IMPOSTO VERDE E DEMOCRACIA: UMA ANÁLISE EMPÍRICA DOS DETERMINANTES POLÍTICOS DA TRIBUTAÇÃO AMBIENTAL

GREEN TAX AND DEMOCRACY: AN EMPIRICAL ANALYSIS OF THE POLITICAL DETERMINANTS OF ENVIRONMENTAL TAXATION

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Resumo: Embora a tributação ambiental seja uma ferramenta primária para internalizar os custos sociais do carbono e financiar a transição ecológica, sua adoção permanece inconsistente em diferentes contextos globais. Este estudo investiga os determinantes político-institucionais das receitas provenientes de impostos ambientais. Com base na economia política ambiental e na teoria institucionalista, examinamos como a qualidade democrática, caracterizada por eleições competitivas e liberdades civis protegidas, molda a capacidade de um Estado em implementar essas medidas fiscais complexas. Utilizando um painel de dados de 25 países entre 2005 e 2021, o estudo emprega um modelo dinâmico System-GMM para fornecer estimativas robustas à endogeneidade, ao mesmo tempo em que captura a persistência temporal das medidas fiscais. Os resultados demonstram que democracias liberais mais fortes são significativamente mais bem-sucedidas na mobilização da tributação ambiental. Esses achados sugerem que a transição verde não é apenas um desafio técnico ou econômico, mas fundamentalmente enraizado na força das instituições democráticas.
Palavras-chave: Tributação Ambiental; Democracia; Política Ambiental; Instituições.
Código JEL: H23, Q54, Q58, P16.

Abstract: While environmental taxation is a primary tool for internalizing the social costs of carbon and financing the ecological transition, its adoption remains inconsistent across global contexts. This study investigates the political-institutional determinants of environmental tax revenues. Drawing on environmental political economy and institutionalist theory, we examine how democratic quality, characterized by competitive elections and protected civil liberties, shape a state's ability to implement these complex fiscal measures. Utilizing a panel dataset of 25 countries from 2005 to 2021, the study employs a dynamic System-GMM model to provide estimates robust to endogeneity while capturing the temporal persistence of fiscal measures. The results demonstrate that stronger liberal democracies are significantly more successful in mobilizing environmental taxation. These findings suggest that the green transition is not merely a technical or economic challenge, but one fundamentally rooted in the strength of democratic institutions.
Key words: Environmental Taxation; Democracy; Environmental Policy; Institutions.
JEL Code: H23, Q54, Q58, P16.

Area 8. Economia Ecológica, Mudança Climática e Sustentabilidade

AKB

2026

1 INTRODUCTION

The climate crisis stands as one of the defining global challenges of the twenty-first century, mainly driven by human activities such as CO_2 emissions, the overexploitation of natural resources, and uncontrolled urbanization. Its consequences are already visible: the global average temperature has risen by more than 1.1 °C above pre-industrial levels, triggering rising sea levels, glacier melting, and shifts in regional climate patterns (IPCC, 2023). At the same time, the frequency of extreme weather events, including droughts, floods, heatwaves, and wildfires, has increased. The economic, social, and ecological repercussions of this degradation are far-reaching, disproportionately affecting developing countries and the most vulnerable populations (IPCC, 2012).

In 2022, the United Nations General Assembly (UNGA) recognized access to a clean, healthy, and sustainable environment as a universal human right, urging national governments to secure this right through the design and implementation of effective public policies. Environmental protection thus becomes not merely a policy choice but a duty of states toward their citizens, requiring deliberate and coordinated state action. Among the available policy instruments, environmental taxation has emerged as a fundamental mechanism. By imposing taxes on activities, products, or sectors that generate negative environmental impacts, such as greenhouse gas emissions, the intensive extraction of natural resources, or fossil fuel consumption, these measures aim to correct negative externalities and encourage more sustainable behavior. Environmental taxes increase the costs associated with harmful practices, effectively internalizing the social costs of degradation. This approach incentivizes individuals and firms to reduce their externalities or adopt cleaner alternatives. Beyond this regulatory function, environmental taxation also plays a redistributive and strategic role, as the revenue collected can be redirected to support climate change mitigation and adaptation policies (Moura, 2016; Williams, 2016).

The formulation and effectiveness of such green policies, however, depend strongly on the political regime and institutional framework in which they are embedded. Because environmental policies directly affect strategic sectors of the economy, patterns of consumption, and distribution, their implementation often requires negotiation among competing interests within the political arena (Moura, 2016). Democracies, in particular, are frequently associated with more favorable conditions for environmental protection. This link derives in part from institutional features such as competitive elections, freedom of expression, and the protection of civil and political rights (Drosdowski, 2006; Fredriksson et al., 2005). These mechanisms enable demands for environmental justice to be voiced and debated publicly, thereby increasing pressure on governments to adopt policies that align with collective interests.

Beyond regime type, institutional quality is equally central to shaping the effectiveness of environmental policies. The literature suggests that countries with a strong rule of law, low levels of

corruption, and professional bureaucracies tend to achieve superior outcomes in implementing complex public policies, including those designed to mitigate climate change. Conversely, weak institutional capacity can undermine policy formulation, whether through susceptibility to short-term political pressures or operational challenges in revenue collection and enforcement (Fredriksson and Vollebergh, 2009; Lisciandra and Migliardo, 2017).

Yet, despite these insights, a gap remains in empirical research specifically addressing the institutional determinants of environmental taxation. Existing studies focus primarily on European countries and rely predominantly on the rule of law as a proxy for institutional quality (Castiglione, Infante and Smirnova, 2014, 2018). While the rule of law is undoubtedly relevant, it captures only part of the institutional dimension, leaving unanswered questions about the broader political and institutional conditions that enable environmental taxation.

To address this gap, this study examines the impact of political-institutional and socioeconomic factors on environmental taxation. Drawing on perspectives from environmental political economy and institutionalist theory, it discusses the effects of democratic quality, legal stability, and administrative capacity on the formulation and implementation of environmental policy, while also assessing the role of environmental taxation as both a fiscal tool to encourage sustainable behavior and a source of financing for the ecological transition.

The empirical analysis is based on panel data from 25 countries spanning from 2005 to 2021. Employing a dynamic System-GMM model, the study estimates the effects of liberal democracy variables on environmental tax revenues. This methodological strategy provides robust estimates that are robust to endogeneity while capturing the temporal dynamics of environmental fiscal policy.

