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Carbon-conscious development: Examining FDI, economic growth, and CO2 emissions in Jordan

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Abstract

This study explores the links between FDI, growth, and environmental impacts in Jordan. It evaluates short- and long-term links between FDI, growth, and carbon emissions. It also examines the EKC, PHVH, and PHLH for 1990-2022. The study uses the Autoregressive Distributed Lag (ARDL) model. It tests long-term relationships tied to these hypotheses. The ARDL bounds test found an inverse link between FDI and CO2 emissions. This supports the Pollution Halo Hypothesis. It also found a positive correlation between GDP and CO2 emissions. Yet, the results do not support the EKC hypothesis for Jordan. Causality testing shows a one-way link. CO2 emissions cause all other variables. FDI affects both GDP and its squared term. These insights stress the need for policies to boost FDI. This is vital in renewable energy, especially solar and wind. It will help Jordan's sustainable development goals.

Keywords: Autoregressive Distributed Lag Model, Carbon Dioxide Emissions, Economic Growth, Foreign Direct Investment.

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1. Introduction

Jordan is one of many countries seeking foreign investment to boost growth. Yet, balancing environmental sustainability remains a big question and challenge. FDI is key to a country's economic development. It boosts tech transfer and creates jobs. Jordan wants to attract foreign investors. It seeks to balance economic growth with environmental sustainability. Jordan faces a global challenge: CO2 emissions. They harm climate and ecology [1].

The Pollution Haven Hypothesis (PHVH) links FDI and CO_2. It is often debated. The PHVH posits that FDI from countries with strict environmental laws tends to increase CO_2. This happens when these investments go to laxly regulated host jurisdictions [2]. The Pollution Halo Hypothesis (PHLH) can be considered an alternative view. It holds that FDI will bring cleaner technologies and higher standards to the host country [3].

Empirical research on the FDI-CO_2 relationship has yielded conflicting and inconclusive results. These inconsistencies prevent an agreed conclusion on the direction and size. The methodologies were very different, with variations in the variables and data sources. Also, the results differ by analysis level, period, income group, and environmental quality. They also vary by control variables [4].

Trends in FDI in Jordan from 1990 to 2022 will provide a clue to the country's economic dynamism. Figure 1 shows that, in early 1990, FDI inflow was low. It was constant but fluctuated a bit. Yet, in 1997, there was a remarkable surge in investments of up to 360.9 million dollars. This could state economic reforms and lenient investment policy during that period. Researchers found the most significant rise between 2000 and 2007. FDI grew almost nine-fold in that time. In 2005, foreign investment was 4,912.3 million dollars. By 2007, it peaked at 6,299.6 million. This shows a positive view of Jordan's business environment. Since then, in 2009, FDI rose slightly by $355.6 million. After 2010, it stayed almost constant through 2022. Despite fluctuations, it shows the long-run stability of FDI inflows in Jordan. We must analyze the economic policies, political stability, and the global economy. This will help us understand the fluctuations. It should clarify the economic conditions that shaped 30 years of investments [5].

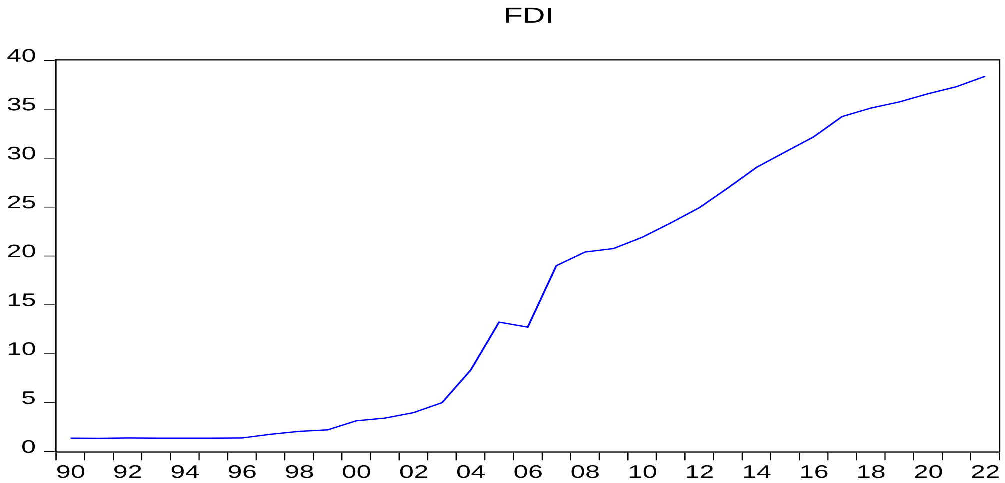

Figure 1.
FDI (in billion US Dollar).

