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Revisiting the impact of political corruption on environmental policies by using data from 40 countries

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Abstract

Background: Political corruption undermines the effectiveness of environmental governance by eroding institutional capacity, distorting regulatory frameworks, and weakening policy enforcement. This study revisits the relationship between political corruption and environmental policy stringency (EPS), focusing on how corruption influences the strength of environmental regulations across countries and over time.

Methods: A cross-national time-series analysis is conducted for 40 countries from 1990 to 2020 using data from the V-Dem Political Corruption Index and the OECD Environmental Policy Stringency Index. The baseline estimation employs a two-way fixed-effects model, complemented by robustness checks using Panel-Corrected Standard Errors (PCSE), Feasible Generalized Least Squares (FGLS), and System Generalized Method of Moments (System GMM).

Findings: Results consistently demonstrate that higher political corruption is significantly associated with lower environmental policy stringency. Corruption weakens institutional oversight and enforcement capacity, thereby reducing governments' ability to implement stringent regulations. Unexpectedly, the negative effect of corruption is more pronounced in developed countries, likely reflecting subtler, institutionalized forms such as regulatory capture and corporate lobbying.

Conclusions: While institutional maturity can limit overt corruption, it does not fully shield advanced economies from its environmental consequences. These findings highlight that anti-corruption reforms should be integral to strategies for strengthening environmental governance.

Keywords: Political corruption, Environmental policy, Stringency, Developed countries, Developing countries, Panel data, EPS Index

1 Introduction

Environmental degradation has emerged as one of the most pressing and globally recognized challenges of our time. Its consequences extend beyond ecological systems, posing direct threats to human well-being, economic stability, and long-term global security [1–3]. Although national governments and international organizations have implemented a wide range of initiatives to address these challenges, progress toward

key environmental targets remains uneven and often falls short of expectations [4]. This persistent gap between commitments and outcomes raises fundamental questions about the institutional and political conditions that enable—or undermine—effective environmental governance [5–7].

A growing body of research highlights that achieving meaningful environmental outcomes requires not only the existence of environmental policies but also policies that are stringent, enforceable, and credibly implemented [8–10]. In this regard, the concept of *environmental policy stringency (EPS)* has become central to evaluating governments' true commitment to environmental protection. The OECD Environmental Policy Stringency Index has been widely adopted as a standardized, cross-national measure capturing how strongly environmental policies impose binding constraints on polluting behavior [11–16].

However, while economic and social determinants of environmental policy stringency have been extensively studied, the political and institutional foundations of environmental regulation remain less understood [17, 18]. In particular, the role of political corruption—the abuse of public power for private or partisan gain—has gained increasing attention as a critical but underexplored factor shaping environmental policy outcomes [19–22]. Political corruption can distort policy design, weaken enforcement, and divert resources from public to private interests, thereby undermining state capacity to implement strong environmental regulations. Yet, despite its significance, much of the existing literature relies on broad or perception-based corruption measures, limiting the precision with which corruption's impact on environmental policymaking can be assessed [19, 23].

This study addresses these gaps by asking two central research questions:

(1) Does higher political corruption lead to weaker environmental policy stringency?
(2) Does this effect differ between developed and developing countries?

To answer these questions, we use a cross-national time-series (CNTS) dataset combining the Varieties of Democracy (V-Dem) Political Corruption Index (PCI) with the OECD Environmental Policy Stringency Index, covering 40 countries from 1990 to 2020. The V-Dem PCI provides a multidimensional and expert-coded measure of political corruption across the executive, legislative, and judicial branches, capturing both overt and institutionalized forms of misconduct [24]. This approach enables a more nuanced investigation of how corruption interacts with institutional capacity, political accountability, and policy enforcement across different economic contexts.

In doing so, this study advances understanding of the political drivers of environmental governance in three key ways:

- First, it conducts a cross-national time-series analysis of the relationship between political corruption and environmental policy stringency (EPS) for 40 countries from 1990 to 2020. This design enables a systematic assessment of how changes in corruption relate to variations in environmental regulatory strength within and across countries over time.

- Second, it applies the V-Dem Political Corruption Index, a multidimensional and empirically grounded measure that captures corruption across the executive, legislative, and judicial spheres. By moving beyond perception-based metrics, the study provides a more rigorous and institutionally specific assessment of political corruption's influence on environmental policymaking.
- Third, it compares the potentially differing effects of corruption on EPS between developed and developing countries can shape the nexus of corruption and environmental policy stringency differently.

We complement the core analysis with a range of political, economic, and structural controls and employ robust econometric approaches to ensure the validity of our findings. By integrating political corruption into the analysis of environmental regulation, this study advances a more nuanced understanding of how governance quality shapes states' ability to pursue stringent environmental action. Based on this discussion, we propose two hypotheses to guide the empirical analysis:

- H1: Higher levels of political corruption are associated with lower levels of environmental policy stringency.
- H2: The negative effect of political corruption on environmental policy stringency is stronger in developing countries than in developed countries.

The remainder of the paper proceeds as follows. Section 2 reviews the literature on the determinants of environmental policy stringency and introduces the conceptual framework and hypotheses. Section 3 outlines the data, variables, and empirical strategy. Section 4 presents the main results and robustness tests. Section 5 discusses the mechanisms underlying our findings and their implications for environmental governance and anti-corruption policy.

2 Literature review

2.1 Economic determinants of environmental policy: beyond the income-stringency nexus

A substantial literature confirms that wealthier nations adopt more stringent environmental regulations than poorer counterparts [25–27]. This income-stringency relationship has been theorized through the Environmental Kuznets Curve (EKC) framework, which posits that environmental degradation initially increases with development but declines after surpassing an income threshold [28–30]. Two mechanisms underpin this transition: first, administrative capacity and fiscal resources enable stricter regulation once degradation threatens growth [5, 31]; second, affluent publics prioritize post-materialist values, threatening environmental quality as a "luxury good" whose demand rises with income [32–34].

Yet, this demand-side account faces two critical empirical challenges. First, substantial variation in EPS persists even among high-income democracies with similar GDP levels [6, 35], suggesting that economic affluence is necessary but insufficient to guarantee regulatory ambition. Second, spatial econometric studies reveal that 30 to 50% of cross-national EPS variation stems from regional spillover effects and policy diffusion rather than domestic income alone [7, 35–37]. These findings indicate that economic capacity

does not automatically translate into policy commitment—a discrepancy that points to intervening political and institutional factors.

Beyond income, researchers identified three structural channels through which economic composition shapes EPS: manufacturing sector concentration creates organized lobbying pressures [26]; trade openness generates regulatory competition dynamics [5]; and social factors such as urbanization, generalized trust, and perceived environmental risk influence public demand for regulation[38–41]. However, these studies reach contradictory conclusions about whether openness strengthens or weakens stringency, and whether social capital complements or substitutes for formal regulation [5, 42]. Such inconsistencies suggest these economic and social factors operate conditionally—their effects likely mediated by domestic political institutions that determine whether structural pressures become binding policy constraints [31]. Therefore, what remains theoretically unresolved is why similar wealthy, democratic countries with comparable public environmental preferences exhibit divergent regulatory stringency. This puzzle cannot be explained by income thresholds, social capital, or regional diffusion alone. Instead, it directs attention towards political-institutional variables, particularly the quality of governance and the integrity of policymaking processes. These variables serve as decisive factors that convert economic capacity and social demand into actual regulatory outcomes. This motivates our focus on political corruption as a potential structural constraint that may undermine environmental policy stringency in different regions with dissimilar economic and social conditions.