The contribution of this study lies in advancing our understanding of the political determinants of environmental policy across diverse national contexts, at a moment when effective governmental responses to the climate crisis are urgently needed. Although international scholarship emphasizes the importance of political institutions for environmental performance, few studies have directly investigated how these factors influence environmental taxation, particularly through comparative, medium-term analyses that also consider fiscal and climatic conditions. By addressing this gap, the study highlights the significance of political systems in shaping the effectiveness of environmental policy.

2 DEMOCRACY AND ENVIRONMENTAL POLICIES

Environmental taxation is not only a fiscal tool but also a political outcome, shaped by the quality of institutions and the nature of democratic governance. Theories of environmental political economy emphasize that competitive politics, institutional stability, and bureaucratic capacity are central to the formulation of sustainability-oriented policies. Building on these insights, this section examines the

interplay between democracy and institutional quality, their impact on environmental protection, and the specific role of taxation as a policy instrument.

2.1 Democracy, institutional quality, and environmental policies

The effectiveness of environmental protection is intrinsically tied to the state's capacity for intervention, which in turn depends on strong and effective institutions capable of designing, implementing, and enforcing regulatory norms. Factors such as the degree of democratic consolidation, levels of corruption, and the protection of political rights have a decisive influence not only on the adoption of environmental policies but also on their practical enforcement. Since economic systems operate within specific institutional contexts, environmental governance cannot be understood in isolation from the political structures that underpin it.

The empirical literature on environmental political economy yields mixed results regarding whether democracies outperform autocracies in environmental policy. Evidence suggests that democratic states are more likely to sign and ratify international environmental agreements, establish national sustainability councils, increase the availability of environmental data, and expand protected areas (Neumayer, 2002). Within democracies, regulatory stringency appears stronger in parliamentary systems, while presidential or presidential–congressional systems resemble autocracies in this regard (Fredriksson and Wollscheid, 2007).

Yet translating international commitments into tangible outcomes remains inconsistent. For instance, both the United Kingdom and Norway are highly democratic and active in treaty adoption, but only the United Kingdom reduced its CO_2 emissions between 1980 and 2004. Treaty ratification alone does not guarantee effective implementation, partly because of countervailing dynamics, such as the free-rider problem and the discounting of future climate benefits, as well as other institutional barriers that limit the conversion of commitments into results (Bättig and Bernauer, 2009).

Despite such challenges, Li and Reuveny (2006) find that higher levels of democracy are associated with lower per capita emissions of CO_2 and NOx, reduced organic water pollution, lower deforestation, and less soil degradation, particularly when long-term effects are considered. However, in low-income contexts, democracy can indirectly contribute to increased environmental degradation; only after a certain income threshold is reached does economic growth help mitigate these impacts. This dynamic aligns with the Environmental Kuznets Curve hypothesis (Dinda, 2004), which posits an inverted U-shaped relationship between income and environmental degradation. In the early stages of development, degradation intensifies as natural resource exploitation increases, but beyond a certain point, rising incomes and stronger institutions facilitate environmental improvements.

More recent scholarship converges on the view that the quality of political institutions is a critical determinant of a regime's ability to address socio-environmental challenges. This suggests

that analyzing democracy in broad terms is insufficient; it is necessary to identify which dimensions of democracy are most closely linked to stronger environmental policies (Dasgupta and De Cian, 2018; Escher and Walter-Rogg, 2018).

Among these dimensions, political participation and electoral competition stand out, as they enable diverse societal groups to influence policy formulation. In contexts where freedoms of expression and association are protected, citizens can mobilize against environmental degradation (Drosdowski, 2006). Fredriksson et al. (2005) demonstrate that weak electoral competition enhances the influence of powerful economic groups, enabling them to shape environmental regulations to their advantage. Conversely, when environmental lobbies operate in highly competitive political environments, regulation tends to be more stringent. The authors conclude that politically competitive regimes adopt stricter standards when environmentalists' mobilization outweighs industrial pressure.

Another key institutional factor is corruption. Research indicates that the positive association between democracy and lower CO_2 emissions holds only in contexts with low corruption. In democracies plagued by corruption, formal guarantees of political freedom, free elections, an independent press, and freedom of association are insufficient to drive rigorous climate action. As a result, such democracies perform no better than equally corrupt authoritarian regimes in reducing emissions (Persson and Povitkina, 2017). Corruption also enables pollution-intensive industries to delay or weaken environmental regulation through bribery, bending public policy to private interests (Lisciandra and Migliardo, 2017).

Socioeconomic inequality further complicates environmental governance. From a political economy perspective, public spending priorities influence the extent of environmental protection. As inequality rises, poorer populations tend to prioritize immediate economic growth over environmental concerns (Kempf and Rossignol, 2007). Boyce (1994) argues that inequality skews environmental policymaking because economic elites, who often hold disproportionate political influence, benefit from polluting activities, while disadvantaged groups bear the negative consequences. Empirical evidence supports this claim: Kashwan (2017), analyzing 137 countries, shows that the relationship between democracy and environmental protection is mediated by income inequality. In consolidated democracies with low inequality, the share of protected areas is significantly higher; however, as inequality increases, this "democratic dividend" diminishes and can disappear entirely above the 75th percentile of the Gini index.

The structure of a country's export portfolio further reinforces this dynamic. Economies heavily dependent on commodity exports, often resource-intensive, face heightened risks of environmental injustice and public health impacts. For developing countries, agricultural export expansion is associated with rising CO_2 emissions, whereas in developed countries, this effect is absent (Saghaian, Mohammadi, and Mohammadi, 2022). This asymmetry reflects global inequalities:

developed nations can outsource environmentally intensive production to countries with weaker regulations, thereby reducing their own environmental burdens while shifting degradation abroad (Saeed and Ghimire, 2022).