Finally, Figure 2 shows nuanced patterns in Jordan's annual CO_2 emissions from 1990 to 2022. This elaborates on the nation's environmental dynamics. The main trend was upward, peaking at 26 thousand Kton in 2017. It then descended a small distance. This shows more industrial activity and energy use. This increase likely aligns with the economic growth during the study. Emissions have been decreasing since 2018. This may signal a shift in the emissions landscape. This may show a shift to cleaner tech, renewable energy, and better energy use. This decrease, timed with global climate efforts, suggests a rise in sustainability awareness. The rise in emissions from 2021-22 raises questions about its causes. Drivers may include: economic recovery, industrial resurgence, post-Covid recovery, or new energy policies.

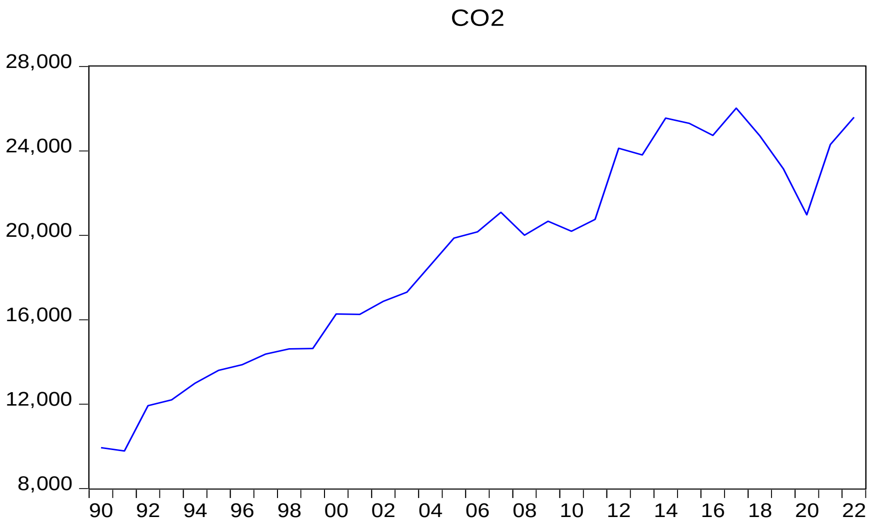

Figure 2.
Line graph of CO_2 (in metric tons).

FDI and CO2 emissions in Jordan show a complex trade-off. We must balance economic growth with environmental sustainability. FDI is vital for economic development. But, we must manage its environmental impact. Jordan's experience shows the challenges and opportunities in aligning its eco-economic and ecological goals. A nuanced understanding of these dynamics is critical. It helps in creating policies for sustainable development. Many studies examine the global relationship. However, Jordan needs to study FDI, economic growth, and CO2 emissions. Also, environmental issues are now more important in all countries, especially developing ones. Besides other reasons, this study is significant in this regard.

This study examines how FDI affects CO2 emissions and growth in Jordan, which seeks sustainable growth. We organize the rest of the paper as follows. Section 2 discusses the Hypotheses and Literature Review. Section 3 explains the methodological considerations and data sources. Section 4 presents the results. It includes the unit root tests, ARDL bound test outcomes, and causality tests. Section 5 concludes the results, research limitations, and future research.

2. Hypothesis and Literature Review

The literature explores key theories and hypotheses essential to understanding the interactions between FDI, economic growth, and environmental impacts. This review delves into three primary concepts: the Environmental Kuznets Curve (EKC), the Pollution Haven Hypothesis (PHH), and the Pollution Halo Hypothesis (PH).

2.1. Environmental Kuznets Curve (EKC)

The Environmental Kuznets Curve, named after economist Simon Kuznets, initially described the relationship between income inequality and economic growth. In environmental economics, this curve now refers to the relationship between economic growth and environmental quality.

The EKC hypothesis suggests that as economies expand, environmental degradation initially increases but eventually decreases, forming an inverted U-shaped relationship. This theory proposes that:

1. In early stages of industrialization, pollution levels and resource depletion tend to increase.
2. With higher income per capita, there is more investment in cleaner technology and stricter environmental regulations.
3. As societies become wealthier, they begin to prioritize environmental quality, leading to a reduction in environmental degradation.

Grossman and Krueger [6] were instrumental in popularizing the EKC concept, estimating that environmental quality indicators improve past a certain income threshold, which implies that growth can enhance the environment. Similarly, Shafik and Bandyopadhyay [7] found mixed evidence, suggesting that while some pollutants fit the EKC model, others do not, indicating a complex relationship.

Panayotou [8] provided stronger evidence, showing that effective policies and robust institutions facilitate the downward slope of the EKC. Later, Cole, et al. [9] found that international trade and technology transfers helped reduce sulfur dioxide emissions in developed nations, supporting the EKC hypothesis.

