“Trade-environment nexus under export-oriented and import-driven regimes: Markov regime-switching regression evidence from Uzbekistan”

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ARTICLE INFO	Akhmadbek Yusupov, Ubaydullo Gafurov, Fozil Xolmurotov, Ergash Ibadullaev, Bakhriddin Berdiyarov, Alimnazar Islamkulov and Xolilla Xolmuratov (2026). Trade-environment nexus under export-oriented and import-driven regimes: Markov regime-switching regression evidence from Uzbekistan. *Environmental Economics*, *17*(2), 41-51. doi:10.21511/ee.17(2).2026.04
DOI	http://dx.doi.org/10.21511/ee.17(2).2026.04
RELEASED ON	Monday, 20 April 2026
RECEIVED ON	Saturday, 06 December 2025
ACCEPTED ON	Tuesday, 17 March 2026
LICENSE	This work is licensed under a Creative Commons Attribution 4.0 International License
JOURNAL	"Environmental Economics"
ISSN PRINT	1998-6041
ISSN ONLINE	1998-605X
PUBLISHER	LLC “Consulting Publishing Company “Business Perspectives”
FOUNDER	LLC “Consulting Publishing Company “Business Perspectives”

NUMBER OF REFERENCES	NUMBER OF FIGURES	NUMBER OF TABLES
32	**1**	**4**

BUSINESS PERSPECTIVES

LLC "CPC "Business Perspectives"
Hryhorii Skovoroda lane, 10,
Sumy, 40022, Ukraine
www.businessperspectives.org

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TRADE-ENVIRONMENT NEXUS UNDER EXPORT-ORIENTED AND IMPORT-DRIVEN REGIMES: MARKOV REGIME-SWITCHING REGRESSION EVIDENCE FROM UZBEKISTAN

Type of the article: Research Article

Received on: 6th of December, 2025
Accepted on: 17th of March, 2026
Published on: 20th of April, 2026

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Conflict of interest statement:
Author(s) reported no conflict of interest

Abstract

This study investigates the nonlinear dynamics of the relationship between foreign trade and carbon dioxide (CO_2) emissions in Uzbekistan over the period 1997–2024. The analysis employs annual time-series data from the World Bank's World Development Indicators (WDI) database, including three key variables: CO_2 emissions per capita (tonnes), exports of goods and services (current USD), and imports of goods and services (current USD). Using the Markov switching regression (MSR) model, the study identifies two distinct economic states: an export-oriented regime (Regime 1) characterized by high industrial production and export activity, and an import-driven regime (Regime 2) characterized by domestic consumption patterns and elevated import flows.

The empirical results demonstrate that the export–emissions relationship is regime-dependent: exports have a statistically significant positive effect on CO_2 emissions only during export-oriented periods ($\beta = 1.54 \times 10^{-10}$, $p < 0.01$), while this relationship becomes insignificant during import-driven periods ($\beta = 5.20 \times 10^{-11}$, $p = 0.378$). In contrast, imports consistently reduce CO_2 emissions across both regimes (Regime 1: $\beta = -1.05 \times 10^{-10}$; Regime 2: $\beta = -1.07 \times 10^{-10}$, both $p < 0.01$), indicating a stable import-substitution effect that displaces domestic production-related emissions. The transition probability analysis reveals high persistence in both regimes ($P_{11} = 79.69\%$, $P_{22} = 81.22\%$), with structural shifts occurring approximately every five years (expected durations: 4.92 years for Regime 1 and 5.32 years for Regime 2). These findings confirm that the trade–emissions relationship in Uzbekistan is nonlinear and regime-dependent, necessitating the development of regime-sensitive environmental and trade policies.

