relatively rapid speed of adjustment, implying that deviations from long-run equilibrium are corrected within a reasonable time frame.

4.3. Model Stability

The stability of the estimated coefficients is assessed using the CUSUM and CUSUM of squares tests, as presented in the Appendix. The plots indicate that the estimated parameters remain stable over the sample period, as the test statistics lie within the critical bounds. This confirms the robustness of the estimated relationships and supports the validity of the long-run and short-run inferences.

Overall, the results provide strong evidence against the Pollution Haven Hypothesis for Türkiye. FDI does not appear to be a significant driver of environmental degradation, suggesting that concerns regarding pollution-intensive capital inflows may be overstated in the Turkish context. Instead, the findings highlight the dominant role of economic growth and energy consumption in shaping emissions dynamics.

The absence of an Environmental Kuznets Curve indicates that income growth alone has not led to environmental improvement, underscoring the importance of structural transformation and energy transition policies. Moreover, the positive association between renewable energy consumption and emissions suggests that renewable expansion must be accompanied by reductions in fossil fuel use to achieve meaningful environmental benefits.

These findings imply that environmental policy in Türkiye should focus less on restricting foreign investment and more on managing energy demand, accelerating genuine energy substitution, and promoting cleaner production technologies. Without such measures, continued economic growth is likely to exacerbate environmental pressures. Controlling for the 2003 structural break ensures that the estimated insignificance of FDI is not driven by pre- and post-reform regime differences, thereby strengthening the rejection of the Pollution Haven Hypothesis for Türkiye.

5. CONCLUSION

This study investigates the validity of the Pollution Haven Hypothesis (PHH) in Türkiye by examining the long-run and short-run relationships between CO₂ emissions per capita and key economic, energy, and globalisation-related variables over the period 1990–2022. Employing an ARDL bounds testing approach and accounting for potential structural breaks, the analysis provides robust empirical evidence on the determinants of environmental degradation in an emerging economy context.

The empirical results consistently reject the Pollution Haven Hypothesis for Türkiye. FDI does not exert a statistically significant effect on CO₂ emissions in either the short run or the long run, indicating that foreign capital inflows are not a primary source of environmental

degradation once economic growth and energy consumption are taken into account. This finding suggests that concerns regarding pollution-intensive relocation of foreign firms to Türkiye may be overstated and that foreign investment is unlikely to undermine environmental quality by itself.

Economic growth and energy consumption emerge as the dominant drivers of CO₂ emissions. Real GDP per capita exhibits a positive and significant relationship with emissions, and the positive coefficient on its squared term indicates the absence of an inverted U-shaped Environmental Kuznets Curve. These results imply that income growth in Türkiye has been largely scale-driven, with limited evidence of efficiency or technique effects sufficient to offset rising energy demand. Total energy consumption per capita has a strong and persistent positive effect on emissions, reflecting the country's continued reliance on fossil fuels.

The results also reveal a positive long-run association between renewable energy consumption and CO₂ emissions. This finding suggests that renewable energy expansion in Türkiye has not yet achieved a sufficient scale to substitute for carbon-intensive energy sources. Instead, renewable energy appears to complement overall energy demand during the early stages of the energy transition, highlighting the importance of structural changes in the energy mix rather than isolated increases in renewable capacity.

Trade openness and economic freedom are found to be statistically insignificant in explaining long-run emissions dynamics. These results imply that economic liberalisation, in the absence of targeted environmental and energy policies, does not necessarily exacerbate environmental degradation. Rather, domestic structural factors—particularly energy demand and production patterns—play a more decisive role in shaping environmental outcomes.

Policy Implications

The findings of this study carry several important policy implications for Türkiye. First, environmental policy should not prioritise restricting FDI on the grounds of environmental protection. Since FDI does not significantly contribute to CO₂ emissions, policies aimed at attracting high-quality and technologically advanced foreign investment can be pursued without compromising environmental objectives. Encouraging foreign firms that adopt cleaner production technologies may, in fact, support environmental improvement.

Second, the strong link between economic growth, energy consumption, and emissions underscores the need for comprehensive energy demand management strategies. Policies aimed at improving energy efficiency across industrial, transport, and residential sectors are essential to decouple economic growth from environmental degradation. Without addressing the scale effect of rising energy demand, emissions are likely to continue increasing despite progress in other areas.

Third, the positive association between renewable energy consumption and emissions highlights the importance of accelerating genuine energy substitution. Renewable energy policies should focus not only on expanding capacity but also on displacing fossil fuel-based energy production. This requires coordinated policies that promote grid integration, energy storage, and the gradual phase-out of carbon-intensive energy sources.

Fourth, the insignificance of trade openness and economic freedom suggests that liberalisation alone is insufficient to improve environmental outcomes. Strengthening environmental regulations, enhancing enforcement mechanisms, and integrating environmental considerations into energy and industrial policies are crucial for achieving sustainable

development.

Finally, the absence of an Environmental Kuznets Curve indicates that environmental improvement cannot be expected as an automatic by-product of income growth. Proactive policy intervention is required to ensure that economic development in Türkiye proceeds along a sustainable path.