Critics like Stern [10] argue that the EKC is not universally applicable, as technological advancements, economic shifts, and trade patterns may influence its validity. Dinda [11] further highlighted the importance of country-specific factors, such as environmental regulations and cultural values, in determining whether the EKC holds.

Recent studies also debate the EKC concerning climate change and CO2 emissions. For example, Apergis and Ozturk [12] found EKC support for CO2 emissions in developing nations, suggesting that economic growth can reduce emissions when accompanied by renewable energy and efficiency policies. Nazar and Ahmad [13] reported mixed results for BRICS countries, noting that renewable energy and trade influence the growth-environment relationship.

The discussion extends to two additional theories: the Pollution Haven Hypothesis (PHH) and the Pollution Halo Hypothesis (PH). The PHH suggests that FDI inflows to countries with lenient environmental laws lead to higher pollution levels, as firms relocate to avoid stricter regulations at home [2]. On the other hand, the PH proposes that FDI can improve environmental conditions by introducing cleaner technologies and higher standards [3].

Empirical findings vary. Gunarto [14] observed no significant link between FDI and CO2 emissions in Asia, challenging the notion that FDI increases long-term emissions. Conversely, Minh, et al. [15] reported that FDI and renewable energy use had significant impacts on Vietnam’s CO2 emissions, lending support to the PH.

2.2. Mixed Evidence from Empirical Studies

Differences in methodologies, data sources, and variables contribute to varying conclusions in FDI-CO2 studies. For instance, Balli, et al. [16] reported that increased FDI worsened air quality, supporting the PHH for APEC countries, while the GDP-CO2 relationship varied by nation, suggesting a complex dynamic.

In a detailed study, Huang, et al. [17] used a Generalized Least Squares method to analyze G20 countries. They found that FDI inflows contribute to CO2 emissions, moderated by income levels and regulatory quality. Wang, et al. [18] similarly noted that while FDI increases emissions at lower income levels, this effect diminishes as economies grow, implying that FDI only reduces emissions at advanced stages of development.

2.3. Additional Relevant Hypotheses

The FDI-CO2 relationship is also examined through the feedback, unidirectional, and neutrality hypotheses. The feedback hypothesis posits that CO2 emissions and economic growth influence each other, as do economic growth and FDI. In contrast, the unidirectional hypothesis suggests one-way causality from economic development to CO2 emissions, or from FDI to economic growth. Studies by Lee [19] and Zhang [20] support this view. Menegaki [21] found no link between renewable energy use and economic growth in Europe, aligning with the neutrality hypothesis.

Research has shown varied causality. Halicioglu [22] found bidirectional causality between energy consumption, income, and CO2 emissions in Turkey. Pao and Tsai [23] demonstrated similar findings for BRIC countries from 1992 to 2007, suggesting that FDI and CO2 emissions are interdependent. Other studies, such as Soytas and Sari [24] for Turkey and Jaunky [25] for high-income nations, generally support the unidirectional hypothesis, indicating that GDP affects CO2 emissions both in the short and long term.

2.4. Methodological Considerations and Data Sources

Inconsistencies in empirical findings may stem from differences in data sources, methodologies, and country-specific attributes. For example, panel data methods like FGLS and GMM may yield results that differ from time-series techniques such as ARDL and VECM. Additionally, the selection of control variables-such as energy consumption, trade openness, and regulatory quality-can significantly influence estimated relationships.

Al-Nimer, et al. [26] reviewed FDI-environment research over several periods, highlighting shifts in focus between 2000 and 2021. Their study underscores the need for further research, particularly in emerging economies, to deepen understanding of the FDI-environment nexus.

Few studies have looked at the link between economic growth, FDI, and CO2 in Jordan. Khudari, et al. [27] studied growth, its causes, and the environment using ARDL for 1990-2022. They found that CO2 positively affects economic growth. Abdouli and Hammami [28] studied the link among environmental quality, FDI, and growth in MENA. Panel VAR model used for 1990–2012. The results show a two-way link between CO2 and FDI. They also show a negative link between CO2 and GDP. This supports PHLH. Aldegheishem [29] studied the links among urbanization, energy use, economic growth, and CO2 emissions in Saudi Arabia, Egypt, and Jordan. It uses an ARDL model for the period 1990–2023 and finds a positive effect of GDP on CO2. Ansari, et al. [30] examined the pollution haven hypothesis for 29 Asian countries. It found a positive but insignificant link between FDI and CO2. It found a negative link with per capita GDP for a subgroup of South Asian countries, including Jordan.

This study uses the ARDL bounds testing approach. It examines the links among FDI, economic growth, and CO2 emissions in Jordan from 1990 to 2022. It looks at both the short and long run. A key reason for choosing this method is that it allows variables with different orders of integration, I(0) or I(1). CO2 and real GDP data came from World Development Indicators. FDI data came from the UNCTAD database.