Keywords trade, environment, exports, imports, carbon emissions, Uzbekistan, regime switching, Markov model

JEL Classification Q56, F18, C24, Q54

INTRODUCTION

Climate change has emerged as one of the most pressing global challenges of the 21st century, with carbon dioxide emissions being the primary driver of global warming. The Paris Agreement, adopted in 2015, set ambitious targets for reducing greenhouse gas emissions, yet achieving these goals while maintaining economic growth remains a fundamental challenge for the global community. This challenge is particularly acute for developing and transition economies, which must reconcile the competing demands of economic development and environmental sustainability. International trade plays a pivotal role in shaping environmental outcomes. As economies become increasingly integrated into global markets, the flow of goods and services across borders directly influences domestic production patterns, energy consumption, and consequently, carbon emissions.

The relationship between trade and environmental quality is not straightforward. Trade liberalization can simultaneously stimulate economic growth that increases emissions through scale effects, alter the sectoral composition of economies, and facilitate the transfer of cleaner technologies. The net environmental impact depends on which of these effects predominates, and this balance may shift over time as economic conditions evolve. Uzbekistan presents a compelling case for examining the trade-environment nexus. As the most populous country in Central Asia with abundant energy resources, the country has undergone profound structural transformations since independence, transitioning from a centrally planned system to a market-oriented economy. The liberalization of foreign trade, particularly accelerated since 2017, has fundamentally reshaped the country's economic landscape. Simultaneously, Uzbekistan's carbon emissions remain significant, driven by its energy-intensive industrial base and reliance on fossil fuels.

The scientific problem underlying this research concerns the inadequacy of conventional approaches to modeling the trade–emissions relationship. Traditional econometric methods assume that the relationship between trade variables and carbon emissions remains constant over time. However, economic systems are inherently dynamic, characterized by structural shifts, policy regime changes, and evolving patterns of specialization. These nonlinearities and regime-dependent dynamics cannot be captured by linear models, potentially leading to misleading conclusions and ineffective policy recommendations.

1. LITERATURE REVIEW AND HYPOTHESES

The relationship between international trade and environmental quality has been extensively examined in the economic literature, with theoretical and empirical studies offering diverse perspectives on how trade activities influence carbon emissions. One of the fundamental theoretical frameworks explaining this relationship is based on the decomposition of trade effects into scale, composition, and technique components (Antweiler et al., 2001; Copeland & Taylor, 2004). The scale effect suggests that trade expansion increases economic activity and energy consumption, thereby raising emissions. The composition effect reflects structural changes in production patterns, where countries specializing in carbon-intensive sectors may experience higher environmental degradation. The technique effect, in contrast, emphasizes technological improvements and cleaner production methods that can reduce emissions as trade promotes innovation and technology transfer. The overall environmental impact of trade depends on the relative dominance of these effects, which may vary across countries and development stages.

Another important theoretical perspective is the Environmental Kuznets Curve (EKC) hypothesis, which proposes a nonlinear relationship between economic development and environmental degradation (Grossman & Krueger, 1991). According to this framework, environmental pressure initially increases during early development stages but declines after reaching a certain income level due to structural transformation and technological progress. While some empirical studies support the EKC hypothesis (Stern, 2004), others highlight its context-specific nature and limited generalizability across pollutants and countries (Dinda, 2004; Sarkodie & Strezov, 2019). These findings indicate that the trade–environment relationship is complex and may vary depending on institutional and structural conditions.

Empirical evidence on the export–emissions relationship has produced mixed results. Several studies report a positive association between exports and carbon emissions, particularly in developing economies with energy-intensive industrial structures (Halicioglu, 2009; Shahbaz et al., 2013; Hossain, 2011). In contrast, export diversification and technological upgrading may mitigate environmental impacts, allowing countries to decouple trade growth from emissions (Gözgör & Can, 2016; Apergis et al., 2018; Wang et al., 2020; Ang & Bekaert, 2002). These contrasting findings imply that the environmental consequences of exports depend on the structure and quality of exported goods.

The relationship between imports and emissions has also received considerable attention. Imports may reduce domestic emissions by substituting

http://dx.doi.org/10.21511/ee.17(2).2026.04

locally produced goods with foreign products, a mechanism often associated with carbon leakage effects (Jayanthakumaran et al., 2012; Aichele & Felbermayr, 2015; Halmuratov et al., 2025). However, some studies indicate that increased imports can stimulate consumption and indirectly raise emissions, particularly in lower-income economies (Salman et al., 2019). Thus, the import–emissions nexus remains empirically ambiguous and may depend on country-specific economic conditions.