2.2 Political institutions and environmental policy: why democracies differ

Comparative research consistently finds that democratic regimes adopt more stringent environmental policies than autocracies, attributable to electoral accountability, civil liberties that enable citizen mobilization, and pluralistic competition that amplifies their environmental demand [43–47]. Barrett and Graddy [44] emphasize that political and civil freedom are necessary conditions for the income-environment relationship theorized in the EKC framework to operate, as citizens must be able to articulate and organize around their political and post-materialist preferences. Yet, substantial variation in environmental policy stringency persists across democracies with comparable levels of freedom and development [13, 16, 19, 42], suggesting that regime type alone cannot explain policy outcomes.

Scholars have thereby examined institutional design features within democracies—including electoral systems, legislative structures, and power-sharing arrangements. Some find that parliamentary systems outperform presidential ones due to greater legislative cohesion [48], while others identify proportional representation as facilitating broader environmental coalitions [49, 50]. Neo-corporatist structures and two-party coalitions have likewise been associated with higher stringency [6, 51]. However, these findings remain contradictory: Scruggs [50] finds no systematic advantage for parliamentary systems, while Vogel [52], analyzing Japan, the United States, and the United Kingdom, concludes that institutional form matters less than the level of public pressure exerted on political entities. These inconsistencies suggest that formal institutional configurations do not mechanically determine policy stringency; rather, their effects depend on whether institutions function with integrity and responsiveness [5].

This realization directs attention toward state capacity—the government's ability and willingness to implement commitments [53]. Political institutions may enable responsiveness, but actual regulatory outcomes depend on whether the state possesses the legitimacy, coherence, and autonomy to enforce regulation [31]. Critically, Bäck and Hadenius [54] demonstrate that the relationship between democracy and state administrative capacity is non-linear, but rather a J-shaped pattern. Their findings explain why similarly democratic states exhibit divergent governance quality—democracy alone is insufficient without complementary state capacity.

From past scholarship, among the most persistent threats to effective state capacity is political corruption [19]. Corruption weakens environmental governance by allowing public officials to pursue personal or political gains at the expense of public interest, manifesting in lax enforcement, underreporting of emissions, regulatory capture, or clientelist appointment of unqualified personnel [21, 55–58].

The theoretical implication as such is clear: variation in EPS across similarly democratic and wealthy states cannot be attributed solely to differences in institutional establishment or public preferences. Instead, it likely reflects variation in the integrity of the political process—that is, the extent to which corruption distorts policy formulation, weakens enforcement credibility, and erodes public trust in environmental commitments [59–62]. This recognition motivates a systematic examination of how political corruption, as a structural constraint operating across regime types and institutional configurations, disrupts environmental policymaking with enduring implications for regulatory effectiveness [63].

2.3 Political corruption and environmental policy: mechanisms and contradictions

The relationship between political corruption and environmental policy stringency has primarily operated through three distinct causal pathways. First, enforcement capture: corruption officials' bribes to overlook violations, undermining the credibility of monitoring systems and reducing the deterrent effect of regulation [55, 64]. Second, legislative capture: corruption distorts policy formulation itself, as interest groups seek regulatory leniency, offering financial or political favors in exchange for weaker standards [57, 65]. Third, trust erosion: when citizens perceive political processes as corrupted, public compliance norms weaken, and pro-environmental collective actions become more difficult to sustain [66]. While these mechanisms are conceptually distinct, existing corruption measures that are predominantly aggregate indices capturing overall "corruptibility" or "corruption control" cannot empirically distinguish which pathway dominates in each given context. Moreover, these indices aggregate diverse institutional determinants of corruption (legal system, press freedom, political instability) identified by Pellegrini and Gerlagh [67], making it difficult to isolate whether corruption's environmental effects operate through executive, legislative, or judicial channels.

Empirical studies broadly confirm that corruption undermines environmental stringency. Fredriksson et al. [65], analyzing 12 OECD countries, find that higher corruption (measured via Transparency International's CPI) associates with weaker energy policy stringency, attributing this to greater susceptibility to industry lobbying. Chen et al. [64] show that corrupt officials in Chinese provinces weaken enforcement even when formal regulations appear stringent. Balsalobre-Lorente et. al. identify similar negative

associations across APEC countries. However, this consensus is not universal. Fredriksson et al. [68] find that lobbying intensity positively predicts Kyoto Protocol ratification, and this effect is amplified under more corrupt regimes—suggesting corruption can sometimes reinforce environmental commitment when aligned with pro-environmental lobbying interests. These contradictory findings reveal a critical theoretical insight, which is that corruption's effect depends not merely on its presence, but on who captures political processes and what institutional safeguards exist to resist capture.

This insight is reinforced by research identifying moderating factors. For instance, Fredriksson and Svensson [69] show that political instability reduces corruption's negative effect by lowering expected returns on bribery. Fredriksson and Vollebergh [70] demonstrate that social trust mitigates corruption's harm by strengthening environmental group mobilization. Economic variables, including developmental level [71, 72], shadow economy size [73], and trade openness [74], further condition how corruption shapes regulatory outcomes.

Collectively, these moderators suggest that corruption does not exert uniform effects across contexts. Rather, its impact varies with the institutional vulnerability to specific capture mechanisms—a pattern that may explain why, in different contexts, institutions remain susceptible to some forms of regulatory influence than others. Yet while these studies establish that corruption operates through enforcement, legislative, and trust-based channels, two critical ambiguities persist. First, theoretical questions remain whether corruption's effects differ systematically between developed and developing countries, and whether institutional safeguards can fully compensate for corruption's harm. Second, methodological limitations constrain our ability to adjudicate between competing mechanisms, as existing measures do not directly operationalize political corruption or enable cross-regional comparisons [19, 23]. The following synthesis evaluates these unresolved puzzles and identifies pathways for empirical advancement.

2.4 Synthesis and research gap

The preceding review establishes three foundational insights. First, economic affluence and democratic institutions are necessary but insufficient conditions for stringent environmental policy. As shown by past scholarship, substantial variation persists among wealthy democracies, and economic capacity does not automatically translate into regulatory ambition (Sect. 2.1). Second, this variation reflects differences in state capacity and institutional integrity, particularly the extent to which political corruption distorts policymaking and enforcement (Sect. 2.2). Third, corruption operates through multiple pathways: enforcement capture, legislative distortion, and trust erosion, but its effects are conditional on institutional safeguards, development levels, and the nature of interest group mobilization (Sect. 2.3).

Yet two theoretical puzzles remain unresolved. First, why do countries with comparable wealth, democratic structures, and public environmental preferences adopt divergent regulatory stringencies? Second, does corruption exert uniform negative effects across development levels, or do distinct capture mechanisms operate differently in developed versus developing contexts? Resolving these puzzles requires addressing two empirical constraints that limit existing research. First, perception-based corruption indices (CPI, ICRG) do not directly operationalize political corruption across governmental branches,

preventing mechanism-specific hypothesis testing. Second, the regional sample (EU, APEC, BRICS) precludes systematic comparisons between developed and developing contexts.