These hypotheses provide a nuanced view of the complex links among FDI, economic growth, and environmental quality. The mixed results highlight one thing: we should recheck the FDI-CO_2 emissions link. We should consider country-specific factors, like regulatory quality, income, and tech levels.

3. Methodological Considerations and Data Sources

We used time-series data to study the effect of foreign direct investment on CO2 emissions from 1990 to 2022. FDI, GDP, and CO2 are the variables covered in this study.

The Model used to study the impact of FDI on CO2 emissions is based on: Bölük and Mert [31]; Mugableh [32] and Phuong [33]. The linear formulation of CO2 is as follows:.

$$CO2_t = \beta_{01} + \beta_{11}FDI_t + \beta_{21}GDP_t + \beta_{31}GDP_t^2 + u_t \quad (1)$$

$$FDI_t = \beta_{02} + \beta_{12}CO2_t + \beta_{22}GDP_t + u_t \quad (2)$$

Where ut is the disturbance term. The endogenous variables, CO2 and FDI, are as follows. CO2 is carbon dioxide emissions in metric tons. FDI is foreign direct investment in US dollars. The exogenous variables GDP and GDP2 are the Gross Domestic Product. They are in level and square terms (in Billion US $).

HypothesesDefinition:

H_1: FDI inflows are positively associated with CO2 emissions in Jordan, thus supporting PHAH.

H_2: FDI inflow is negatively associated with CO2 emissions in Jordan, thus supporting the PHLH.

The Environmental Kuznets Curve (EKC) posits that environmental degradation rises as the economy increases up to a turning point, after which it begins to decrease with continued growth in the economy.

H_3: There is a humped relationship between GDP and CO2 emissions in Jordan, supporting the Environmental Kuznets hypothesis.

Formal Representation:

- H_1: $\beta_{11} > 0$
- H_2: $\beta_{11} < 0$
- H3: $\beta_{21} > 0$ and $\beta_{31} < 0$

This study used time series data for Jordan covering 1990-2022. The data for CO2 emissions and GDP are the World Development Indicators. The United Nations Conference on Trade and Development (UNCTAD) provided the FDI data.

The EKC hypothesis says a degree 2 binomial function can link economic growth and CO2 emissions. CO2 emissions rise with GDP, but only to a point. The relationship changed; CO2 emissions decreased while GDP increased. B12 must be positive, and B13 must be negative for this to occur.

In 1973, the Jordanian government needed to amend laws and policies to attract FDI. Foreign direct investment hit record levels at the start of the 21st century. Investors valued the net of investments at about 647.5 million JD. This means it doubled in 26 years to over 76 times. Environmental pollution is reaching a critical level worldwide. The pollution level is lower than the world average. But we cannot deny that pollution is harming Jordan. Table 1 shows the descriptive statistics of the variables.

Table 1.
Descriptive statistics of the variables of the paper.

Variables	Mean	Maximum	Minimum	SD	Observation
CO2 (KT)	18916.1060	26021.8000	9781.2000	4972.5365	33
FDI (B$)	19.4517	35.1145	3.2744	13.0019	33
GDP (B$)	28.1067	44.1019	12.3987	10.6451	33

Figure 3 shows no apparent inverted U-shaped effect in Jordan. This contradicts the Kuznets hypothesis on pollution and economic growth.

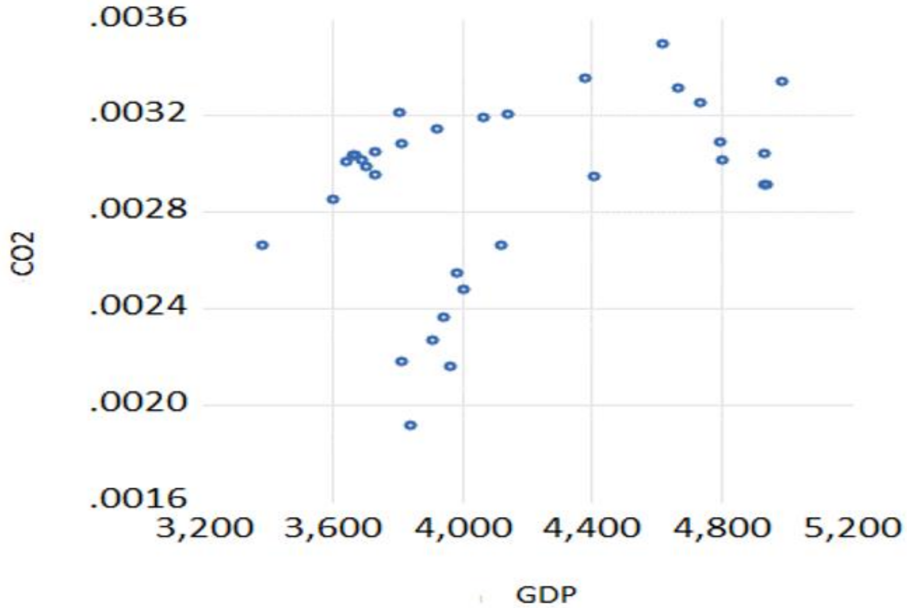

Figure 3.
Scatter graph of CO2 (in metric tons) and GDP (in Billions of constant 2010 US Dollar).