Recent literature has increasingly emphasized the importance of nonlinear modeling approaches in analyzing environmental relationships. Conventional econometric models such as ARDL, VECM, and panel cointegration typically assume parameter stability over time, which may lead to biased conclusions in economies undergoing structural transformation. Markov regime-switching models provide an alternative framework by allowing parameters to change across unobserved states and capturing structural breaks endogenously (Hamilton, 1989; Krolzig, 1997; Guidolin, 2011; Xolmurotov & Xolmuratov, 2025). Applications of regime-switching models in environmental economics remain relatively limited but demonstrate their usefulness in capturing regime-dependent dynamics in energy consumption, emissions, and sustainability indicators (Charfeddine, 2017; Konstantakis et al., 2025).

Despite growing research in this area, empirical evidence for Central Asia and Uzbekistan remains scarce. Existing studies primarily rely on linear econometric approaches and focus on the relationships between energy consumption, economic growth, and emissions (Zhang, 2019; Nguyen, 2019; Qodirov et al., 2024; Nurjanov et al., 2025). Research specifically examining the trade–environment nexus in Uzbekistan is limited, and no prior study has investigated whether this relationship varies across different economic regimes. Given the country's structural economic changes and evolving trade patterns, ignoring potential nonlinearities may lead to incomplete conclusions.

Overall, previous literature suggests that the relationship between trade and carbon emissions is complex, context-dependent, and potentially nonlinear. However, regime-dependent dynamics remain insufficiently explored, particularly in transition economies such as Uzbekistan.

Therefore, this study aims to investigate the relationship between foreign trade (exports and imports) and carbon dioxide emissions in Uzbekistan over the period 1997–2024 using a Markov regime-switching regression framework. The analysis evaluates whether the effects of trade variables on emissions differ across economic regimes and identifies structural shifts in the trade–environment nexus.

The following hypotheses are proposed:

H_1: *Exports are positively associated with CO_2 emissions in Uzbekistan, reflecting the energy-intensive nature of the country's export structure.*

H_2: *Imports are negatively associated with CO_2 emissions, indicating an import-substitution effect that reduces domestic production-related emissions.*

H_3: *The relationship between trade and emissions is regime-dependent, with export and import effects varying across economic regimes.*

H_4: *The Uzbek economy experiences periodic structural shifts between export-oriented and import-driven regimes over time.*

2. METHODOLOGY

This study employs a Markov regime-switching regression model to examine the relationship between foreign trade and carbon dioxide (CO_2) emissions in Uzbekistan under potential structural changes. The Markov switching framework, originally developed by Hamilton (1989), allows model parameters to vary across unobserved regimes and captures nonlinear dynamics that cannot be adequately represented using conventional linear econometric approaches. This methodology is particularly suitable for transition economies experiencing structural transformations, policy shifts, and changing trade patterns over time.

http://dx.doi.org/10.21511/ee.17(2).2026.04

Annual data covering the period 1997–2024 are used in the analysis. All variables are obtained from the World Bank's World Development Indicators (WDI) database. Carbon dioxide emissions per capita (metric tons per capita) are used as the dependent variable. The explanatory variables include exports of goods and services and imports of goods and services, both measured in current U.S. dollars. These indicators are widely employed in empirical studies on the trade–environment nexus and ensure comparability across time.

The empirical specification assumes that the dependent variable evolves according to different economic regimes governed by an unobserved state variable. The two-regime Markov switching regression model is specified as:

$$CO_{2,t} = \alpha_{s_t} + \beta_{1,s_t} EXPORT_t + \beta_{2,s_t} IMPORT_t + \varepsilon_t, \quad (1)$$

where $CO_{2,t}$ denotes carbon emissions per capita at time t, $EXPORT_t$ and $IMPORT_t$ represent exports and imports, respectively, and *sts_tst* is an unobserved regime indicator that takes values 1 or 2. The error term ε_t is assumed to be normally distributed with zero mean and regime-dependent variance. The coefficients α_{st}, $\beta_{1,st}$, and $\beta_{2,st}$ vary across regimes, allowing the impact of trade variables on emissions to differ depending on the prevailing economic state.

