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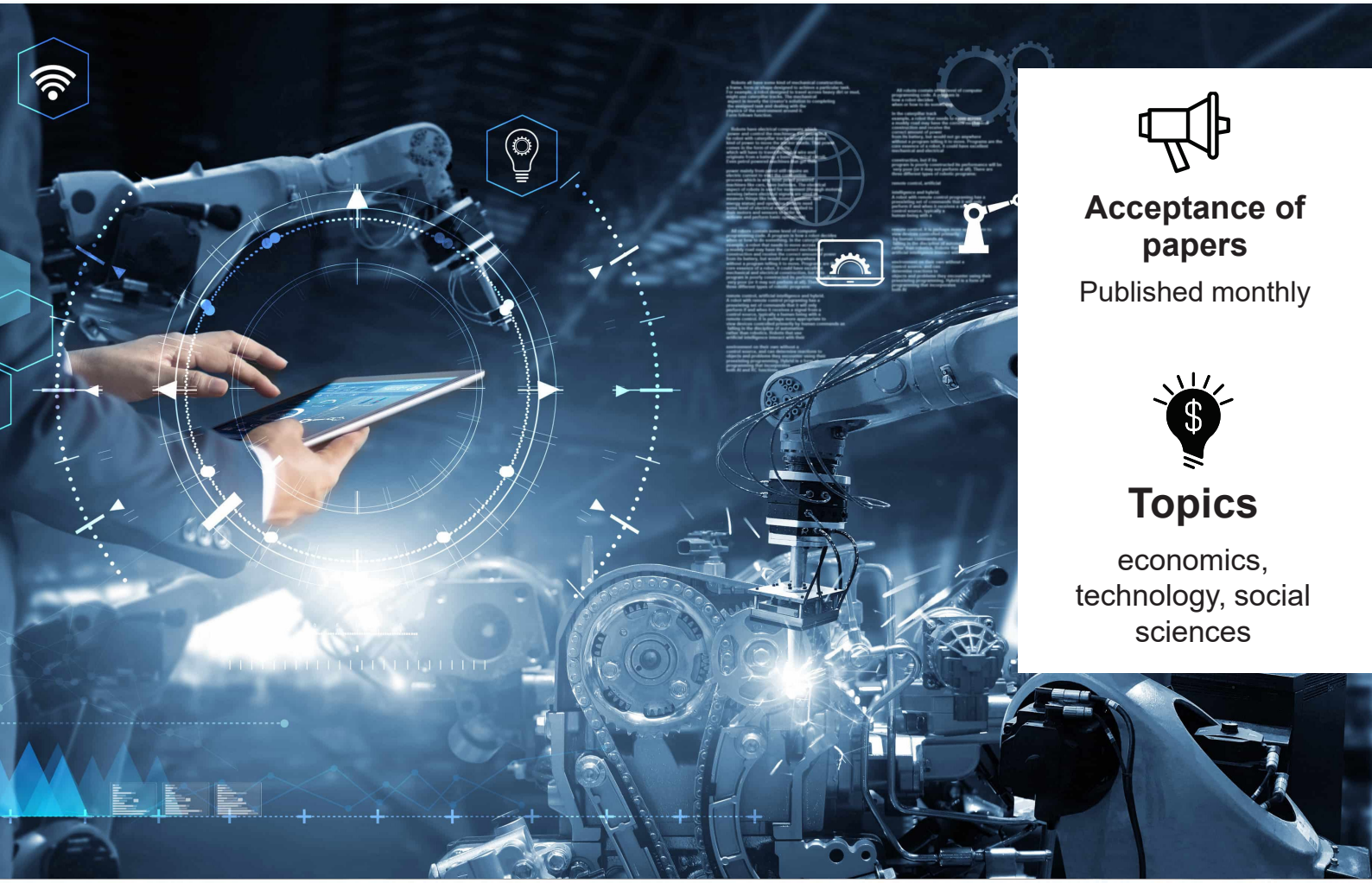