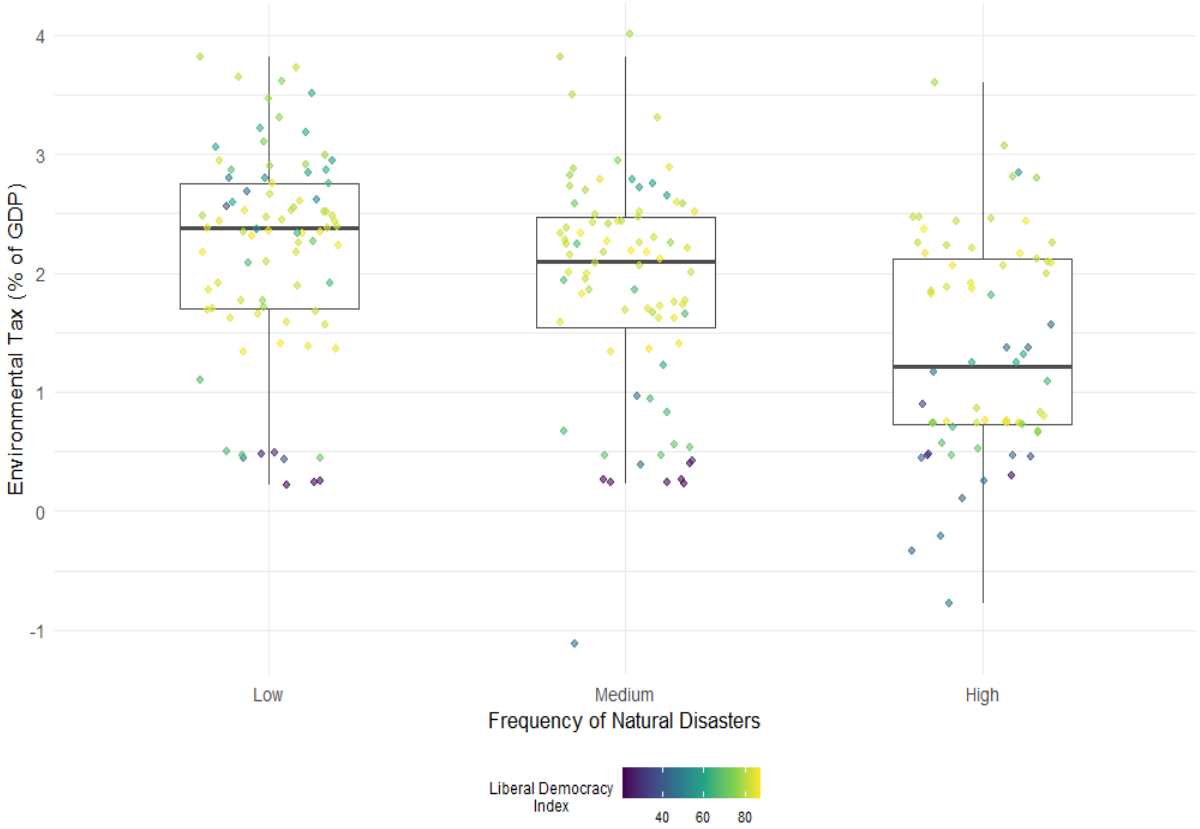
Institutional quality also shapes how states respond to natural disasters, one of the most immediate consequences of the climate crisis. These events often expose the weaknesses of local response systems, highlighting the need for coordination across levels of government and for mobilizing external resources. Robust democratic institutions are better able to coordinate early warning systems, invest in resilient infrastructure, and implement effective contingency plans, reducing human and material losses (Kahn, 2005; Persson and Povitkina, 2017). At the same time, disasters can act as catalysts for institutional change. The heightened visibility of extreme events through media coverage, civic mobilization, and public scrutiny can reshape political dynamics (Olson and Gawronski, 2010). Civil society organizations, NGOs, and community groups often step in to fill gaps in state responses, gaining legitimacy and, at times, pressuring governments toward greater transparency and accountability (Rydén et al., 2024). In this sense, natural disasters may serve as "windows of opportunity" for institutional transformation and democratic strengthening (Acemoglu and Robinson, 2001; Aidt and Leon, 2016).

Within this broader institutional landscape, environmental taxation has become one of the main green policy instruments in OECD countries. It is widely recognized as a driver of sustainable development, green innovation, and shifts in consumption patterns (Andreoni, 2019). Recent evidence suggests that increases in environmental tax revenue led to reductions in both CO_2 emissions and the frequency of extreme temperatures, particularly when the revenues are reinvested in environmental budgets and green research and development (R&D) (He et al., 2023). By contributing to measurable reductions in climate-related risks, environmental taxation has proven an effective instrument for addressing climate change.

Figure 1 displays the distribution of environmental taxation across three categories of natural disaster frequency. The overlaid scatter points, colored by countries' Liberal Democracy Index, illustrate how levels of democracy vary within each disaster-frequency group and across levels of environmental taxation. The boxplots reveal a pattern: countries with low disaster frequency exhibit higher median environmental tax revenues, while those in the medium and high categories show progressively lower medians. This suggests that increased exposure to natural hazards is associated with a lower share of environmental tax collection in GDP.

The overlaid scatter points reveal a vertical gradient tied to democratic quality. Countries shaded in lighter yellow green (higher liberal democracy scores) are concentrated in the upper range of environmental taxation across disaster categories. Conversely, darker purple–blue observations (weaker democracies) tend to occupy the lower end of the tax distribution across all three groups.

Figure 1. Environmental Taxation Across Disaster Frequency Groups



Source: Authors' elaboration based on EM-DAT and V-Dem data.

This preliminary evidence underscores that institutional quality (particularly democratic strength) may play a decisive role in determining environmental tax capacity. Given its relevance, the following section discusses the main factors that facilitate the adoption and effectiveness of environmental taxation, drawing on the most recent literature.

2.2 Political and economic determinants of the implementation of environmental taxation

Environmental taxation serves a dual purpose: raising state revenue for public services and shaping economic behavior. By penalizing harmful activities and promoting sustainable ones, taxes can support sustainable development (Williams, 2016). This extra-fiscal role places environmental taxation at the intersection of economics, politics, and institutions, where effectiveness depends on the state's capacity to implement, enforce, and coordinate policy instruments.

The design and implementation of environmental taxes must account for potential economic distortions. Poorly calibrated or isolated taxes, for instance, can trigger carbon leakage, where emission-intensive industries relocate to jurisdictions with weaker environmental regulations, displacing emissions geographically without reducing them globally. Addressing this risk requires

corrective mechanisms such as carbon border adjustments and international policy coordination, as highlighted by the OECD (2021).