The regime transitions follow a first-order Markov process characterized by transition probabilities:

$$P_{ij} = P\left(s_t = j \middle| s_{t-1} = i\right), i, j \in \{1, 2\}, \quad (2)$$

which are summarized in a transition probability matrix. The expected duration of each regime is calculated as:

$$D_i = \frac{1}{1 - P_{ii}}, \quad (3)$$

where P_{ii} denotes the probability of remaining in regime i.

Prior to model estimation, the time-series properties of the variables are examined using the Augmented Dickey–Fuller unit root test to ensure that the statistical inference is not affected by spurious relationships. The results indicate that the variables exhibit non-stationary behavior in levels, which is typical for macroeconomic time-series data. The Markov switching framework remains appropriate in this context because regime shifts capture structural changes and allow parameter variation over time.

Model parameters are estimated using the maximum likelihood estimation procedure. The likelihood function is constructed as a mixture of regime-specific conditional densities weighted by their respective probabilities. Filtered probabilities are obtained using the Hamilton filter, providing real-time estimates of the probability that the economy is in a particular regime at each point in time. Smoothed probabilities are also computed to identify the most likely regime over the entire sample period.

In addition to coefficient estimation, the model produces transition probabilities and expected regime durations, enabling interpretation of the persistence and timing of structural shifts in the economy. Robust standard errors are used to address potential heteroskedasticity. This methodological framework allows assessment of whether the effects of exports and imports on carbon emissions differ across economic regimes and provides a more comprehensive understanding of the trade–environment relationship compared to conventional linear models.

3. RESULTS

The empirical analysis begins with examining the statistical properties of the variables to ensure the validity of the econometric estimation. Table 1 presents the descriptive statistics for carbon dioxide (CO_2) emissions per capita, exports, and imports over the period 1997–2024. The results indicate substantial variability across the sample period, reflecting structural changes in Uzbekistan's trade dynamics and economic development. CO_2 emissions display moderate dispersion, while exports and imports exhibit larger variability, consistent with significant fluctuations in foreign trade activity during the transition period.

http://dx.doi.org/10.21511/ee.17(2).2026.04

Table 1. Descriptive statistics of variables

Statistic	CO_2	EXPORT	IMPORT
Mean	4.499	1.08×10^{10}	1.44×10^{10}
Std. Dev.	0.590	7.12×10^{9}	1.26×10^{10}
Minimum	3.488	2.99×10^{9}	2.67×10^{9}
Maximum	5.359	2.62×10^{10}	4.36×10^{10}
Observations	28	28	28

Prior to model estimation, the stationarity properties of the time series are examined using the Augmented Dickey–Fuller (ADF) unit root test. The results, reported in Table 2, indicate that all variables are non-stationary in levels but become stationary after first differencing, suggesting integration of order one. These findings are consistent with typical macroeconomic time-series behavior and support the appropriateness of the Markov regime-switching framework for capturing structural dynamics in the data.

Table 2. Augmented Dickey–Fuller unit root test results

Variable	Level	p-value	First Difference	p-value
	t-statistics		t-statistics	
CO_2	–1.152	0.6797	–6.657***	0.0000
EXPORT	1.062	0.9960	–4.094***	0.0041
IMPORT	2.036	0.9998	–4.053***	0.0047

Note: Critical values: 1% = –3.700; 5% = –2.976; 10% = –2.627.

The main empirical results are presented in Table 3, which reports the parameter estimates of the two-regime Markov switching regression model. The estimation identifies two distinct economic regimes characterized by different relationships between trade variables and CO_2 emissions.