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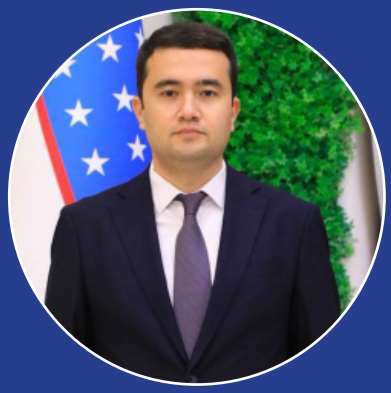



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## Editorial board:

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CONTENTS

# EFFECTIVENESS OF ENVIRONMENTAL TAXES IN REDUCING CARBON EMISSIONS IN UZBEKISTAN: AN ECONOMETRIC APPROACH

**Kuziboev Bekhzod Hamidovich**
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**Abstract:** This article analyzes the effectiveness of environmental taxes in reducing carbon dioxide ($CO_2$) emissions in Uzbekistan using econometric methods. Based on panel data covering the period 2000–2023, the Autoregressive Distributed Lag (ARDL) model and the Granger causality test were applied. The research findings indicate that a 1 percent increase in the share of environmental tax revenues in GDP leads to a 0.43 percent reduction in $CO_2$ emissions in the long run. At the same time, industrial production and population income levels were found to have a significant impact on emissions. As policy recommendations, the study proposes the gradual introduction of a carbon tax and the provision of tax incentives for green investments.

**Key words:** environmental tax, carbon emissions, ARDL model, Granger causality, Uzbekistan, green economy, environmental policy.

**Annotatsiya:** Ushbu maqolada O‘zbekistonda karbonat angidrid ($CO_2$) emissiyalarini kamaytirishda ekologik soliqlarning samaradorligi ekonometrik usullar asosida tahlil qilingan. 2000–2023-yillarni qamrab oluvchi ma’lumotlar asosida Avtoregressiv taqsimlangan kechikish modeli (ARDL) hamda Granger sababiylik testi qo‘llanilgan. Tadqiqot natijalari ekologik soliq tushumlarining YaIMdagi ulushi 1 foizga oshishi uzoq muddatda $CO_2$ emissiyalarining 0,43 foizga kamayishiga olib kelishini ko‘rsatdi. Shu bilan birga, sanoat ishlab chiqarishi va aholi daromadlari darajasi emissiyalarga sezilarli ta’sir ko‘rsatishi aniqlangan. Siyosiy tavsiyalar sifatida uglerod solig‘ini bosqichma-bosqich joriy etish va yashil investitsiyalar uchun soliq imtiyozlarini taqdim etish taklif etilgan.

**Kalit so‘zlar:** ekologik soliq, karbon emissiyasi, ARDL modeli, Granger sababiyligi, O‘zbekiston, yashil iqtisodiyot, ekologik siyosat.

**Аннотация:** В данной статье с использованием эконометрических методов анализируется эффективность экологических налогов в сокращении выбросов углекислого газа ($CO_2$) в Узбекистане. На основе данных за 2000–2023 годы были применены модель авторегрессии с распределёнными лагами (ARDL) и тест причинности Грейнджера. Результаты исследования показали, что увеличение доли поступлений от экологических налогов в ВВП на 1 процент приводит к снижению выбросов $CO_2$ на 0,43 процента в долгосрочном периоде. Одновременно было установлено, что промышленное производство и уровень доходов населения оказывают значительное влияние на объёмы выбросов. В качестве политических рекомендаций предлагаются поэтапное введение углеродного налога и предоставление налоговых льгот для зелёных инвестиций.

**Ключевые слова:** экологический налог, выбросы углерода, модель ARDL, причинность Грейнджера, Узбекистан, зелёная экономика, экологическая политика.