We address these gaps by (1) employing the V-Dem Political Corruption Index, which measures corruption across executive, legislative, and judicial branches; (2) analyzing 40 countries spanning OECD and non-OECD contexts, enabling us to test whether corruption's effects on environmental policy stringency differ systematically by development level.

2.5 Hypotheses

Building on the theoretical insights derived from Sects. 2.1, 2.2, 2.3, we argue that political corruption systematically weakens environmental policy stringency through three interrelated pathways. First, enforcement capture occurs when corrupt officials accept bribes or political favors to overlook violations, eroding the credibility of monitoring and sanctioning mechanisms. Second, legislative capture arises when policymakers receive rent-seeking incentives from interest groups seeking lenient standards or exemptions, leading to diluted or selectively enforced regulations. Third, trust erosion reduces public compliance and support for environmental initiatives, as corruption undermines confidence in the fairness and legitimacy of governmental processes. Collectively, these mechanisms diminish both the formulation and implementation of stringent regulation, transforming economic and institutional capacity into symbolic rather than substantive commitments. Accordingly, we expect that higher levels of political corruption will be associated with lower overall environmental policy stringency.

H1 Political corruption undermines environmental stringency.

Conventional expectations from the EKC and governance literature suggest that economically developed countries should be more resilient to corruption's harmful effects on environmental policy. Advanced economies typically possess stronger institutional frameworks—characterized by professionalized bureaucracies, independent judiciaries, and robust transparency mechanisms—that constrain corrupt actors and reduce the scope for enforcement and legislative capture [67, 71, 72, 75]. Higher levels of social trust and civic engagement further strengthen institutional integrity by increasing the reputational and political costs of rent-seeking behavior. Publics in these societies also tend to exhibit greater environmental awareness and stronger demands for regulatory quality, thereby heightening electoral accountability and limiting opportunities for corrupt interference in environmental policymaking [40, 76].

By contrast, developing countries often face weaker administrative capacity, fragmented enforcement agencies, and limited checks on executive and legislative discretion, creating fertile ground for corruption to influence both policy design and implementation. Under such institutional settings, enforcement capture becomes more pervasive as limited oversight allows violations to go unpunished, legislative capture intensifies as policymakers rely on clientelist or industry-based exchanges, and trust erosion deepens as citizens lose confidence in the fairness and legitimacy of environmental regulation [40, 67, 76]. Consequently, corruption exerts a more pronounced negative effect on

environmental policy stringency in developing contexts, where institutional and societal safeguards are insufficient to prevent these distortionary dynamics.

H2 The negative effect of political corruption on environmental policy stringency is weaker in developed countries than in developing countries.

3 Methods

3.1 Study focus and key variables

This study employs a cross-national time-series (CNTS) analysis to examine the effect of political corruption on environmental policy stringency (EPS), with the unit of analysis being the country-year. Because the OECD Environmental Policy Stringency (EPS) Index—the most comprehensive and methodologically consistent cross-national dataset of its kind—provides data for a limited number of countries and years, the analysis is restricted to 40 countries over the period 1990–2020. The dataset covers countries for which reliable and consistent information on environmental policy instruments is available, primarily in the areas of climate change and air-pollution mitigation. Specifically, it includes 34 of the 38 OECD member countries (excluding Colombia, Costa Rica, Latvia, and Lithuania due to data unavailability) and six non-OECD emerging economies—Brazil, China, India, Indonesia, Russia, and South Africa. While the sample captures considerable variation in economic development, institutional capacity, and governance systems, it remains weighted toward OECD and upper-middle-income countries, reflecting the current scope of the EPS dataset.

The EPS Index measures the degree to which environmental policies impose regulatory or fiscal costs on polluting activities, ranging from zero (least stringent) to six (most stringent). It is constructed from 13 policy instruments grouped into three sub-indices: market-based policies (e.g., carbon taxes, emissions-trading schemes, and fuel taxes), non-market-based policies (e.g., emission limits and performance standards), and technology-support policies (e.g., public R&D funding and renewable-energy incentives). This multidimensional framework captures the economic, regulatory, and innovation-driven pillars of environmental governance. By integrating these complementary policy domains, the EPS Index provides a comprehensive measure of the diverse strategies countries employ to address environmental challenges through pricing mechanisms, regulatory standards, and technological support.

For the key explanatory variable, we used the V-Dem Political Corruption Index, a composite measure that evaluates corruption across the executive, legislative, and judicial branches on a scale from 0 to 1, where higher values indicate greater political corruption. This indicator aggregates six distinct dimensions of political corruption, capturing both bribe-taking and embezzlement within the executive and administrative sectors, as well as undue influence and irregularities within the legislature and judiciary. This multidimensional approach allows the index to reflect not only the prevalence of corruption but also the institutional arenas through which it operates.

The V-Dem measure is particularly suitable for this study because it directly operationalizes political corruption, rather than relying solely on broad perceptions of integrity or corruption control, as do indices such as the CPI or the ICRG. Its disaggregated

design enables cross-national comparisons of how corruption manifests across branches of government, which is theoretically consistent with our focus on enforcement capture, legislative capture, and trust erosion as distinct causal pathways. Moreover, V-Dem's expert-coded methodology provides higher temporal consistency and institutional sensitivity, which are crucial for detecting within-country variation over time and for distinguishing between formal rules and actual governance practices [87]. Combined, these features make the V-Dem Political Corruption Index a conceptually valid and empirically robust measure for assessing how different forms of political corruption constrain environmental policy stringency across countries and development levels.

3.2 Control variables

In addition, we include a set of control variables identified in the existing literature as potential factors influencing environmental policy stringency (EPS). These variables are defined in Table 1, with descriptive statistics and the correlation matrix presented in Table 2. Although some correlations among the explanatory variables are relatively high in the correlation matrix—particularly between Democracy and Corruption (−0.83), Economic Development and Corruption (−0.75), Economic Globalization and Economic Development (0.72), and Population Density and Economic Development (0.69)—we formally tested for multicollinearity using Variance Inflation Factors (VIFs). The results, reported in Table 6 in Appendix, show that all VIF values remain below the commonly accepted threshold of 10 (mean VIF = 2.88), with the highest values observed for Corruption (4.94) and Economic Development (4.41). These diagnostics indicate that while moderate intercorrelations are present, their influence appears manageable within the model specification and does not materially distort the estimated relationships.