The results reveal that exports exert a statistically significant positive impact on CO_2 emissions during Regime 1, with a coefficient of 1.54×10^{-10} ($p < 0.01$), while the export coefficient becomes statistically insignificant in Regime 2 (5.20×10^{-11}, $p = 0.378$). This indicates that the environmental impact of exports is conditional on the prevailing economic state, suggesting that export expansion contributes to emissions primarily during periods characterized by higher industrial production intensity.

In contrast, imports demonstrate a consistent negative association with CO_2 emissions across both regimes. The estimated coefficients are -1.05×10^{-10} in Regime 1 and -1.07×10^{-10} in Regime 2, both statistically significant at the 1% level. The similarity of these coefficients across regimes suggests a stable import-substitution effect that reduces domestic production-related emissions regardless of the economic state.

The regime-specific intercepts also differ substantially, with Regime 2 exhibiting a higher baseline emission level compared to Regime 1. This finding suggests that factors other than trade, such as domestic energy efficiency or consumption-related energy demand, may contribute to emission dynamics during import-driven periods.

Model adequacy is evaluated using standard diagnostic statistics, including log-likelihood values

Table 3. Markov regime-switching regression results

Variable	Coefficient	Standard error	z-Statistics	p-value
Regime 1				
C (Constant)	4.3471	0.1025	42.393	0.0000***
EXPORT	1.54×10^{-10}	2.33×10^{-11}	6.593	0.0000***
IMPORT	-1.05×10^{-10}	1.23×10^{-11}	–8.543	0.0000***
Regime 2				
C (Constant)	5.3002	0.1593	33.275	0.0000***
EXPORT	5.20×10^{-11}	5.89×10^{-11}	0.882	0.3777
IMPORT	-1.07×10^{-10}	3.15×10^{-11}	–3.414	0.0006***
General parameters				
LOG(SIGMA)	–1.8005	0.2033	–8.855	0.0000***
Transition matrix				
P11-C	1.3669	0.8048	1.699	0.0894*
P21-C	–1.4644	0.8102	–1.807	0.0707*

Note: *** p < 0.01; * p < 0.10.

and information criteria. The relatively high likelihood values and reasonable information criteria confirm the suitability of the Markov switching specification for the analyzed data.

Table 4 presents the estimated transition probabilities between regimes. The results indicate a high probability of remaining within the same regime, with persistence probabilities of 79.69% for Regime 1 and 81.22% for Regime 2, suggesting moderate stability of economic states over time. These probabilities confirm the presence of persistent economic regimes in Uzbekistan.

Table 4. Transition probability matrix

Variable	To Regime 1	To Regime 2
From Regime 1	0.7969	0.2031
From Regime 2	0.1878	0.8122

The expected duration of each regime is calculated based on the transition probabilities. Regime 1 persists for approximately 4.92 years, while Regime 2 lasts about 5.32 years on average, indicating periodic structural shifts occurring roughly every five years.

The temporal evolution of regimes is illustrated using filtered and smoothed probabilities derived from the Markov switching estimation. Figure 1 presents the smoothed probabilities of Regime 1 over the sample period, showing clear transitions between export-oriented and import-driven phases of economic activity.

The probability dynamics reveal several distinct regime periods that correspond to major phases of Uzbekistan's economic development, including early transition years, periods of trade expansion, and post-reform structural adjustments. These regime shifts confirm the presence of nonlinear dynamics in the trade–environment relationship.

Overall, the empirical findings demonstrate that the relationship between foreign trade and carbon emissions in Uzbekistan is not constant over time but varies across economic regimes, supporting the relevance of nonlinear modeling approaches for analyzing environmental impacts in transition economies.