## INTRODUCTION

Climate change has become an increasingly pressing global issue. According to the latest reports of the Intergovernmental Panel on Climate Change, the average global temperature has already increased by 1.1°C compared to the pre-industrial era, posing serious risks to the economies of many countries (IPCC, 2023) [1]. The primary cause of this problem is identified as the excessive increase in greenhouse gas emissions, particularly carbon dioxide ($CO_2$) emissions. The Republic of Uzbekistan has also been directly affected by this global problem. During the period 2000–2023, economic growth led to a significant increase in $CO_2$ emissions resulting from fuel combustion and industrial production. According to data from the World Bank, per capita $CO_2$ emissions in Uzbekistan were 4.1 tons in 2000, while by 2022 this figure had decreased to 3.8 tons, indicating the presence of a certain positive trend despite ongoing economic growth [2]. However, it has not yet been fully determined whether this reduction is the result of consistent and sustainable environmental policies or caused by other factors. The government of Uzbekistan has set a target to reduce greenhouse gas emissions per unit of GDP by 35 percent by 2030 compared to the 2010 level (Sustainable Development Goals of the Republic of Uzbekistan until 2030, 2021) [3]. In order to achieve these objectives, various policy instruments are being considered, including environmental taxes and other market-based mechanisms.

Environmental taxes are financial instruments aimed at increasing the cost of environmentally harmful activities through the internalization of negative externalities. This approach, based on the Arthur Cecil Pigou theory of Pigouvian taxation (Pigou, 1920), has been widely applied in the economies of European and developing countries [4]. However, the effectiveness of environmental taxes may vary depending on different economic conditions. The main objective of this study is to empirically evaluate the effectiveness of the existing environmental tax system in Uzbekistan in reducing $CO_2$ emissions using econometric methods and to develop relevant policy recommendations.

## REVIEW OF LITERATURE ON THE SUBJECT

The theoretical and empirical literature examining the relationship between environmental taxes and emissions is extensive and has developed along several major directions. Arthur Cecil Pigou (Pigou, 1920) was the first to provide a theoretical justification for the tax rate required to internalize environmental externalities. Later, this theory evolved further through the "double dividend" hypothesis, which argues that environmental taxes not only contribute to environmental protection but also create opportunities to reduce other distortionary taxes (Goulder, 1995) [5].

From the perspective of empirical research, Eurostat-based studies by Avlona et al. (2022) found that environmental taxes have a statistically significant negative effect on $CO_2$ emissions in European Union countries [6]. However, this effect varied depending on the level of economic development, with stronger impacts observed in more developed economies. For developing countries, Ngo and Trinh (2023), using the example of ASEAN countries, demonstrated that environmental taxes are relatively ineffective in the short run but become significantly effective in the long run [7]. In addition, they tested the Environmental Kuznets Curve (EKC) hypothesis. Research on Central Asian and post-Soviet economies remains relatively limited. Abdullayev and Yusupov (2021) identified a correlation between the ratio of environmental taxes to GDP and emissions in Uzbekistan, however, their study did not account for long-term dynamics [8]. To fill this gap, the present study applies the ARDL methodology to jointly analyze both long-run and short-run relationships.

## RESEARCH METHODOLOGY

The study applied the following step-by-step econometric procedure. The first stage involved unit root tests. The order of integration of all variables was examined using the ADF (Augmented Dickey–Fuller) and KPSS tests. This constitutes a necessary condition for applying the ARDL model. The second stage involved the ARDL Bounds Testing approach. Developed by M. Hashem Pesaran, Yongcheol Shin, and Richard J. Smith (2001), this method allows the identification of long-run relationships among variables with different orders of integration (I(0) and I(1)) [9]. The main equation is as follows:

$$\Delta \ln CO_2 t = \alpha 0 + \beta 1 \ln CO_2(t-1) + \beta 2 \ln ET(t-1) + \beta 3 \ln Y(t-1) + \beta 4 \ln IND(t-1) + \beta 5 \ln EI(t-1) + \Sigma \gamma i \Delta \ln CO_2(t-i) + \Sigma \delta j \Delta \ln ET(t-j) + \varepsilon t$$

Here, $\Delta$ denotes the first-difference operator, t represents the time index, and $\varepsilon_t$ is the error term. The optimal lag lengths are selected using the Akaike Information Criterion (AIC). The third stage involved estimating the long-run and short-run coefficients. After the Bounds Test confirmed the existence of a relationship, the Error Correction Model (ECM) was applied. In addition, the Granger causality test was used to determine the direction of causality among the variables. The fourth stage consisted of diagnostic tests. Tests for autocorrelation (Breusch–Godfrey), heteroskedasticity (White test), normality (Jarque–Bera), and structural stability (CUSUM and CUSUMSQ) were

conducted. All calculations were performed in R version 4.3.2 using the "dynlm" and "ARDL" packages.