- Democracy: Democracy reflects the extent to which political power is distributed through free and fair elections, ensuring accountability and citizen participation in governance. Leaders in democratic systems are incentivized to prioritize policies, including environmental ones, that align with public preferences to secure re-election and maintain political survival [77]. Democratic institutions also promote transparency and reduce corruption, fostering stronger enforcement of environmental regulations [77].
- Elections: Elections are a fundamental aspect of democratic systems, enabling citizens to select their representatives and shape policy priorities. The prospect of re-election motivates leaders to implement policies that appeal to voters, including environmental measures, to avoid electoral punishment. However, the need to secure short-term voter approval may lead governments to prioritize immediate economic gains over long-term environmental sustainability [78].
- Economic development: Economic development reflects a country's level of wealth and industrialization, often measured through GDP per capita. Higher levels of economic development typically provide the financial resources and institutional capacity to implement and enforce stricter environmental policies [79].
- Economic globalization: Economic globalization might undermine EPS as it reflects a government's reliance on global economic activities such as trade, exports, and foreign investment. In highly globalized economies, governments

Table 1 Descriptive statistics

Variable	Description	Mean	SD	Min	Max	Source
EPS	OECD Environmental Policy Stringency (EPS) index is a tool used to measure how strictly a country's environmental policies are enforced. It ranges from 0 to 6, with 6 being the most stringent	1.9617	1.1659	0.0000	4.7222	[86]
Corruption	A composite index that assesses corruption across the executive, legislative, and judicial branches ranging from 0 to 1, with higher values indicating higher levels of corruption	0.1427	0.3500	0.0000	1.0000	[87]
Democracy	A continuous variable (ranging from 0 to 1) representing the level of democracy, calculated as the average of five V-DEM democracy scores for each country-year	0.7001	0.1676	0.0734	0.8608	[87]
Election	A binary variable of whether a legislative or presidential election is held, where 1 indicates such election is taking place, 0 otherwise	0.3124	0.4637	0.0000	1.0000	[88]
Economic Development	GDP Per Capita in Current US Dollars (logged)	9.8165	1.1036	5.7133	11.7254	[89]
Economic Globalization	Economic globalization exposure consists of two key dimensions: actual economic flows and restrictions on trade and capital. The sub-index on actual economic flows (includes data on trade, foreign direct investment), and portfolio investment. The sub-index on restrictions considers factors (includes hidden import barriers, mean tariff rates, taxes on international, and an index of capital controls). The composite index are measured on a scale from 0 to 100, where higher values indicate greater levels of globalization exposure	68.3004	15.0372	14.2600	93.5700	[90]
Manufacturing Sector	Value added by the manufacturing sector as a percentage of the national GDP	16.0326	5.2516	4.5500	34.8600	[89]
Population Density	De-facto population divided by land area within the national boundary in square kilometers (logged)	4.2733	0.2354	3.2406	4.5858	[89]

may be unwilling to implement stringent environmental policies due to fears of discouraging foreign investors or reducing the competitiveness of export-driven industries. This reliance on global markets can lead to weaker environmental regulations, as governments prioritize economic growth and integration over stringent environmental standards [80].

- Manufacturing sector: The manufacturing sector's resistance to EPS is often met with government unwillingness to enforce stricter regulations due to fears of economic repercussions, such as reduced industrial output or job losses. Governments reliant on manufacturing for economic growth or exports may prioritize industrial competitiveness over environmental sustainability, leading to weaker or delayed implementation of stringent environmental policies [81].

Table 2 Correlation matrix

	EPS	Corruption	Democracy	Election	Economic Development	Economic Globalization	Manufacturing Sector	Population Density
EPS	1							
Corruption	− 0.3671***	1						
Democracy	0.3216***	− 0.8349***	1					
Election	− 0.0255	− 0.0414	0.0468	1				
Economic Development	0.5806***	− 0.7529***	0.6136***	0.0364	1			
Economic Globalization	0.5452***	− 0.6782***	0.5911***	0.0112	0.7214***	1		
Manufacturing Sector	− 0.1853***	0.3525***	− 0.3643***	− 0.0160	− 0.3909***	− 0.2616***	1	
Population Density	0.1673***	− 0.5234***	0.4181***	0.0177	0.6908***	0.4078***	− 0.3848***	1

$p < 0.01$*, $p < 0.05$**, $p < 0.01$***. t-values are in the parentheses

- Population density**:** Population density affects EPS as governments in densely populated areas face greater pressure to protect larger populations from the adverse effects of pollution, resource scarcity, and environmental degradation. With more people impacted by environmental hazards, governments are incentivized to enforce stricter policies to ensure public health, maintain quality of life, and address urban challenges. In contrast, low-density countries may experience less pressure for stringent policies due to fewer people being directly affected by environmental issues [82].

3.3 Empirical modelling

Under a cross-national time-series (CNTS) framework, we examine the relationship between political corruption and environmental policy stringency (EPS). For the baseline estimation, we employ a two-way fixed-effects (2WFE) model that incorporates both country-fixed effects and year-fixed effects. This specification helps control for time-invariant country characteristics (such as geography, institutional history, and cultural background) and common time-specific shocks (including global economic fluctuations or international environmental commitments) that could otherwise bias the results. In this setup, the fixed-effects approach allows us to focus on within-country variation over time rather than on cross-country differences.

A Hausman test is conducted to evaluate whether the fixed-effects or random-effects estimator is more appropriate. The test result is statistically significant at the 5% level, indicating that the unobserved country-specific effects are correlated with one or more explanatory variables. In such cases, the random-effects estimator would produce biased and inconsistent coefficients because it assumes that these unobserved effects are uncorrelated with the regressors. By contrast, the fixed-effects approach explicitly allows for correlation between unit-specific characteristics and the explanatory variables by removing time-invariant components through

within-transformation. This makes it more suitable for our cross-national panel, where institutional, historical, and structural differences across countries are likely to influence both levels of corruption and environmental policy stringency. Hence, the fixed-effects model is preferred as it yields more consistent and reliable within-country estimates, focusing on how changes in corruption within each country over time are associated with changes in environmental policy stringency.

For the baseline results, we also adopt a stepwise modeling approach, gradually adding political, economic, and structural control variables to test the stability of the main relationship. This sequential approach helps to identify whether the estimated impact of corruption on EPS is sensitive to model specification or omitted-variable bias. By introducing the controls progressively, we can observe how the coefficient on corruption behaves across different specifications, which provides additional confidence that the relationship is not driven by unaccounted confounding factors. The baseline empirical model can therefore be expressed as:

$$EPS_{it} = a_0 + a_1 PolCor_{it} + a_2 X_{it} + c_i + y_t + e_{it} \quad (1)$$

where:

- EPS_{it} represents the environmental policy stringency score for country i at time t.
- Pol_{it} denotes the political corruption score for country i at time t.
- X_{it} is a vector of control variables in Sect. 4.2 accounting for other factors influencing EPS.
- c_i captures country-fixed effects.
- y_t captures year-fixed effects.
- e_{it} represents the error term.

In addition to the baseline regression results, a series of robustness checks was conducted to strengthen the validity of our findings and ensure that the observed relationship between political corruption and environmental policy stringency (EPS) is not driven by model specification or data limitations. These additional analyses were designed to address potential econometric concerns—particularly heteroskedasticity, autocorrelation, and endogeneity—that may bias or weaken standard fixed-effects estimates. The first robustness test involved examining cross-country heterogeneity by dividing the sample into developed and developing countries to assess whether the relationship between corruption and EPS varies across different levels of institutional and economic development, as hypothesized in H2. This analysis provides insight into whether structural and governance differences condition the impact of corruption on environmental regulation. To ensure consistency and comparability, we follow the International Monetary Fund's (IMF) widely used classification, which distinguishes between "Advanced Economies" (developed countries) and "Emerging Markets and Developing Economies." Following this categorization, 12 countries in our sample are classified as developing and 28 as developed, allowing for a systematic exploration of variation in the corruption–EPS nexus across economic contexts.