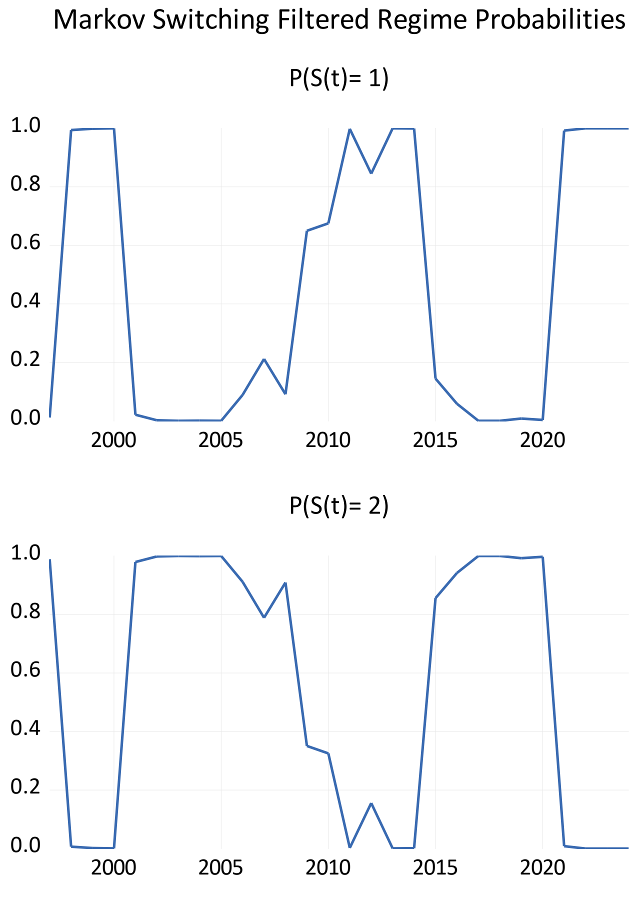

Figure 1. Smoothed probabilities of Regime 1

http://dx.doi.org/10.21511/ee.17(2).2026.04

Based on the empirical findings presented above, the four hypotheses proposed in this study can be evaluated as follows:

Hypothesis H_1 (*Exports are positively associated with CO_2 emissions in Uzbekistan*) is partially supported. The results confirm a statistically significant positive relationship between exports and CO_2 emissions during the export-oriented regime ($\beta = 1.54 \times 10^{-10}$, $p < 0.01$), consistent with the energy-intensive nature of Uzbekistan's export structure. However, this relationship becomes statistically insignificant during the import-driven regime ($\beta = 5.20 \times 10^{-11}$, $p = 0.378$), indicating that the hypothesis holds conditionally rather than universally.

Hypothesis H_2 (*Imports are negatively associated with CO_2 emissions*) is fully supported. The estimated import coefficients are negative and statistically significant at the 1% level across both regimes (Regime 1: $\beta = -1.05 \times 10^{-10}$; Regime 2: $\beta = -1.07 \times 10^{-10}$), providing strong evidence of a stable import-substitution effect that reduces domestic production-related emissions regardless of the prevailing economic state.

Hypothesis H_3 (*The relationship between trade and emissions is regime-dependent*) is supported. The Markov regime-switching regression clearly identifies two distinct economic states with different parameter structures, particularly for the export–emissions relationship. The substantial difference between regime-specific intercepts (4.3471 vs. 5.3002) and export coefficients further confirms that trade–emissions dynamics are not constant over time but vary across economic regimes.

Hypothesis H_4 (*The Uzbek economy experiences periodic structural shifts between export-oriented and import-driven regimes*) is supported. The transition probability analysis reveals high regime persistence ($P_{11} = 79.69\%$, $P_{22} = 81.22\%$) with expected durations of 4.92 years for Regime 1 and 5.32 years for Regime 2, indicating that the Uzbek economy undergoes structural shifts approximately every five years. The smoothed probabilities depicted in Figure 1 further corroborate the presence of distinct regime transitions throughout the 1997–2024 period.

Collectively, these results validate the appropriateness of applying a nonlinear regime-switching framework to the trade–environment nexus in Uzbekistan and confirm that the effects of exports and imports on CO_2 emissions cannot be adequately captured by conventional linear models.

4. DISCUSSION

The empirical findings of this study reveal important patterns in the trade-environment relationship that warrant detailed interpretation and comparison with existing literature.