## ANALYSIS AND RESULTS

During the period 2000–2023, environmental tax revenues in Uzbekistan accounted for an average of 1.3 percent of GDP, declining to 0.8 percent in 2009 and increasing to 2.1 percent in 2021. $CO_2$ emissions also exhibited significant fluctuations during this period: decreases were observed during economic crises (2008–2009 and 2020), while upward trends were recorded during periods of economic growth (Table 1).

Table 1.
Results of ADF and KPSS Unit Root Tests[1]

| Variable | ADF (Level) | ADF (1st difference) | KPSS (Level) | KPSS (1st difference) | Order |
|---|---|---|---|---|---|
| lnCO□ | −1.23 | −4.87*** | 0.68** | 0.12 | I(1) |
| lnET | −1.45 | −5.12*** | 0.71** | 0.09 | I(1) |
| lnY | −0.98 | −4.23*** | 0.79** | 0.11 | I(1) |
| lnIND | −1.67 | −4.56*** | 0.63** | 0.14 | I(1) |
| lnEI | −2.13 | −3.98*** | 0.58* | 0.16 | I(1) |

The results of the ADF and KPSS unit root tests indicate that all variables are non-stationary at level form but become stationary after taking the first difference. Therefore, all variables are integrated of order one, I(1), which confirms the suitability of applying the ARDL Bounds Testing approach.

The results of the ARDL Bounds Test show that the F-statistic (F = 7.34) significantly exceeds the upper critical bound (4.85 at the 5% significance level for I(1)). This provides sufficient evidence to confirm the existence of a long-run cointegration relationship among all variables (Table 2).

Table 2.
ARDL(2,1,2,1,1) Model: Long-Run Coefficients[2]

| Variable | Coefficient | Standart Error | t-Statistic | p-Value |
|---|---|---|---|---|
| lnET | −0.432*** | 0.089 | −4.856 | 0.000 |
| lnY | 0.614*** | 0.132 | 4.652 | 0.000 |
| lnIND | 0.287** | 0.114 | 2.518 | 0.019 |
| lnEI | 0.523*** | 0.097 | 5.392 | 0.000 |
| Constant | −1.287*** | 0.342 | −3.762 | 0.001 |

The long-run estimation results indicate that environmental taxes have a statistically significant negative effect on $CO_2$ emissions. Specifically, a 1 percent increase in environmental tax revenues reduces $CO_2$ emissions by approximately 0.43 percent in the long run. This finding confirms the effectiveness of environmental taxation as a policy instrument for environmental protection in Uzbekistan. At the same time, economic growth (lnY), industrial production (lnIND), and energy intensity (lnEI) exert positive and statistically significant effects on carbon emissions. In particular, the positive coefficient of energy intensity suggests that inefficient energy use remains one of the key drivers of environmental degradation in the country.

The Error Correction Model (ECM) reflects the short-run dynamics and the speed at which variables return to long-run equilibrium. The ECM coefficient (−0.387, $p < 0.01$) indicates that approximately 38.7 percent of deviations from the long-run equilibrium are corrected within one year following random shocks. In the short run, the direct effect of environmental taxes (−0.168) is considerably weaker than its long-run effect. This suggests that environmental policy measures require a certain period of time before their full effectiveness can be realized.

The results of the Granger causality test confirm the existence of a unidirectional causal relationship running from environmental taxes to $CO_2$ emissions ($F = 8.23$, $p = 0.004$). Meanwhile, a bidirectional causal relationship was identified between economic growth (lnY) and $CO_2$ emissions ($p < 0.05$). This finding partially supports the Environmental Kuznets Curve (EKC) hypothesis as well as the "growth first, environment later" scenario that is commonly observed in developing countries.