Limitations and Future Research

Despite its contributions, this study has some limitations. The analysis relies on aggregate national data, which may mask sector-specific dynamics and regional heterogeneity. Future research could extend this framework by employing sectoral or firm-level data to explore whether pollution-intensive activities are concentrated in specific industries. Additionally, incorporating alternative measures of environmental quality and regulatory stringency may provide further insights into the environmental consequences of globalisation.

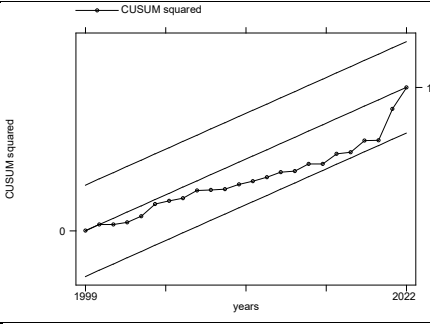
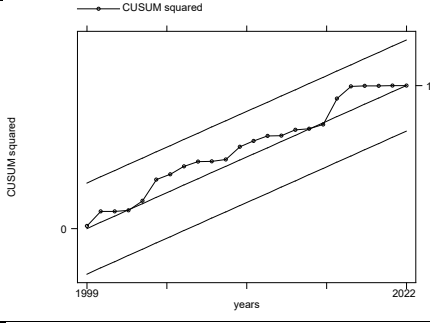
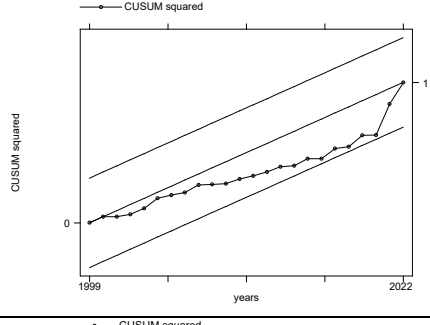
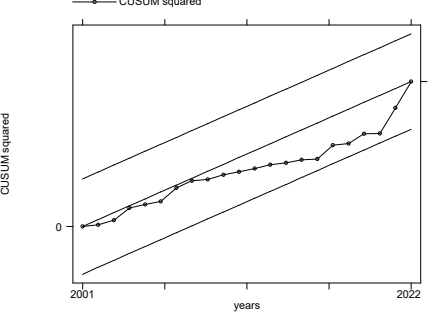
6. Bibliography List :

- Acaravci, A., & Ozturk, I. (2010). On the relationship between energy consumption, CO₂ emissions and economic growth in Europe. *Energy*, Oxford, 35(12), pp. 5412–5420.
- Cole, M. A., Elliott, R. J. R., & Shimamoto, K. (2008). Why the grass is not always greener: The competing effects of environmental regulations and factor intensities on U.S. specialization. *Ecological Economics*, Amsterdam, 54(1), pp. 95–109.
- Copeland, B. R., & Taylor, M. S. (2004). Trade, growth, and the environment. *Journal of Economic Literature*, Nashville, 42(1), pp. 7–71.
- Dogan, E., & Seker, F. (2016). Determinants of CO₂ emissions in the European Union: The role of renewable and non-renewable energy. *Renewable Energy*, Oxford, 94, pp. 429–439.
- Dogan, E., & Turkekul, B. (2016). CO₂ emissions, real output, energy consumption, trade, urbanization and financial development: Testing the EKC hypothesis for the USA. *Renewable and Sustainable Energy Reviews*, Oxford, 61, pp. 466–474.
- Eskeland, G. S., & Harrison, A. E. (2003). Moving to greener pastures? Multinationals and the pollution haven hypothesis. *Journal of Development Economics*, Amsterdam, 70(1), pp. 1–23.
- Halicioglu, F. (2009). An econometric study of CO₂ emissions, energy consumption, income and foreign trade in Turkey. *Energy Policy*, Oxford, 37(3), pp. 1156–1164.
- Mouhouni, M. (2022). Consommation d'énergie, la population urbaine, les émissions de CO₂ et la croissance économique en Algérie durant la période 1971-2020. *أبحاث إقتصادية*, معاصرة, 5(2), 612-597.
- Ozturk, I., & Acaravci, A. (2013). The long-run and causal analysis of energy, growth, openness and financial development on carbon emissions in Turkey. *Energy Policy*, Oxford, 54, pp. 262–267.
- Shahbaz, M., Lean, H. H., & Shabbir, M. S. (2012). Environmental Kuznets Curve hypothesis in Pakistan: Cointegration and Granger causality. *Renewable and Sustainable Energy Reviews*, Oxford, 16(5), pp. 2947–2953.

Shahbaz, M., Ozturk, I., Afza, T., & Ali, A. (2013). Revisiting the environmental Kuznets curve in a global economy. *Renewable and Sustainable Energy Reviews*, Oxford, 25, pp. 494–502.

7. Appendices

CUSUM of Squares of Models

Model 1	
Model 2	
Model 3	
Model 4	

Model 5