The export-emissions relationship in Uzbekistan exhibits clear regime-dependence, with a statistically significant positive coefficient of 1.54×10^{-10} ($p < 0.01$) during export-oriented periods (Regime 1) and an insignificant coefficient of 5.20×10^{-11} ($p = 0.378$) during import-driven periods (Regime 2). This regime-dependent pattern represents a key departure from previous studies that assumed constant parameters over time. Halicioglu (2009), using ARDL methodology for Turkey (1960–2005), found a consistently positive and significant export-emissions relationship throughout the entire observation period. Similarly, Shahbaz et al. (2013), applying ARDL bounds testing to Indonesian data (1975–2011), reported a stable positive long-run relationship between exports and CO_2 emissions. In contrast, our findings for Uzbekistan demonstrate that this positive relationship holds only during specific economic conditions (Regime 1), while becoming statistically negligible during import-driven periods. This difference can be attributed to two factors: first, the methodological advantage of Markov switching models in detecting structural breaks that linear ARDL models cannot capture; and second, Uzbekistan's more pronounced economic regime fluctuations compared with Turkey and Indonesia, reflecting the country's transition-economy characteristics and vulnerability to external shocks.

The magnitude of the export coefficient in Regime 1 (1.54×10^{-10}) indicates that a one-dollar increase in exports is associated with approximately 1.54×10^{-10} tonnes increase in per capita CO_2 emissions. While direct coefficient comparison across studies is complicated by different variable specifications and measurement units, the positive direction of this effect is consistent with the broader literature on developing economies. Hossain (2011), examining newly industrialized countries, and Kasman and Duman (2015), studying EU candidate states, both found positive export-emissions relationships in economies with energy-intensive industrial bases. However, these studies reported universally significant effects, whereas our analysis reveals that such significance is conditional on the economic regime. This finding suggests that previous estimates based on linear models may have averaged across distinct economic states, potentially masking important regime-specific dynamics.

The import-emissions relationship demonstrates remarkable stability across both regimes, with coefficients of -1.05×10^{-10} (Regime 1) and -1.07×10^{-10} (Regime 2), both statistically significant at the 1% level. This near-identical magnitude across regimes (difference of only 0.02×10^{-10}) stands in sharp contrast to the heterogeneous import effects documented in prior research. Salman et al. (2019), using panel quantile regression for seven ASEAN countries, found that import effects varied dramatically across income quantiles: imports increased emissions in lower quantiles but reduced emissions in higher quantiles, with coefficient signs changing from positive to negative as income levels rose. Jayanthakumaran et al. (2012), comparing China and India, similarly reported country-specific import effects that differed in both magnitude and significance. The uniformity of the import coefficient in Uzbekistan across both economic regimes suggests that the import-substitution mechanism operates through a fundamentally different channel than in these Asian economies. Specifically, Uzbekistan's imports appear to consistently displace domestic production regardless of the prevailing economic structure, whereas in ASEAN countries and China and India, the import effect is mediated by income levels and development stages. This difference may reflect Uzbekistan's relatively homogeneous import composition (dominated by machinery, equipment, and consumer goods that directly substitute for domestic production) compared to the more diverse import baskets of larger Asian economies.

The identification of distinct economic regimes with transition probabilities of 79.69% (P_{11}) and 81.22% (P_{22}) indicates moderate regime persistence. The expected duration analysis shows that Regime 1 lasts approximately 4.92 years while Regime 2 persists for approximately 5.32 years. Charfeddine (2017), applying Markov switching equilibrium correction model to Qatar's ecological footprint data (1970–2015), identified similar regime-dependent dynamics but with higher persistence probabilities exceeding 90%. This difference in persistence levels reflects the contrasting economic structures: Qatar's oil-dominated economy exhibits greater stability, while Uzbekistan's more diversified but transition-oriented economy experiences more frequent structural shifts. Konstantakis et al. (2025), analyzing carbon emissions during COVID-19 using a two-state MSR model, found that external shocks can trigger rapid regime transitions. Our filtered probability analysis confirms this pattern for Uzbekistan, with the 2017 currency liberalization appearing as a clear transition point that shifted the economy from Regime 2 to the current Regime 1 phase.