All diagnostic tests confirmed the adequacy and reliability of the model. The Breusch–Godfrey LM test (p =

1 Author's development
2 Author's development

0.312) indicated the absence of autocorrelation, while the White heteroskedasticity test (p = 0.198) confirmed homoskedasticity. In addition, the Jarque–Bera test (p = 0.247) suggested that the residuals are normally distributed. Furthermore, the CUSUM and CUSUMSQ tests demonstrated the structural stability of the model parameters at the 5 percent significance level.

The results of the study demonstrate that environmental taxes in Uzbekistan do contribute to reducing $CO_2$ emissions in the long run. At the same time, the obtained elasticity coefficient (0.43) indicates the existence of additional opportunities to further strengthen the effectiveness of environmental taxation mechanisms in the future. This can be explained by several factors. First, environmental tax rates in Uzbekistan are currently being gradually improved and therefore still provide broad potential for more fully reflecting actual environmental costs. According to 2022 data, pollution-related taxes compensated for about 12–18 percent of the economic damage caused by environmental degradation, which highlights the importance of ongoing reforms in this area.

Second, the existing system of energy subsidies continues to support households and industrial sectors during the transition toward greener economic development. At the same time, Robert Gross and Karl Steininger (2020) theoretically explained the "contradictory policy" effect, emphasizing the importance of balancing environmental taxation with social support measures. Third, institutional capacity and implementation mechanisms continue to improve progressively. Further modernization of tax administration systems and strengthening compliance mechanisms may enhance the regulatory effectiveness of environmental taxation in the coming years. The positive and relatively high coefficient of GDP per capita (lnY = 0.614) indicates that Uzbekistan remains in an active stage of economic growth associated with industrial expansion and rising production activity. Nevertheless, the gradual decline in energy intensity (by 18 percent during 2010–2023) and the growing share of renewable energy sources demonstrate the emergence of positive structural transformations in the economy. The positive and statistically significant impact of industrial production (0.287) reflects the ongoing industrialization process and simultaneously underlines the importance of further modernizing production through the wider adoption of green technologies. The relatively small short-run effect (−0.168) and the moderate ECM adjustment coefficient (0.387) provide an important message for policymakers: environmental taxation reforms require a gradual adaptation period before their full long-run effects become visible. Therefore, temporary support mechanisms and transition incentives for industries and households may play an important facilitating role during the adjustment process.

## CONCLUSIONS AND SUGGESTIONS

This study is among the first comprehensive academic works to empirically confirm the long-run negative impact of environmental taxes on $CO_2$ emissions in Uzbekistan using the ARDL econometric model. The main conclusions are as follows:

A 1 percent increase in environmental taxes reduces $CO_2$ emissions by 0.43 percent in the long run;

Industrial activity and energy intensity are among the main drivers of emissions;

The short-run impact is relatively weak, and a transition period of 3–5 years is required to achieve full effectiveness;

Environmental taxes are a necessary, but not sufficient, condition for achieving Uzbekistan's 2030 climate goals.

Based on the findings of the study, the following policy recommendations are proposed:

Recommendation 1: Gradual introduction of a carbon tax. At the initial stage, it would be appropriate to introduce a carbon tax for large industrial enterprises at a rate of USD 10–15 per ton of $CO_2$, gradually increasing it to USD 30–35 by 2030. This approach has been successfully implemented in the European Union.

Recommendation 2: Tax incentives for green investments. It is necessary to establish a system of targeted tax incentives for enterprises investing in renewable energy, energy-efficient technologies, and green infrastructure. Such measures would balance the burden of environmental taxation and accelerate the adoption of green technologies.

Recommendation 3: Gradual removal of energy subsidies. To enhance the effectiveness of environmental taxes, environmentally harmful energy subsidies should be phased out gradually and replaced with targeted social assistance mechanisms for vulnerable households.

Recommendation 4: Allocation of tax revenues to green infrastructure. At least 60 percent of revenues generated from environmental taxes should be directed toward environmental protection, green transport, and energy-efficiency programs in order to ensure the "double dividend" effect.

The main limitation of the study is the relatively short time series (24 observations) and the incomplete availability of environmental tax statistics for certain years in Uzbekistan. Future research is recommended to expand the analysis using quarterly data and regional-level panel datasets.

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