Next, to assess the robustness of parameter estimates to violations of ordinary least squares (OLS) assumptions, we employed Panel-Corrected Standard Errors (PCSE) and

Feasible Generalized Least Squares (FGLS) estimators. These methods explicitly account for heteroskedasticity and autocorrelation—two common problems in macro-panel data covering long time periods and multiple countries. The PCSE approach, following Beck and Katz [83], corrects for panel-specific heteroskedasticity and contemporaneous correlation across cross-sections, producing more reliable standard errors without altering coefficient estimates. Complementarily, the FGLS method re-estimates model coefficients using weighted least squares to provide more efficient and consistent results when the error variance is non-constant or correlated over time. Employing both estimators enables a robustness assessment under different assumptions about error structure, improving confidence in the stability of our results.

Finally, to mitigate endogeneity concerns—such as potential reverse causality or omitted variable bias—we applied the System Generalized Method of Moments (System GMM) estimator. This dynamic panel model, developed by Arellano and Bover [84] and Blundell and Bond [85], uses lagged levels and differences of the variables as internal instruments, allowing for more reliable estimation when explanatory variables are endogenous or persistent over time. The System GMM framework also incorporates a lagged dependent variable (L.EPS) to capture dynamic adjustment behavior and path dependence in environmental policy stringency. Diagnostic tests, including the Arellano–Bond tests for serial correlation and Hansen and Sargan tests for instrument validity, confirm that the instruments used are appropriate and that higher-order autocorrelation is absent. Together, these additional estimations robustly validate the negative effect of political corruption on environmental policy stringency across multiple model specifications and econometric techniques.

4 Results

4.1 Baseline results

For the reported baseline results from Table 3, we noted that when we only regress the corruption variable against EPS in Model 1, an additional unit increase in corruption leads to a decline of 2.0909 units of EPS, significant at the 1% level. This suggests that corruption is significantly and negatively associated with environmental policy stringency when other factors are not included. As we gradually include more political control variables incrementally in Models 2 to 4, namely democracy and election, the reported coefficients range from −2.7098 to −0.6820, remaining statistically significant (at the 1% or 5% levels), and the overall negative association remains largely stable. Upon the inclusion of economic control variables in Models 5 and 6, specifically economic development and economic globalization, the reported coefficients are −0.9903 and −2.0605, respectively, while maintaining statistical significance at conventional levels. Finally, with the inclusion of manufacturing sector and population density in Model 7, the coefficient remains significantly negative at −2.1298 ($p < 0.001$). As such, even with the successive inclusion of political and economic control variables, our results remain consistent in indicating that higher levels of corruption are associated with lower environmental policy stringency, reaffirming a robust negative relationship between corruption and EPS overall.

Figure 1 provides a scatterplot illustrating the bivariate relationship between political corruption (V-Dem) and EPS. The fitted regression line (dashed) shows a clear

Table 3 Baseline results of two-way fixed effects

	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7
Corruption	− 2.0909*** (0.6321)	− 2.7098*** (0.7643)	− 2.7147*** (0.7645)	− 0.6820* (0.3662)	− 0.9903** (0.4447)	− 2.0605*** (0.4681)	− 2.1298*** (0.4710)
Democracy		− 0.7530 (0.5234)	− 0.7554 (0.5235)	− 0.8320*** (0.3227)	− 1.3216*** (0.3116)	− 2.2566*** (0.3158)	− 2.3596*** (0.3257)
Election			− 0.0338 (0.0574)	− 0.0285 (0.0349)	− 0.0247 (0.0333)	− 0.0249 (0.0324)	− 0.0243 (0.0324)
Economic Development				1.4489*** (0.0322)	1.1799*** (0.0396)	1.1629*** (0.0479)	1.1334*** (0.0531)
Economic Globalization					0.0296*** (0.0027)	0.0313*** (0.0029)	0.0312*** (0.0029)
Manufacturing Sector						− 0.0608*** (0.0078)	− 0.600*** (0.0078)
Population Density							0.4738 (0.3684)
Countries	40	40	40	40	40	40	40
N	1237	1237	1237	1234	1230	1127	1127
R^2	0.1316	0.1210	0.1217	0.3499	0.3793	0.3315	0.3163

$p < 0.05$*, $p < 0.01$**, $p < 0.001$***. Standard errors are in the parentheses

downward slope, suggesting a negative association—countries with higher corruption tend to exhibit lower levels of environmental policy stringency. Likewise, Fig. 2 illustrates country-level time-series trends for both variables between 1990 and 2020. The red lines represent political corruption (left axis, 0–1 scale), while the blue lines represent environmental policy stringency (right axis, OECD index). Each panel corresponds to a specific country and displays the year-to-year variation in both indicators over the study period. Across most countries—such as Sweden, Norway, Germany, Japan, and Australia—the blue EPS lines consistently rise over time while red corruption lines remain low or show a declining pattern, indicating divergent movements between the two indicators. In several emerging economies, such as Brazil, Russia, Turkey, and Indonesia, both lines exhibit more moderate or fluctuating trajectories, but EPS generally increases more slowly compared to changes in corruption. Other countries, including China and Hungary, show instances where reductions in corruption correspond with more pronounced growth in EPS. Overall, the panels visually demonstrate that changes in environmental policy stringency and political corruption often move in opposite directions over time, with higher or improving EPS values typically accompanying lower levels of corruption.

4.2 Heterogeneity analysis

Next, we split our sample into developed and developing countries as reported in Table 4. For the developing-country sample, the coefficient for corruption is –0.8463 (0.4556), significant at the 5% level, indicating that a one-unit increase in corruption is associated with a 0.85-unit decrease in EPS on average. In contrast, among developed countries, the corruption coefficient is substantially larger at –6.2758 (0.9855) and significant at the 1% level, suggesting that a similar increase in corruption leads to a 6.28-unit reduction in EPS. Taken together, the results demonstrate that the adverse effect of corruption on

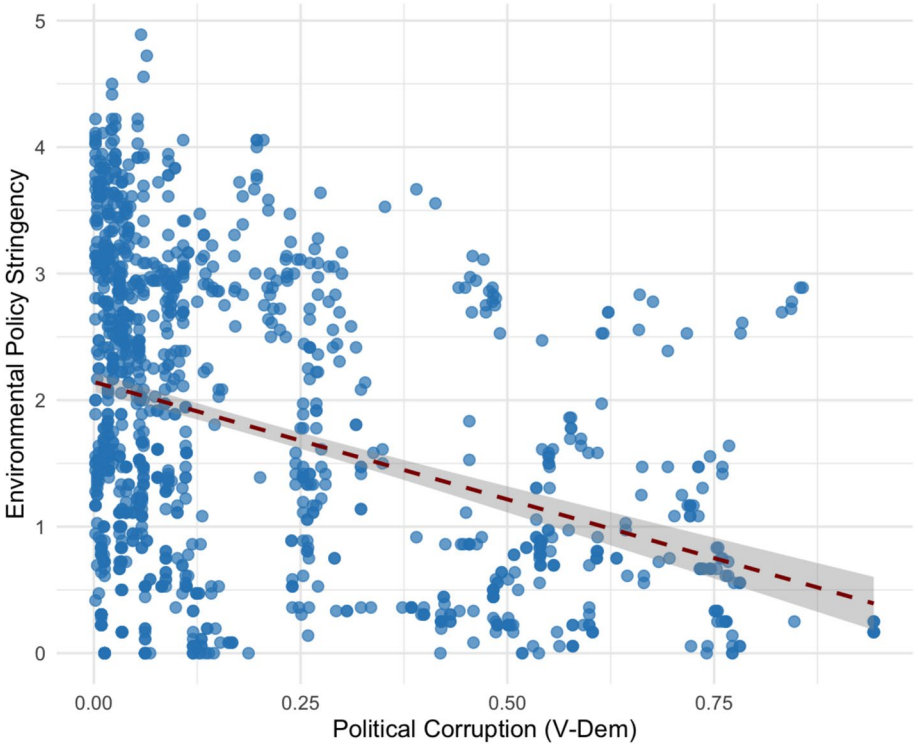

Fig. 1 Scatterplot showing the relationship between Political Corruption (V-Dem) on the x-axis and Environmental Policy Stringency on the y-axis