4. Results and Discussion

4.1. Unit Root Test for

The first step is to test for stationarity. We use standard tests, like the augmented Dickey-Fuller and Phillips-Perron tests, to check if CO2, FDI, GDP, and GDP squared are stationary. In addition, we test for stationarity in the presence of structural breaks because structural breaks and unit roots are related. So, we perform the Augmented Dickey-Fuller and Zivot-Andrews tests. The results of all unit root tests on Jordanian variables are presented in Table 3. The results show that the CO2, FDI, GDP, and GDP square variables are I(1) or I(0). Therefore, applying the (ARDL), Autoregressive distributed lags method in Equations 1 and Equation 2 is applicable.

Table 2.
Standard unit root test.

Test Statistic /Assumption	Level		First Difference		Conclusion
	Augmented Dickey and Fuller	Phillips and Perron	Augmented Dickey and Fuller	Phillips and Perron	
CO2	-2.4261	-2.4492	-6.0424***	-7.1947***	I(1)
	(0.3601)	(0.3492)	(0.0001)	(0.0000)	
FDI	-1.8960	-2.0972	-6.5959***	-6.4922***	I(1)
	(0.6332)	(0.5278)	(0.0000)	(0.0000)	
GDP	-1.2945	-1.8011	-4.4760***	-4.6838***	I(1)
	(0.8706)	(0.6806)	(0.0063)	(0.0038)	
GDP^2	-1.8806	-2.1626	-3.7996***	-3.9105***	I(1)
	(0.6403)	(0.4932)	(0.03016)	(0.02361)	
Unit root test with break point					
Test Statistic /Assumption	Level		First Difference		Conclusion
	Augmented Dickey and Fuller	Break date	Augmented Dickey and Fuller	Break date	
CO2	-2.0834	2003	-7.7964***	2020	I(1)
	(0.9761)		(0.0100)		
FDI	-5.0006***	2003	-	-	I(0)
	(0.0100)				

Test Statistic /Assumption	**Level**		**First Difference**		**Conclusion**
	Augmented Dickey and Fuller	**Phillips and Perron**	**Augmented Dickey and Fuller**	**Phillips and Perron**	
GDP	-3.6918	2003	-5.0274***	2007	I(1)
	(0.2867)		(0.0100)		
GDP^2	-2.2137	2003	-4.7847**	2003	I(1)
	(0.9611)		(0.0186)		
Test Statistic /Assumption	Level		First Difference		Conclusion
	Zivot & Andrews	Break date	Zivot & Andrews	Break date	
CO2	-3.4843**	2017	-	-	I(0)
	(0.0409)				
FDI	-6.9283***	2004	-	-	I(0)
	(0.0001)				
GDP	-4.4388**	2005	-	-	I(0)
	(0.0455)				
GDP^2	-3.6418**	2006	-	-	I(0)
	(0.0334)				

4.2. Optimal Lag Length Selection Results

We use the optimal lag length criteria for the ADF unit root test. This defines an autoregressive time series and a residual. The results of the optimal lag-length criteria are listed in Table 3.

Table 3.
The Optimal Lag Length test.

Optimal Lag length			
	0	**1**	**2**
AIC	30.0101	23.1131	22.9128*
SC	30.1489	23.6681*	23.8843
HQ	30.0553	23.2940	23.2295*

Note: * Indicates lag order selected by the criterion AIC: Akaike information criterion; SC: Schwarz information criterion; HQ: Hannan-Quinn information criterion.

Table 3 shows that both AIC and HQ, with the lowest value for the two lags selected for further processing, are 22.9128 and 23.2295, respectively.