Besides minimizing distortions, environmental taxation generates revenue that can support other environmental policies. Costa Rica provides a compelling example: from 2010 to 2021, green taxes accounted for approximately 10% of tax revenue and 2.3% of GDP, above OECD averages of 6.8% and 2.2%. Much of this revenue is earmarked for environmental programs: 3.5% of the fuel tax funds the National Forestry Financing Fund for Payments for Environmental Services, covering 90% of its budget, while a quarter of water use fees supports forest conservation (OECD, 2023).

Environmental taxes also embody the concept of a "double dividend." By internalizing the social costs of pollution, they create price signals that discourage carbon-intensive activities. Simultaneously, the revenue generated can be used to reduce other distortionary taxes, such as those on labor or capital, delivering both environmental and economic efficiency gains (Pearce, 1991).

Despite these potential benefits, the introduction of environmental taxes often face political resistance. Moura (2016) notes that fiscal measures imposing costs on the productive sector are frequently opposed by affected groups, which lobby to block or weaken them. The Clean Development Mechanism (CDM) illustrates this dynamic: Business and Industry NGOs (BINGOs) used privileged access to delay Carbon Capture and Storage (CCS) adoption, prioritizing sectoral interests over climate goals (Vormedal, 2008). Similarly, Cheon and Urpelainen (2013) found that renewable energy subsidies in 14 democracies from 1989 to 2007 reflected ongoing battles between renewable advocates and industrial lobbies. Their analysis shows that while more renewables increase clean energy tariffs, this effect wanes as industrial lobbies grow, highlighting how political competition shapes fiscal incentives.

Empirical studies on institutional quality and environmental taxation remain limited and mostly Eurocentric. Castiglione, Infante, and Smirnova (2014, 2018) advanced this by testing the Environmental Taxation Kuznets Curve (ETKC), linking institutional quality (property rights, contract enforcement, low corruption) to long-term growth and public acceptance of taxes. In this view, the environmental tax base first expands with income, peaks as institutional capacity enables enforcement, and then declines as emissions fall, forming an inverted U. The timing and peak of this decline depend on institutional strength: good governance speeds compliance and adaptation, thereby maximizing the benefits of taxation.

Yet gaps persist. Most empirical work evaluates only a narrow set of institutional indicators, rarely considering broader political-institutional dimensions, democratic quality, socioeconomic inequality, or the frequency of natural disasters. These factors can reinforce or constrain the adoption of environmental taxes: functional democracies may be more inclined to implement green fiscal measures, but high inequality or extreme events can amplify distributive pressures or disrupt policy

execution. Methodologically, previous studies have predominantly employed fixed-effects models, which limit their ability to address endogeneity and omitted-variable biases.

2.3 A theoretical framework for the dynamical relationship between environmental taxation and democracy

Consider that in the long run the output of the economy is a positive function of democracy. In formal terms, we have $Y = F(HL, K, D)$, where: Y is the output of the economy; L is labor augmented with the stock of human capital, H; K is the capital stock; D accounts for the level of democracy; and $F(.)$ is a given function with constant returns to scale. Normalizing the output by the level of effective labor, LH, yields $y = F(1, k, d)$, where: $y = Y/HL$; $k = K/HL$; and $d = D/HL$. Assuming k remains unchanged for simplicity, we can rewrite the production function as $y = f(d)$.

The first motion equation governs the time evolution of democratic institutional quality, denoted by $\dot{d} = dd/dt$. We posit that environmental taxation shapes economic behavior not merely as a fiscal instrument, but as a structural driver of civic stability. By penalizing harmful externalities and incentivizing sustainable modes of production, these taxes foster a socioeconomic environment conducive to democratic deepening. Assuming the environmental tax, $\tau_e f(d)$, operates effectively as a Value-Added Tax (VAT) on aggregate economic output, the tax rate becomes directly associated with the mobilization of resources necessary to support public goods and institutional integrity. Consequently, the model assumes that higher levels of environmental taxation positively influence the rate of change of democracy. However, the trajectory of institutional improvement is not unbounded. As a polity approaches high levels of democratic consolidation, further gains become increasingly complex to implement due to structural rigidities. To capture this saturation effect, the current level of democracy enters the equation as a negative feedback term, reflecting the inherent difficulty of improving the level of democracy once a mature standard has been reached.

$$\dot{d} = \alpha \tau_e f(d) - \gamma d$$

where α and γ are constants.

The second motion equation describes the time evolution of environmental taxation, $\dot{\tau}_e = d\tau_e/dt$, driven by the premise that the effectiveness of green fiscal policy relies heavily on state capacity and democratic institutions. The ability to successfully implement, enforce, and coordinate policy instruments is not automatic; rather, it is endogenous to the strength of the political system. Furthermore, the model incorporates the role of the frequency of natural disasters, ε. While such events create baseline social pressure for environmental action, this pressure is significantly amplified in robust democracies where civil society participation is high and channels for public demand are open. Consequently, we model this dynamic by interacting with the frequency of natural disasters

with a function $g(d)$, reflecting that the policy response to climate shocks is conditioned by the quality of democratic institutions. However, the expansion of environmental taxation is not unchecked; it faces inherent political resistance. Because these fiscal measures impose direct costs on the productive sector, as aforementioned, they inevitably trigger opposition from affected interest groups who lobby to block or weaken the policy. This resistance acts as a structural drag on the accumulation of environmental taxes, moderating the rate of policy adoption.

$$\dot{\tau}_e = g(d)\varepsilon - \delta\tau_e$$

where $\varepsilon \sim Poisson(\lambda)$; and λ is the mean of natural disasters; and δ is a constant. In equilibrium, $\dot{d} = \dot{\tau}_e = 0$, we have two non-homogeneous solutions: (d^U, τ_e^U) and (d^S, τ_e^S) where $d^U < d^S$ and $\tau_e^U < \tau_e^S$.