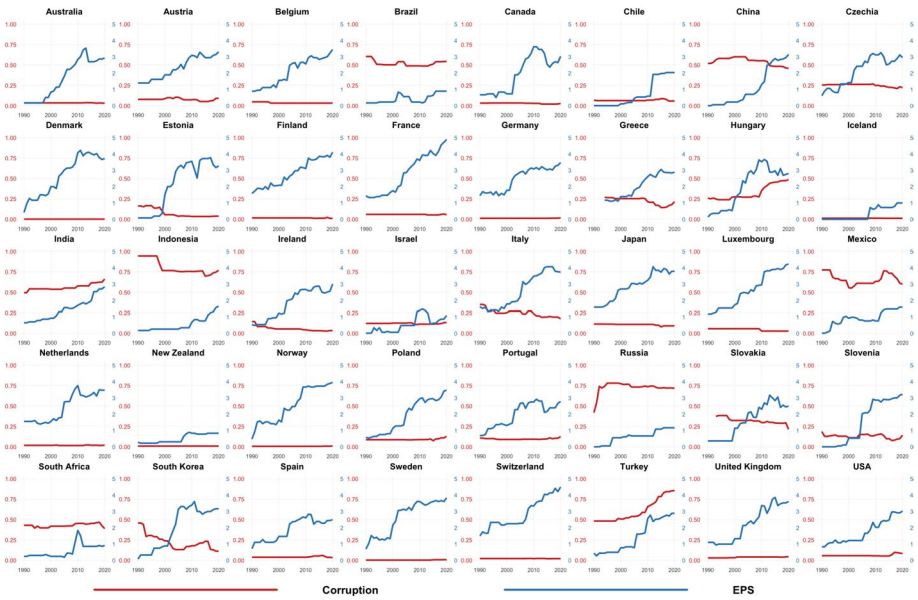

Fig. 2 Trends in Political Corruption (V-Dem) and Environmental Policy Stringency (OECD) across the 40 countries, 1990–2020

environmental policy stringency is much stronger in developed countries compared to developing ones.

Table 4 Heterogeneity test

	Developing	Developed
Corruption	− 0.8463* (0.4556)	− 6.2758*** (0.9855)
Democracy	− 1.4352*** (0.3594)	0.1531 (0.8138)
Election	− 0.0053 (0.0547)	− 0.0223 (0.0322)
Economic Development	0.8910*** (0.0855)	1.2946*** (0.0592)
Economic Globalization	0.0277*** (0.0036)	0.0284*** (0.0037)
Manufacturing Sector	0.0279** (0.0116)	− 0.0818*** (0.0090)
Population Density	0.4530 (0.5186)	3.9982*** (0.5259)
Countries	12	28
N	324	763
R^2	0.2752	0.1104

$p < 0.05$*, $p < 0.01$**, $p < 0.001$***. Standard errors are in the parentheses

4.3 Alternative empirical modelling

In the next step, we conducted robustness checks using the Panel-Corrected Standard Errors (PCSE) and Feasible Generalized Least Squares (FGLS) estimators to ensure that our results are robust to potential violations of standard regression assumptions and to correct for issues such as heteroskedasticity and autocorrelation in the panel data, thereby improving the efficiency of the estimates [83]. In addition, we include the System GMM model to further address possible endogeneity concerns.

As shown in Table 5, the coefficient for corruption remains negative and statistically significant across both robustness estimations, underscoring the stability and consistency of the inverse relationship between corruption and environmental policy stringency (EPS). Under the PCSE estimator, the coefficient of –2.3596 (0.7514) is significant at the 1% level, indicating a strong and statistically robust link even after correcting for heteroskedasticity and contemporaneous correlation across panels. This result suggests that variations in corruption are systematically associated with lower levels of environmental policy stringency across countries, and that the relationship holds when accounting for potential cross-sectional dependence in the data.

Under the FGLS estimation, the estimated coefficient for corruption is –0.4912 (0.2901), significant at the 10% level. Although the magnitude is smaller than that produced by the PCSE model, the sign and level of significance remain consistent, reinforcing confidence in the robustness of the relationship. The reduced magnitude likely reflects the FGLS model's explicit correction for panel-specific heteroskedasticity and first-order autocorrelation, which often produces more conservative but efficient estimates. Together, the PCSE and FGLS outcomes confirm that the negative relationship between corruption and environmental policy stringency is not driven by econometric artefacts such as serial correlation, heteroskedasticity, or cross-sectional dependence.

We also conduct a System GMM estimation to address potential concerns of endogeneity and serial correlation related to corruption and the persistence of environmental

Table 5 Alternative empirical modelling

	PCSE	FGLS	System GMM
L.EPS			0.9624*** (0.0127)
Corruption	− 2.1298* (1.0710)	− 0.4912* (0.2901)	1.2548*** (0.4664)
Democracy	− 2.3596*** (0.7514)	− 0.3712 (0.2962)	0.9252** (0.3574)
Election	− 0.0243 (0.0190)	− 0.0007 (.0083)	− 0.0134 (0.0110)
Economic Development	1.1333*** (0.1433)	0.4413*** (0.0444)	0.1402*** (0.0290)
Economic Globalization	0.0312*** (0.0090)	0.0143*** (0.0026)	0.0024 (0.0015)
Manufacturing Sector	− 0.0600** (0.0275)	− 0.0246*** (0.0057)	0.0025 (.0035)
Population Density	0.4737 (1.0656)	− .6383*** (0.1272)	− 0.0990 (0.1185)
AR (1)—p-value			0.000
AR (2)—p-value			0.472
Sargan—p-value			0.422
No. of instruments			36
Countries	40	40	40
N	1127	1127	1127

$p < 0.05$*, $p < 0.01$**, $p < 0.001$***. Standard errors are in the parentheses

policy stringency (EPS). This dynamic specification includes a lagged dependent variable (L.EPS) as an explanatory variable to capture path dependence and dynamic adjustment effects over time, while using internal instruments derived from lagged values of the regressors to mitigate possible endogeneity bias. The results, presented in Table 5, show that the coefficient of the lagged EPS variable is positive and highly significant (0.9624 (0.0127), $p < 0.001$), confirming strong persistence in environmental policy stringency across periods. The coefficient of corruption also remains positive and significant at the 1% level (1.2548 (0.4664)), indicating that when dynamic effects are controlled for, the influence of corruption on EPS remains statistically meaningful.