4.3. Cointegration Test and Research Method

A joint integration test is vital for analyzing variable relationships. Many tests check for the common integration of variables. The integration test is the most appropriate [34, 35]. The two tests also focus on the study's time series. It must be static on the first difference for accurate results [36]. The ARDL self-test method also solves the problem of static time series after differencing. The static time series can be analyzed on the first difference I(1) and the static on the level I(0), or any mix of them. Researchers can also apply it in cases where the sample size is small, unlike most traditional standard tests that require a large sample size to estimate the results and be more efficient. Using ARDL, we define Equations 1 and Equation 2 as follows:

$$\Delta CO2_t = \beta_0 + \beta_1 CO2_{t-1} + \beta_2 FDI_{t-1} + \beta_3 GDP_{t-1} + \beta_4 GDP^2_{t-1} + \sum_{i=0}^{m} \beta_{5i}\,\Delta CO2_{t-i} + \sum_{i=0}^{m} \beta_{6i}\,\Delta FDI_{t-i} + \sum_{i=0}^{m} \beta_{7i}\,\Delta GDP_{t-i} + \sum_{i=0}^{m} \beta_{8i}\,\Delta GDP^2_{t-i} + \mu_t \qquad (3)$$

$$\Delta FDI_t = \delta_0 + \delta_1 FDI_{t-1} + \delta_2 CO2_{t-1} + \delta_3 GDP_{t-1} + \sum_{j=0}^{n} \delta_{4j}\,\Delta FDI_{t-j} + \sum_{j=0}^{n} \delta_{5j}\,\Delta CO2_{t-j} + \sum_{j=0}^{n} \delta_{6j}\,\Delta GDP_{t-j} + \vartheta_t \qquad (4)$$

where β1 to β4 are estimators for the long-run impacts of Equation 1 and δ1 and δ3 are estimators for the long-run impacts of Equation 2, m, n are optimal lag lengths of the models, and error terms are denoted by μt and.

4.4. ARDL Bound Test

This study performs the analyses of ARDL Bounds testing, as suggested by Pesaran, et al. [36]. The ARDL model is mainly used. It is an advanced econometric technique for time-series data. This model is appropriate for small samples [36]. such as a sample of only 33 observations, where the null hypothesis is no cointegration Equation 3 H0: β1 = β2 = β3

= β4 = 0, and alternative hypothesis H1: β1 ≠ β2 ≠ β3 ≠ β4 ≠ 0. The same theory is used in Equation 4. If the F-statistic is larger than the critical I(1) value, it rejects H0. It shows there are long-term common relationships among the model variables. The test results bound to reward three and Equation 4 are listed in Table 5.

Table 4.
ARDL bounds test results.

F-Bounds Test for Equation 3		**Null Hypothesis: No levels of relationship**			
Test Statistic		**Value**	**Signif.**	**I(0)**	**I(1)**
F-statistic	6.1009	10%		2.72	3.77
K	3	5%		3.23	4.35
		1%		4.29	5.61
F-Bounds Test for Equation 4			**Signif.**	**I(0)**	**I(1)**
F-statistic	2.9205	10%		3.17	4.14
K	2	5%		3.79	4.85
		1%		5.15	6.36

From the bound test results, the F-statistic of Eq. Three equals 6.1009, while the I (1) critical value is 5.61. Thus, H0 is rejected. This indicates long-run cointegration among the variables in Equation 3. However, the F-statistic of Equation 4 equals 2.9205, which is smaller than I(1)= 3.17 at a significance level of 10%. Thus, H0 cannot be rejected. So, no long-run cointegrated relationships exist between the variables in Equation 4.

4.5. Results of Estimation with the ECM

Using the AIC standard and sample data, researchers found Model 3. It had an optimal delay length of ARDL (1,1,0,1). However, the constancy of the variables is only at the first level, with common relationships between the model variables. This study uses the ECM to examine links among growth, pollution, and foreign investment in Jordan. The findings of monitoring through ECM are presented in Table 6.

Table 5.
Results of ECM for CO2 ARDL (1,1,0,1).

Variable	**Coefficient**	**Std. Error**	**t-Statistic**	**Prob.**
		Equation 3		
Long Run Estimates				
C	-1736.0856	2457.4854	-0.7064	0.4864
CO2 (-1)	-0.6251***	0.1438	-4.3471	0.0002
FDI (-1)	-163.9701**	68.0210	-2.4106	0.0236
GDP	731.7761***	256.8816	2.8487	0.0087
GDP^2	-5.1418	3.0572	-1.6818	0.1051
R^2= 0.5417	Adjusted R^2= 0.4317	F-statistic= 4.9242	P(F-statistic)= 0.0019	D-W= 1.9146
Short Run Estimates				
D(FDI)	-17.9574	73.4687	-0.2444	0.8089
D(GDP^2)	10.4132	6.7864	1.5344	0.1375
Coefficient of ECM (-1)	-0.6251***	0.1196	-5.2280	0.0000
R^2= 0.5417	Adjusted R^2= 0.4926	F-statistic= 11.0302***	P(F-statistic)= 0.0001	D-W= 1.9146
		Equation 4		
Short Run Estimates				
C	-1.4385	1.1031	-1.3041	0.2036
D(FDI (-1))	-0.3543*	0.1832	-1.9341	0.0641
D(GDP)	1.4114	0.8798	1.6041	0.1208
D(GDP (-1))	1.2045	0.8783	1.3713	0.1820
D (CO2)	0.0004	0.0005	0.8082	0.4263
R2= 0.2663	Adjusted R2= 0.1534	F-statistic= 2.3593*	P(F-statistic)= 0.0797	D-W= 1.7538

Note: *, ** and *** indicate the rejection of the null hypothesis at 10%, 5% and 1% level of significance, respectively.