Next, we analyze the stability conditions around the equilibrium solutions. From equations (1) and (2), we obtain the Jacobian matrix:

$$\boldsymbol{J} = \begin{bmatrix} \alpha\tau_e f'(d) - \gamma & \alpha f(d) \\ g'(d)\lambda & -\delta \end{bmatrix}$$

where $\varepsilon = \lambda$. The trace and determinant of the Jacobian matrix are given by:

$$Tr(\boldsymbol{J}) = \alpha\tau_e f'(d) - \gamma - \delta$$

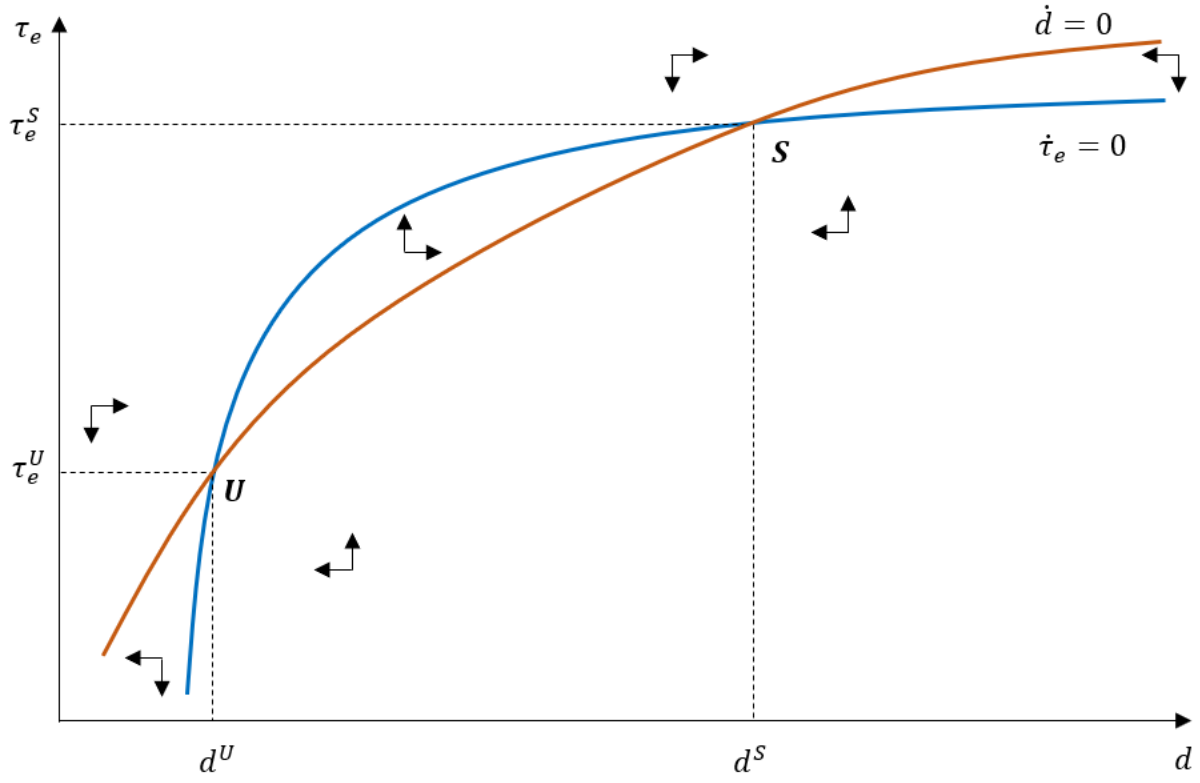
$$Det(\boldsymbol{J}) = \delta\big(\gamma - \alpha\tau_e f'(d)\big) - \alpha f(d) g'(d)\lambda$$

where $f'(d) > 0$; $f''(d) < 0$; $g'(d) > 0$; and $g''(d) < 0$.

Sufficiently low levels of democracy, d^U, yield higher $f'(d)$ and $g'(d)$ and hence $Det(\boldsymbol{J}) < 0$. Therefore, the solution (d^U, τ_e^U) is a Saddle Point.

As d increases, $f'(d)$ and $g'(d)$ converge to zero. Thus, a sufficiently high level of democracy, d^S, is likely to result in $Tr(\boldsymbol{J}) \to -\gamma - \delta < 0$ and $Det(\boldsymbol{J}) \to \delta\gamma > 0$. Hence, the solution (d^S, τ_e^S) may be either a Stable Spiral or a Stable Node.

Figure 2. The phase diagram



Source: Authors' elaboration.

For an economy in the unstable equilibrium, $\boldsymbol{U} = (d^U, \tau_e^U)$, any decrease in the levels of either d^U or τ_e^U triggers a vicious circle of democratic backsliding accompanied by environmental tax cuts. Analogously, an increase in either d^U or τ_e^U may set the economy in a virtuous circle towards the stable equilibrium $\boldsymbol{S} = (d^S, \tau_e^S)$.

For an economy in the stable solution, $\boldsymbol{S} = (d^S, \tau_e^S)$, note that an upward shift in the isocline $\dot{d} = 0$ ($\dot{\tau}_e = 0$) reduces (increases) both d^S and τ_e^S. Therefore, in the stable equilibrium, democracy and environmental taxation seem to be directly associated.

Thus, our theoretical framework yields the following testable hypothesis:

Hypothesis: *environmental taxation increases with higher levels of democracy*.

Next, we present our empirical strategy.

3 METHODOLOGY

This study estimates a dynamic panel data model for 25 countries from 2005 to 2021. This approach examines political and institutional determinants of environmental taxation while accounting for endogeneity, time dynamics, and cross-country differences.

3.1 The model

The model to be estimated is defined as follows:

$$ET_{it} = \alpha_i + \beta_1 LDem_{i,t-1} + \beta_2 \boldsymbol{X}_{i,t-1} + \varepsilon_{it}$$

where ET_{it}represents the environmental tax revenue for country *i* in period *t*; α_i denotes the country's fixed effect, capturing characteristics that remain constant over time; $LDem_{i,t-1}$ is the liberal democracy index lagged by one period; $X_{i,t-1}$ represents the lagged control variables; finally, ϵ_{it} is the error term, encompassing unexplained variation. Regressors are included with a one-period lag to account for the delayed response of tariff policies to changes in explanatory factors.

3.2 Empirical Strategy

The analysis employs a panel dataset for 25 countries from 2005 to 2021 (country details are provided in the Appendix). Panel data enable the observation of the same units over time, increasing information, reducing collinearity among variables, and improving estimation efficiency. This structure reveals dynamic effects not seen in cross-sectional data and controls for unobserved time-invariant heterogeneity, which could otherwise bias estimates (Gujarati and Porter, 2009).