To verify that the estimation effectively addresses these econometric issues, we perform several diagnostic tests. The Arellano–Bond tests for serial correlation show significant first-order correlation (AR(1): $p = 0.0000$)—expected in first-differenced models—but no evidence of second-order serial correlation (AR(2): $p = 0.472$), confirming that residual autocorrelation has been adequately addressed. The Sargan ($p = 0.422$) and Hansen ($p = 0.422$) tests both lie within the acceptable range (0.1–0.9), indicating that the instruments are valid and that the model is free from over-identification bias. Furthermore, the number of instruments (36) relative to the number of groups (40) yields a ratio of 0.9, which is within the recommended limit, minimizing the risk of instrument proliferation.

Overall, these results confirm that the System GMM specification effectively mitigates endogeneity through the use of lagged instruments and corrects for serial correlation through its dynamic structure and diagnostic validation, thereby reinforcing the robustness and reliability of the main findings.

All in all, our baseline results, along with the heterogeneity tests, suggest that corruption does lead to a reduction in EPS, with its effects being more pronounced in developed countries. We also conduct alternative empirical modelling, including PCSE, FGLS, and System GMM, which confirms that the negative relationship between corruption and EPS continues to hold even after accounting for potential heteroskedasticity, autocorrelation, and endogeneity concerns. Hence, in the subsequent section, we will reveal the potential reasons behind our findings.

5 Discussion and conclusion

5.1 Reasons for the result

5.1.1 Overview and Hypothesis 1: corruption undermines environmental policy stringency

While a substantial body of research has examined the relationship between corruption and environmental governance, relatively few studies have employed measures that explicitly focus on political corruption or considered how its effects may differ across countries at different levels of economic development. This study seeks to address both gaps by using the V-Dem Political Corruption Index—a conceptually grounded and methodologically transparent measure that more directly operationalizes political corruption—and by adopting a comparative framework that distinguishes between developed and developing countries across a globally representative sample of 40 states. In doing so, it contributes to a more nuanced understanding of how political corruption may shape environmental policy stringency across varied economic contexts.

Our empirical findings offer consistent support for the first hypothesis. In line with the mainstream literature, we find that higher levels of political corruption are significantly associated with lower levels of environmental policy stringency [19, 23]. This relationship holds across multiple estimation strategies, including PCSE, FGLS, and difference-in-differences specifications. These results suggest that political corruption systematically undermines the credibility, enforcement, and political commitment required for stringent environmental regulation. When political actors are susceptible to bribery, rent-seeking, or collusion with industry interests, environmental rules are more likely to be diluted at both the formulation and implementation stages [62]. Political corruption may also distort incentive structures within regulatory agencies [55], prioritize private over public interests [21], and reduce bureaucratic accountability [61]. Over time, these dynamics can erode public trust in institutions [59, 60, 91], further weakening state capacity to enforce environmental goals. Taken together, the findings underscore that corruption is not merely a governance deficit but a structural constraint on the state's ability to legislate and implement strict and effective environmental policies.

5.1.2 Hypothesis 2: the stronger effect in developed countries—a counterintuitive finding

By contrast, our second hypothesis was not supported. Contrary to the conventional expectation that economically developed countries are better insulated from the negative effects of corruption [92], our results indicate that political corruption exerts a more pronounced negative impact on environmental policy stringency in developed countries than in developing ones. Specifically, among the 28 countries in our sample, an additional unit increase in corruption reduces by 3.6670 units, compared with 1.0443 units among the 12 developing countries. This counterintuitive finding requires

careful theoretical explanation, as it challenges the prevailing assumption that institutional maturity and economic affluence necessarily protect against corruption's environmental costs.

5.1.3 Reconciling divergent findings in the literature

Our finding that political corruption's adverse environmental effects are stronger in developed countries diverges from prior findings, and understanding why these divergences exist is critical for interpreting our contribution. Welsch [72] examined six ambient indices across 106 countries using the World Bank's corruption perception index and concluded that corruption's environmental harm was strongest in lower-income contexts, attributing to two mechanism: (1) a direct effect via reduced stringency and enforcement of environmental regulation; and (2) an indirect effect via corruption's suppression of economic growth, which at developing contexts lead to higher pollution. Zhou et al. [93] examined climate risk across 171 countries using two corruption indices (Control of Corruption and Bayesian Corruption Index) from 2006 to 2019 and concluded that corruption's climate risk impact was particularly pronounced in developing countries, demonstrating that institutional corruption exacerbates climate vulnerability disproportionately in low-capacity contexts through both penetrative and reactive channels.

These divergences are not contradictory but reflect measurement differences, sample composition, and different corruption mechanisms operating at different developmental stages. First, prior studies relied on perception-based or subjective aggregate corruption indices rather than political corruption specifically. These measures may conflate illegal bribery with legal influence mechanisms, making it difficult to identify which type of corruption dominates in each context. Our use of V-Dem PCI, which directly measures corruption across executive, legislative, and judicial branches, enables us to isolate political corruption's effects on policy stringency rather than just environmental outcomes. This conceptual precision may explain why we detect stronger effects in developed countries, where political corruption operates through policy formulation rather than just enforcement failure.

Second, Zhou et al. [93] and Welsch [72] examined climate vulnerability and environmental quality outcome, whereas we analyze policy stringency—the design and ambition of the regulatory framework [18]. Corruption may affect these two dimensions differently. In developing countries, weak enforcement capacity means that even stringent policies fail to improve outcomes, resulting in policy-level effects [94]. In developed countries, corruption's primary impact may occur upstream in policy formation processes, weakening the stringency of rules before enforcement even begins [95]. Our EPS Index captures this formulation-stage capture that prior measures miss.

Third, the theoretical mechanism through which corruption undermines environmental governance likely differs qualitatively across development contexts. In developing countries, corruption predominantly takes the form of overt transactional corruption—bribery of inspectors, illegal permit sales, and enforcement failures [94, 96]. These mechanisms are well-documented but may have limited impact on formal policy stringency if regulatory frameworks are already weak or if corruption is so pervasive that it affects all sectors equally. In developing countries, by contrast, corruption increasingly operates

through institutionalized legal mechanisms—lobbying, regulatory capture, campaign finance, and revolving-door appointments between industry and government [62, 92, 95, 97]. These mechanisms directly shape the content and ambition of environmental regulations during the legislative process, before enforcement even begins. Because such influence is exercised through formally legal channels, it may be both more difficult to detect and more effective at diluting policy stringency than overt bribery. Hence, our findings do not refute prior research but complement it by examining a different dimension of environmental governance using a more precise corruption measure. The divergence with Zhou et al. [93] and Welsch [72] likely reflect the fact that corruption undermines developing countries' environmental outcomes primarily through enforcement failure, whereas it undermines developed countries' environmental policy stringency through legislative and regulatory capture. Both mechanisms coexist, but their relative importance varies across development contexts—a heterogeneity that aggregate cross-national studies cannot easily capture.

5.1.4 Why corruption may be more damaging in developed contexts: the legal corruption hypothesis

The finding that political corruption's effects on environmental policy stringency are stronger in developed countries requires a more precise theoretical explanation, as it challenges conventional assumptions about institutional resilience. We propose that this pattern reflects the legal corruption mechanisms that are particularly salient in advanced economies. As Kaufmann and Vicente [98] demonstrate, corruption in high-income economies increasingly manifests as legal corruption—formally lawful practices such as lobbying, campaign finance, regulatory capture, and revolving-door appointments between regulatory agencies and regulated industries. Rose-Ackerman and Palifka [62] provide the theoretical foundation for understanding why this matters. In advanced democracies, statutes are not merely expressions of voter preferences and elected officials' ideals, but the result of political deals that reflect the interests of those who lobby or make donations to influence provisions in their favor [97]. These legally sanctioned influence channels create a revolving door between public agencies and private industry that is open to abuse, even when outright bribes are uncommon [92, 99].