Table 5 lists the results of the ARDL Bound testing method for Equations 3 and 4. The results suggest that CO2 is cointegrated with other variables. But, FDI is not cointegrated with its variables. The lag order for Equation 3 is (1,1,0,1), based on the Schwarz information criterion. The ARDL long-run coefficients show a significant, adverse effect of lag CO2 on current CO2 emissions. All else being equal, a one kiloton increase in lag CO2 will reduce current emissions by 0.14 kiloton. This suggests that the Jordanian government may know of the harm from rising CO2 emissions and is trying to fix it. A one billion dollar increase in lag foreign direct investment will, in the long run, decrease CO2 emissions by 68 kilotons. This may support the earlier finding. Some rules aim to prevent the effects of CO2 emissions from foreign direct investment. They are effective. The results show that FDI has no effect on CO2 emissions in the short term. The effect of real GDP on CO2 emissions is positive and highly significant in the long run, but not in the short run. The results show that, all else being equal, a billion-dollar increase in real GDP will raise CO2 emissions by 257 kilotons in the long run. Also, researchers tested the inverted Kuznet curve hypothesis. They found it insignificant during the study period.

The ECM coefficient (-1) shows the speed of change from the short to the long run. It is negative and highly significant, with a value of 0.625. This means that the economy corrects short-run shocks by 63% each year.

The result for Equation 4 shows only short-run results. The ARDL bounds test fails to reject H0. So, there are no long-term relationships between FDI and its explanatory variables. The results state that lagged real FDI significantly affects real FDI. If other things stay the same, a $1 billion rise in lagged real FDI will cut real FDI by $0.35 billion this year.

4.6. Diagonostic Tests

We performed sufficiency and robustness tests. The results are in Table 6 for Equations 3 and 4. The Lagrange Multiplier test checks for serial correlation. The results do not reject the null hypothesis of no autocorrelation. The results do not reject the null hypothesis of the Ramsey RESET test. It checks for model misspecifications. The test of normality of residuals does not reject the null hypothesis of normally distributed residuals, except for Equation 4. The Durbin-Watson (D-W) value of 1.92 for model 3 and 1.72 for model 4 confirms no autocorrelation problem. Besides, we provide robustness checks for model three in the Appendix A.

Table 6.
Diagnostic Tests.

Test Name	Test- Statistics	Prob.
Equation 3		
Serial Correlation LM Measures	F -statistics = 0.5929	Prob. F(2,23) = 0.5609
Ramsey Model Specification Test	F -statistics = 0.4181	Prob= 0.6632
Residual Normality Test	Jarque Pera test= 1.3273	Prob= 0.5180
Equation 4		
Serial Correlation LM Measures	F -statistics = 0.7458	Prob. F(2,23) = 0.4850
Ramsey Model Specification Test	F -statistics = 1.6953	Prob= 0.2048
Residual Normality Test	Jarque Pera test= 7.9762	Prob= 0.0185

4.7. The Wald Test

The Wald test was used to determine the causal relationship and its direction between FDI, CO2, and other variables. The results of this test establish the directions of the causal relationships between variables in the model and are provided in Table 7.

Table 7.
The Wald Causality test.

Equation 3			
Dependent variable	**Wald F-test**	**P-value**	**Conclusions (at 5% significance level)**
FDI	3.6459	0.0408	FDI cause CO2 in the short run
GDP	8.1150	0.0087	GDP cause CO2 in the short run
GDP^2	6.7234	0.0046	GDP^2 cause CO2 in the short run
Equation 3			
GDP	3.1998	0.0572	GDP does not cause FDI in the short run
CO2	0.6532	0.4263	CO2 does not cause FDI in the short run
Authers calculation			

The results of the Wald test in Table 7 show a unidirectional relationship between FDI, GDP, and GDP square to CO2.

4.8. CUSUM Test

When estimating standard models, we must check for a change in their behavior over time. CUSUM is one of the most commonly used tests in this field. The null hypothesis of the test assumes consistent coefficients and values for the series, beyond the expected limit. This implies that there was no structural change in the model over time. So, we tested the assumption that the parameters were stable throughout the study. So, we estimated the model's constant parameters for the study period [37]. The results of the CUSUM test for Equation 3 are shown in Figure 4.