While fixed-effects estimation is consistent under assumptions of no serial correlation, homoscedasticity, and strict exogeneity, it has limitations for dynamic panels, where past outcomes influence current values (Imai and Kim, 2019). In the context of this study, changes in liberal democracy are unlikely to have an immediate effect on environmental tax revenues, as institutional reforms typically operate over longer horizons. Similarly, control variables, such as the frequency of natural disasters, may exert delayed effects, as environmental taxation is a planning instrument rather than an emergency response tool.

Fixed-effects estimation is also inconsistent in the presence of endogenous regressors. For example, while democratic regimes may promote higher environmental taxation, successful green policies can, in turn, reinforce democratic legitimacy by responding to societal demands for sustainability, creating a feedback loop. Similarly, extreme climate events may trigger institutional reforms, while increased environmental tax collection can fund preventive measures that reduce future disaster risk.

To address these issues, the generalized method of moments (GMM) with instrumental variables was employed, following the work of Arellano and Bond (1991), Arellano and Bover (1995), and Blundell and Bond (1998). This methodology is well-suited for dynamic panel data with a relatively small number of periods (T) and a larger number of cross-sectional units (N).

There are two main GMM specifications: difference GMM and system GMM. The Difference GMM, as proposed by Arellano and Bond (1991), removes unit-specific fixed effects through first-differencing and utilizes lagged levels of endogenous variables as instruments. Although this gives

consistent estimates, it works poorly when variables have low variability, as much information is lost in differencing (Blundell and Bond, 1998).

System GMM was employed to address this issue. It combines moment conditions in first differences with those in levels, using lagged differences as instruments for the level equation. This addresses the correlation between endogenous regressors and unobserved effects, giving more efficient and consistent estimates than difference GMM (Blundell and Bond, 1998). The Hansen and the Arellano-Bond tests were employed to evaluate the validity of instruments. Following Roodman (2009), the number of instruments was kept below the number of cross-sectional units. In this study, only the Liberal Democracy Index was instrumentalized.

3.3 Data

The dataset comprises a panel structure of 25 countries spanning the period from 2005 to 2021. The description of the variables and the descriptive statistics are presented in Tables 1 and 2:

Table 1. Variables and Sources

Variable	Description	Source
Environmental Taxes	Taxes levied on physical units that generate negative environmental impacts (energy, transportation, pollution, and resources). Measured as a percentage of GDP and total tax revenue.	EM-DAT
Liberal Democracy	Liberal democracy prioritizes the protection of individual and minority rights against oppression by the state and the majority. It ranges from 0 (not at all democratic) to 1 (completely democratic).	V-DEM
Frequency of disasters	Frequency of natural disasters.	EM-DAT
Number of people affected by natural disasters	The number of people requiring immediate assistance during the emergency period because of the disaster, whether for medical assistance or due to material losses.	EM-DAT
Number of deaths caused by natural disasters	Sum of all confirmed deaths directly attributed to the disaster and of missing people whose location remains unknown.	EM-DAT
Total Population	The total number of inhabitants residing in a territory.	World Population Prospects
Index of affected by disasters	Number of affected plus the number of deaths from disasters, divided by the population size.	Author's own elaboration
Rule of Law	This indicator measures the degree to which individuals trust and comply with societal rules. These indicators include perceptions of crime incidence, the effectiveness and predictability of the judicial system, and the ability to enforce contracts. Together, these elements measure society's success in creating an environment where fair and predictable rules form the	V-DEM

	basis of economic and social interactions, as well as the degree of protection of property rights. Varies from -1 to 2.	
Commercial Services Exports	Encompasses international service transactions, recorded in the Balance of Payments, excluding those related to government that do not involve remuneration and those related to goods (merchandise). Measured in current US$.	WTO
Merchandise Exports	Covers all physical goods that cross international borders and are recorded in customs statistics. Measured in current US$	WTO
Machinery Exports	Includes industrial and agricultural machinery, electrical equipment, information technology devices, and high-precision transport. Measured in current US$.	WTO
Commodity dependency index	(Merchandise exports - Machinery exports) / (Commercial services exports + Merchandise exports).	Author's own elaboration
GDP *per capita*	GDP is divided by population size.	World Bank
Gini Index	Inequality in the distribution of income within a given population.	World Bank
Population Density	Total number of inhabitants by territorial size.	World Population Prospects

Source: Authors' elaboration.

Table 2. Descriptive Statistics

Variable	Min	1st Qu	Median	Mean	3rd Qu.	Max
Environmental Tax	0.22	1.25	2.12	1.91	2.51	4.01
Liberal Democracy	20.70	65.8	80.4	72.4	83.7	87.2
Frequency of disasters	0.00	1.00	2.0	4.05	4.00	43
Gini Index	36.82	45.64	49.8	51.07	56.78	74.64
GDP per capita	0.17	0.47	1.49	68.84	3.82	1444.2
Population density	2.63	41.21	92.4	141.66	197.61	1331.15
Commodity dependency index	0.02	0.08	0.11	0.13	0.15	0.52
Total Tax Revenue	7.90	13.78	20.52	18.89	23.61	27.21
Rule of Law	-0.97	0.38	1.26	0.87	1.61	1.99

Source: Authors' elaboration.

The dependent variable of this study is the environmental tax revenue, as defined by the Organization for Economic Co-operation and Development (OECD). It corresponds to the sum of revenue collected by the State on four categories: energy, transport, pollution, and resources. Energy taxes cover taxes on energy products used for transport and stationary purposes, such as fossil fuels and electricity. Transport taxes refer to the ownership and use of motor vehicles, as well as related equipment and services, such as taxes on flights. Pollution taxes are levied on emissions into the air and water, as well as on the generation of solid waste. Finally, resource taxes cover taxes on the extraction of raw materials such as water, sand, and minerals. As shown in Table 2, environmental

taxation in the heterogeneous sample of 25 countries accounts for an average of 1.88% of GDP, a value slightly lower than the average for OECD countries, which is 2.3% (OECD, 2023).

The explanatory variable of interest is the Liberal Democracy Index. Democracies, in general, tend to exhibit greater adherence to international treaties and higher environmental performance. This pattern reflects regime characteristics, such as political participation and the protection of civil rights, which enable citizens to organize against environmental degradation and demand stricter regulation (Neumayer, 2002; Li and Reuveny, 2006). Beyond regime type, it is also important to identify which institutional dimensions are most closely associated with the adoption of sustainable environmental policies (Dasgupta and De Cian 2018; Escher and Walter-Rogg 2018). In this context, both democracy and institutional quality are expected to exert a significant and positive influence on environmental taxation. Building on this foundation, additional variables are introduced to capture a broader range of influences.