The baseline emission levels reveal a counterintuitive pattern: Regime 2 exhibits a higher constant term (5.300) compared to Regime 1 (4.347), despite lower export activity. This finding contradicts the implicit assumption in much of the trade–environment literature that emission intensity is primarily production-driven. Previous studies, including Dogan and Inglesi-Lotz (2020) for European countries and Caporin et al. (2024) for Central Asia, focused predominantly on production-side factors when explaining emission variations. Our results suggest that during import-driven periods, domestic energy inefficiency in consumption-related activities (residential heating, transportation, retail services) contributes substantially to baseline emissions even when industrial production is relatively subdued. This finding aligns with Zhang's (2019) observation that Central Asian countries face significant challenges in energy efficiency, but extends the analysis by demonstrating that these inefficiencies manifest differently across economic regimes.

The carbon leakage implications of our findings merit careful consideration. The consistent negative import coefficient across both regimes supports the carbon leakage hypothesis articulated by Aichele and Felbermayr (2015), who

http://dx.doi.org/10.21511/ee.17(2).2026.04

found that Kyoto Protocol commitments led to increased carbon content in imports for signatory countries. However, our findings differ in an important respect: while Aichele and Felbermayr (2015) documented carbon leakage as a response to environmental policy stringency, the import-substitution effect in Uzbekistan appears to operate independently of environmental regulations. This suggests that for transition economies with limited environmental policy frameworks, carbon leakage occurs through market mechanisms rather than regulatory arbitrage. Jakob et al. (2014) argued for consumption-based emission accounting to address such leakage; our findings provide empirical support for this recommendation in the Central Asian context.

The policy implications emerging from these findings differ substantially from recommendations based on linear model estimates. Gözgör and Can (2016) and Apergis et al. (2018), based on their linear analyses, recommended uniform export diversification strategies to reduce emission intensity. However, our regime-dependent results suggest that such strategies would be effective primarily during export-oriented periods (Regime 1), while during import-driven periods (Regime 2), policy focus should shift toward domestic energy efficiency improvements. The predictable periodicity of regime transitions (approximately every five years) provides policymakers with a temporal framework for anticipating structural shifts and adjusting environmental strategies accordingly.

This study has limitations that should be acknowledged. The aggregate national-level analysis may mask sectoral heterogeneity that could reveal more nuanced patterns in specific industries. The binary regime specification, while parsimonious and supported by the data, may not capture intermediate economic states or gradual transitions. The 28-year sample (1997–2024), while adequate for Markov switching estimation following Kim's (1994) guidelines, constrains estimation precision. Future research should disaggregate the analysis by industrial sector, explore three-regime specifications, and extend the framework to comparative studies across Central Asian economies.

CONCLUSION

This study investigates the regime-dependent relationship between foreign trade (exports and imports) and carbon dioxide (CO_2) emissions in Uzbekistan over the period 1997–2024 using a Markov regime-switching regression framework.

The empirical results reveal three main findings. First, exports are positively associated with CO_2 emissions only during export-oriented periods, while this relationship becomes statistically insignificant during import-driven periods, indicating that the environmental impact of exports depends on the prevailing economic regime. Second, imports consistently reduce CO_2 emissions across both regimes, suggesting a stable import-substitution effect that displaces domestic production-related emissions. Third, the Uzbek economy experiences structural shifts between export-oriented and import-driven regimes approximately every five years, with relatively high persistence probabilities in both states.

These findings indicate that the trade–emissions relationship in Uzbekistan is nonlinear and regime-dependent, implying that conventional linear models assuming parameter constancy may provide incomplete policy guidance for transition economies. Environmental and trade policies should therefore be calibrated to the prevailing economic regime: during export-oriented periods, policy interventions should focus on reducing emissions in export sectors through cleaner production technologies and efficiency improvements, whereas during import-driven periods, priority should be given to enhancing domestic energy efficiency. The consistently negative impact of imports on emissions also suggests the presence of carbon leakage effects, highlighting the importance of considering consumption-based emission accounting when evaluating environmental performance.

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