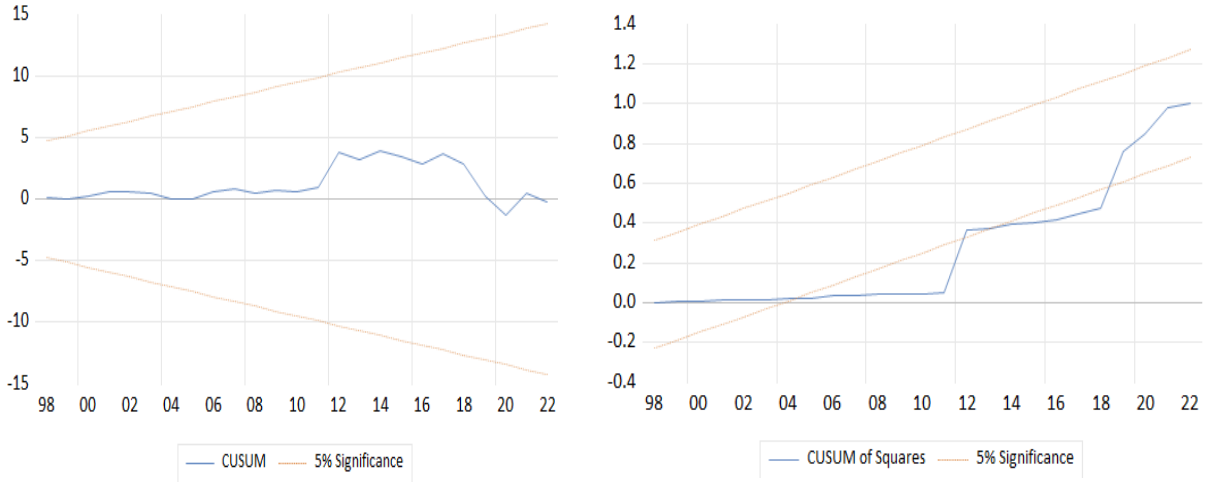

Figure 4.
Graph (a) of CUSUM Equation 3 and Graph (b) of CUSUM Equation 4.

5. Conclusions and Future Works

This study uses the ARDL bounds test. It uses data from 1990 to 2022 to study the link between FDI, economic growth, and CO2 emissions in Jordan. Diagnostic tests showed that the variables were I(1) and I(0). It also tests the EKC, Pollution Haven Hypothesis, and Pollution Halo Hypothesis.

The results confirm a cointegration between CO2 emissions and FDI, GDP, and GDP^2. Researchers found no cointegration for FDI as the dependent variable. In the long run, FDI significantly increases CO2 emissions. This supports the Pollution Halo Hypothesis (H2) and rejects H1. Abdouli and Hammami [28] found this. This finding suggests that FDI transfers clean tech to the host country [3].

Also, higher historical FDI levels harm CO2 emissions. They link to lower current carbon emissions.

This may suggest that policymakers could design policies to:

1. Support foreign direct investment in green industries.
2. Facilitate the advancement of eco-friendly technologies.
3. Set environmental standards for industries receiving foreign investment.

GDP raises CO2 emissions. But, Ansari, et al. [30] found no support for the EKC hypothesis. (2019) and Aldegheishem [29]. The effect of GDP^2 was insignificant at the 10% level. The ARDL bound test found no evidence of the EKC hypothesis for Jordan. Policymakers should invest in green tech. They should also incentivize emission reductions and support FDI in green industries.

A higher GDP means higher CO2 emissions, and more output causes more carbon emissions. Policymakers should balance growth with sustainability. They must advocate for green practices, set energy standards, and speed up the shift to renewables, like solar and wind.

The lag of CO2 on CO2 suggests an improving environment. Policymakers should invest in green tech. They should boost incentives to cut emissions. Also, they must raise public awareness of the impact of past emissions on current carbon levels.

This study examines the link between environmental quality, FDI, and economic growth in Jordan. It has many limitations, including a short data span, an estimation method, and the lack of country-specific variables. The use of other variables also reflects changes in environmental and regulatory regimes.

Future research may include:

- Longitudinal studies.
- Sector-specific econometric methods.
- Panel studies with similar countries for comparison.
- FDI regulation affects different environmental measures.

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Appendix A

Table 8.
Results of Fully modified method.

Variable	Coefficient	Std. Error	t-Statistic	Prob.
		Equation 3		
Long Run Estimates				
C	-3787.911	3735.2620	-1.0141	0.3195
FDI (-1)	-179.3424**	86.7327	-2.0678	0.0484
GDP	1280.6600***	285.7367	4.48200	0.0001
GDP^2	-11.0927***	3.8454	-2.8847	0.0076
R^2= 0.9431			Adjusted R^2= 0.9367	

Notes: *, **, and *** indicate the rejection of the null hypothesis at the 10%, 5%, and 1% levels of significance, respectively.
In this section, we provide robustness checks for the results obtained from equation three. The results of the fully modified method yielded similar results with the same signs. This proves that the results are consistent.