To account for climate-related pressures, EM-DAT data were used to construct two control variables: the annual frequency of natural disasters and an index of people affected by such events. The latter was calculated as the sum of individuals affected and disaster-related deaths, divided by the total population (see Table 1). Although no empirical studies directly examine the link between environmental taxation and natural disasters, the literature suggests that such events create "windows of opportunity" for political change. Media attention and heightened social vulnerability in the aftermath of extreme weather events often generate political pressure for policy responses (Acemoglu and Robinson, 2001; Pelling and Dill, 2010; Rydén et al., 2024). This approach allows testing whether countries facing recurrent climate stress employ environmental taxation as a long-term mitigation strategy.

A commodity dependency index was also developed using foreign trade data from the World Trade Organization (WTO). While trade openness is commonly included in models explaining environmental impacts, as it can shape domestic production and consumption patterns and encourage efficiency gains through comparative advantage and technological diffusion (Li and Reuveny 2006), openness alone does not capture the environmental intensity of export composition. Recent studies have shown that countries with export portfolios concentrated in primary commodities, especially agricultural goods, tend to exacerbate specific environmental impacts, notably methane (CH_4) and nitrous oxide (N_2O) emissions (Saeed and Ghimire, 2022; Saghaian, Mohammadi, and Mohammadi, 2022). Therefore, higher commodity dependence is expected to have a positive impact on environmental taxation, given the adverse ecological consequences of this production structure.

Finally, several standard control variables were included: per capita income, population density, total tax revenues, and the Gini index. Per capita income influences both institutional quality and environmental taxation. Wealthier countries not only raise more fiscal resources but also possess

greater capacity to finance socio-environmental policies, experience stronger societal pressure for green measures, and exhibit higher administrative capacity to design and enforce environmental taxes (Castiglione, Infante, and Smirnova 2014). Inequality, by contrast, is expected to hinder the adoption of taxation and green policies, as greater disparities undermine social cohesion and reduce support for fiscal reforms targeting environmentally harmful activities (Boyce 1994; Kashwan 2017). Population density is widely used as a proxy for urban pressure, as densely populated areas typically exhibit more intensive consumption and production, which generate environmental stress and, consequently, a greater demand for regulatory instruments (Li and Reuveny 2006; Povtika 2018). Lastly, total tax revenues capture state fiscal capacity: in general, higher tax-to-GDP ratios indicate greater room to introduce or expand environmental taxes without jeopardizing budgetary stability.

4 RESULTS

Table 3 presents the results of four estimation models, with the GMM-System estimation being the focus of this work. The estimations in first difference (FD), fixed effects (FE), and feasible generalized least squares with fixed effects and instrumental variables (FGLS-IV) serve as a robustness check. Although the FGLS-IV and GMM-System models present unbiased estimates for the coefficient of the variable of interest, GMM-System models tend to be more efficient when dealing with multiple instruments or heteroscedastic errors (Abrevaya and Donald, 2017).

Both statistical tests employed indicate the validity of the model. The Hansen test does not reject the null hypothesis of the joint validity of the instruments, and the null hypothesis of the AR(2) test is also not rejected, suggesting that the error term does not present serial autocorrelation.

Table 3. Results

	Dependent Variable: Environmental Tax (%GPD)			
	FD	**FE**	**FGLS-IV**	**GMM-Sys**
Liberal Democracy, lagged	0.018*	0.030**	0.019*	0.043*
	(0.007)	(0.007)	(0.011)	(0.023)
Index of affected by natural disasters, lagged	-0.0005	-0.002	0.004	-0.002
	(0.004)	(0.001)	(0.002)	(0.003)
Frequency of disasters, lagged	-0.003	-0.012	-0.001	-0.010
	(0.005)	(0.011)	(0.004)	(0.015)
Gini Index, lagged	-0.025***	-0.003	0.033*	-0.034
	(0.009)	(0.014)	(0.017)	(0.024)
Population density, lagged	-0.025**	0.001	-0.012	0.001
	(0.009)	(0.008)	(0.010)	(0.001)
GDP *per capita*, lagged	0.005**	0.003*	2.078***	0.001**
	(0.003)	(0.003)	(0.608)	(0.0003)

Commodity dependency index, lagged	1.294	-0.063	-2.740*	-1.316
	(-1.000)	(1.311)	(1.381)	(1.537)
Total tax revenue, lagged	0.003	0.084***	0.025	0.060**
	(0.014)	(0.021)	(0.018)	(0.028)
Rule of Law, lagged	0.177	-0.833***	-0.566***	-0.663*
	(0.149)	(0.291)	(0.183)	(0.366)
Observations	180	180	180	236
N. of countries	24	24	24	25
Instruments			22	22
Hansen test of overidentification (p-value)				0.156
Arellano-Bond AR(2) test (p-value)				0.123
Adjusted R^2	0.1	0.08		

Source: Author's elaboration.
Note:
1. Below the coefficients we report the standard errors.
2. Windmeijer (2005) heteroscedasticity correction is applied to the standard errors.
3. Unobserved individual effects are removed by first differencing in all models.
4. All the control variables are considered strictly exogenous in the FGLS-IV and GMM-System models.
5. From the second to the sixth lag of the first difference of the endogenous variable, Liberal Democracy, were used as instruments for the lagged endogenous variable in the FGLS-IV model. Likewise, from the second to the sixth lag of the endogenous variable, both in levels and in first differences, were used as instruments for the endogenous variable in the GMM-System model.
6. We have collapsed the instruments in order to restrict the number of instruments in the GMM-System model (Roodman, 2009).
7. The Hansen test: the null hypothesis is that the instruments are not correlated with the residuals.
8. The Arellano-Bond test for AR(2) in first difference: the null hypothesis is that the errors in the first difference regression have no second order serial correlation.
9. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.10$

The estimates corroborate the central hypothesis of this study, indicating that countries with higher democratic quality are more likely to adopt green taxation. At the 10% significance level, a 1-unit increase in the liberal democracy index in the previous year is associated with a 0.043 percentage-point increase in environmental taxes as a percentage of GDP in the current year. The liberal component of democracy protects individual and minority rights. In practice, this dimension encompasses constitutionally guaranteed civil liberties, an independent judiciary, the rule of law, and institutional checks and balances that constrain executive power. The positive effect found here is consistent with Escher and Walter-Rogg (2018) and Von Stein (2022), reinforcing the idea that civil rights protections foster a more transparent political environment, greater access to information, and, in turn, higher public awareness of environmental challenges. Moreover, freedom of association facilitates collective organization and resource mobilization, creating channels for citizens to pressure governments into adopting green policies.

The estimates for the remaining variables should be interpreted with caution, as they were not instrumentalized in the model and may be subject to bias. Only the variable of interest yields a coefficient robust to endogeneity and omitted variable bias; the others are included as controls to refine the relationship between democracy and environmental taxation.

Within the domain of democratic quality, the Rule of Law index captures social trust in institutions, judicial effectiveness, contractual protection, and enforcement of property rights. These elements are theoretically expected to foster environmental policies. Surprisingly, however, the model reveals that a one-unit increase in the rule of law index in the previous year reduces environmental tax revenues by 0.66 percentage points of GDP in the current year. This finding contrasts with prior studies, such as those by Castiglione, Infante, and Smirnova (2018) and Castiglione et al. (2014), which report positive and significant effects.

Natural disasters and the number of affected individuals did not show statistical significance. Although no prior studies have directly linked these variables to environmental taxation, the literature suggests that extreme events can operate as "windows of opportunity," triggering stronger civic engagement and pressure for reform, and potentially yielding temporary improvements in democratic quality (Acemoglu & Robinson, 2001; Rydén et al., 2024).

Per capita income is positive and statistically significant at the 5% level, aligning with expectations. This result is consistent with the Environmental Kuznets Curve hypothesis, which posits that environmental degradation tends to increase in the early stages of economic growth before declining at higher income levels. The linear positive effect may also reflect the greater institutional and administrative capacity of wealthier countries to implement environmental policies (Castiglione, Infante and Smirnova, 2014; Povtíkina, 2018).

Population density, included as a control to capture the effects of demographic concentration, did not reach statistical significance. While denser populations are often associated with higher consumption and production pressures that could stimulate demand for regulatory instruments such as taxation, the empirical results do not support this expectation (Li and Reuveny, 2006; Povtíkina, 2018).

Neither commodity dependence nor the Gini index presents statistical significance. Saghaian, Mohammadi, and Mohammadi (2022) argue that the expansion of agricultural exports in developing countries undermines environmental quality, yet such structural effects do not appear to translate into higher environmental taxation.

Finally, total tax revenue exerts a positive and significant effect on the dependent variable. A broader tax base tends to signal greater state capacity, not only in terms of revenue collection but also in the institutional ability to design and administer complex fiscal instruments.

5 FINAL REMARKS

In light of the ecological and socioeconomic challenges posed by the climate crisis, governments must adopt public policies that promote sustainable development. The academic literature broadly suggests that democracies outperform non-democracies in environmental policy, as they are more

likely to ratify international agreements, reduce pollution, and allocate larger areas of land for conservation. These outcomes are often attributed to electoral competition and the protection of civil and political rights (Neumayer, 2002; Escher and Walter-Rogg, 2018; Li and Reuveny, 2006).

Nonetheless, the effectiveness of democracies in environmental governance is far from uniform. Outcomes depend on institutional quality, corruption levels, and the representativeness of political systems that incorporate diffuse interests, such as environmental protection (Fredriksson and Wollscheid, 2007; Lisciandra and Migliardo, 2017; Povtíkina, 2018).

Within this context, taxation represents a key policy instrument for advancing environmental goals. By imposing higher taxes on activities, sectors, or products with negative environmental externalities, governments can simultaneously shape behavior and generate revenue to finance mitigation measures (Moura, 2016; Williams, 2016). Nevertheless, the literature on how institutional determinants affect green taxation remains limited, with most studies focused on European countries and the rule of law (Castiglione, Infante & Smirnova, 2014, 2018).

This study contributes to closing this gap by analyzing the effects of democratic and institutional quality on environmental taxation. Employing a system-GMM model for a panel of 25 countries from 2005 to 2021, the analysis treats the liberal democracy index as the key explanatory variable, instrumented with its lags, while other controls are lagged. This approach yields consistent estimates even in the presence of endogeneity (Roodman, 2009) and is particularly suitable for dynamic panels where past institutional conditions shape current fiscal outcomes (Imai & Kim, 2019).

The results demonstrate that improvements in democratic quality are positively associated with environmental taxation, suggesting that more open and responsive political systems are better equipped to adopt fiscal measures that support sustainability. The Liberal Democracy Index (Coppedge et al., 2025) shows a significant and positive coefficient. Statistical tests (Hansen and Arellano-Bond) confirm the validity of instruments and the absence of serial correlation in the error term.

Beyond methodological rigor, this study makes a significant contribution by including a sample that is not limited to developed countries, indicating that the positive democracy–taxation nexus holds across diverse socioeconomic contexts. The findings thus offer relevant policy insights: strengthening civil and political rights, transparency, and equality before the law may be as important as technical reforms for financing the ecological transition. In this sense, climate and democratic challenges should be treated as mutually reinforcing agendas.

That said, limitations remain. The dataset covers only 25 countries, excluding those without reliable data on environmental taxation. Furthermore, only the liberal democracy index was instrumented, while other controls, such as income inequality and commodity dependence, may still

be subject to bias. Finally, the environmental taxation indicator is aggregated, encompassing energy, transport, natural resources, and pollution taxes without distinguishing among them.

Future research could address these limitations by expanding the sample to additional regions and time periods, and by adopting more disaggregated measures, such as specific carbon taxes or alternative dimensions of democracy. Such approaches would further clarify the political and institutional conditions under which democratization drives environmental fiscal policies.

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APPENDIX

List of countries included in the model:

Argentina	Costa Rica	Greece	Latvia	Philippines
Austria	Germany	Hungary	Mexico	Portugal
Australia	Ecuador	Ireland	Malta	United States
Belgium	France	Italy	Malaysia	South Africa
Switzerland	United Kingdom	Lithuania	Peru	Bulgaria