In environmental policymaking, this dynamic is particularly salient for three reasons. First, technical complexity creates information asymmetries. Environmental regulation in developed economies is highly technical, involving emissions trading schemes, life-cycle assessments, and technology-specific standards. This technical complexity creates opportunities for the industry to dominate expert committees, provide biased technical guidance, and shape regulatory details in ways that appear scientifically justified but systematically favor polluters [100]. Second, fragmented regulatory authority enables targeted capture. Unlike developing countries, where environmental governance may be centralized or simply absent, developed countries have specialized agencies, multi-level governance structures, and sector-specific regulators. This fragmentation creates multiple entry points for influence, allowing industries to forum shop and capture the specific agencies or legislative committees most relevant to their interests [101]. Third, high compliance costs incentivize political investment. Stringent environmental policies in developed countries impose substantial compliance costs on polluting industries—costs

that are worth lobbying against. Industries facing costly regulations have strong incentives to invest in political influence, creating what Rose-Ackerman and Palifka [62] call the quid pro quo of legal corruption: politicians weaken regulations in exchange for campaign contributions, post-office employment, or support from organized interest groups.

Admittedly, we cannot directly test the legal corruption mechanism without data on lobbying expenditures, campaign finance, or revolving-door appointments; several auxiliary findings lend indirect support to this interpretation. In developed countries, we find a statistically significant negative association between the size of the manufacturing sector and EPS, which may reflect the influence of organized industrial interests in shaping regulatory outcomes [65]. Similarly, the negative effect of opposition influence suggests that greater political competition does not necessarily translate into stronger environmental oversight, potentially due to entrenched elite networks or bipartisan collusion [102]. These patterns are consistent with Olson's [103] prediction that stable democracies develop organized special interests that can resist redistributive or regulatory policies, and with Rose-Ackerman and Palifka's [62] argument that formally legal influence channels can distort policy outcomes even in institutionally robust settings.

An alternative explanation can be drawn from the economic literature, particularly through the lens of Cole's [71] interpretation of the EKC hypothesis. In theory, developed countries that have passed the EKC turning point, continued economic growth is expected to reduce pollution through technological upgrading and more stringent regulation [29, 104]. However, if corruption undermines economic performance or distorts the allocation of regulatory resources, it may also disrupt this trajectory. In such cases, political corruption not only weakens environmental institutions but also impedes the economic and technological pathways that would otherwise deliver environmental gains [71]. This mechanism aligns with Gründler and Potrafke's [105] finding that the relationship between economic development and environmental outcomes is mediated by governance quality. Thus, the relationship between economic development and the environmental costs of corruption is neither linear nor uniformly protective; rather, its effects are contingent on the broader institutional framework through which environmental governance is enacted.

Taken together, our findings suggest that the relationship between economic development and corruption's environmental costs is neither linear nor uniformly protective. Rather, its effects are contingent on the institutional framework through which environmental governance is enacted. In developing countries, corruption undermines environmental outcomes primarily through enforcement failure and administrative incapacity. In developed countries, corruption undermines environmental policy stringency primarily through legislative capture and regulatory dilution—mechanisms that operate earlier in the policy process and may be more structurally embedded because they exploit formally legal influence channels. This heterogeneity has important implications for both theory and policy. Theoretically, it challenges models that treat corruption as a uniform governance deficit, suggesting instead that corruption's mechanisms and effects are context dependent. Empirically, it underscores the importance of using measures like the V-Dem Political Corruption Index that capture political corruption specifically, and outcome measures like the EPS Index that capture policy stringency rather than just

environmental results. Methodologically, it reinforces the need for comparative frameworks that allow corruption's effects to vary across development contexts rather than assuming universal relationships.

5.2 Societal and policy implications

These findings carry important implications for both policy reform and broader environmental governance agendas. First, they underscore that political corruption constitutes not only a governance challenge but a structural barrier to effective environmental regulations. In both developing and developed contexts, political corruption undermines the state's ability to credibly commit to environmental goals, weakening enforcement, distorting incentives, and skewing policymaking towards vested interests. Anti-corruption measures, therefore, should not be viewed as peripheral reforms, but as foundational components of credible environmental governance architecture.

For developing countries, where policy implementation often suffers from weak administrative capacity [96], strengthening bureaucratic accountability, increasing transparency in environmental permitting and enforcement, and insulating regulatory agencies from political interference are thus essential components of capacity-building strategies. Moreover, international environmental cooperation and climate finance mechanisms need to take the political economy of corruption seriously, ensuring that external mechanisms do not unintentionally reinforce rent-seeking behaviors.

At the same time, the stronger adverse effects of political corruption observed in developed countries challenge the assumption that institutional maturity and economic affluence necessarily inoculate states from the environmental cost of corruption. In these contexts, the subtle and legalistic forms of corruption—such as lobbying, revolving-door appointments, and regulatory capture—require a rethinking of how environmental policy integrity is safeguarded. Traditional anti-corruption frameworks that focus narrowly on illegality may be insufficient. Instead, reforms must address the structural entanglement of political and economic power, for example, by enhancing transparency in political financing, tightening post-office employment rules, and establishing independent oversight bodies with real enforcement authority.

5.3 Limitations and future research directions

Despite the contributions this study makes to understanding how political corruption influences environmental governance, several limitations should be acknowledged. First, the analysis relies on the OECD Environmental Policy Stringency (EPS) Index as the principal measure of environmental regulation. Although the EPS is widely recognized for its methodological rigor and cross-national comparability, it encompasses only a subset of policy instruments—primarily those aimed at mitigating greenhouse gas emissions and local air pollution [17]. Consequently, other critical environmental domains such as water management, biodiversity protection, waste governance, and land-use control fall outside its empirical scope. This limited coverage may understate the scope of environmental ambition in countries that adopt diverse or non-market instruments. Future research could advance this work by developing a new composite environmental policy index that builds on and extends the OECD EPS framework. Such an index could incorporate additional environmental dimensions—covering adaptation measures,

natural resource management, and sustainability policies—thereby offering a more multidimensional evaluation of states' environmental commitment across all major ecological domains.

Second, the study's empirical analysis is restricted to the 40 countries for which complete and consistent EPS data are available for 1990–2020. This limitation, determined by data coverage, confines the sample to 34 OECD member countries (excluding Colombia, Costa Rica, Latvia, and Lithuania) and six major emerging economies—Brazil, China, India, Indonesia, Russia, and South Africa. Although this sample captures meaningful variation in governance quality, development levels, and regulatory capacity, it remains weighted toward OECD and upper-middle-income contexts where institutional frameworks are relatively mature. Therefore, the results should be interpreted primarily in the context of more institutionalized policy environments. Future extensions could integrate data from Sub-Saharan Africa, South Asia, and Latin America, once comparable indicators become available, to explore whether the corruption–environmental policy relationship differs in less institutionalized or resource-constrained settings. Expanding the geographical and developmental scope of analysis would significantly enhance the external validity and global relevance of the findings.

Third, this study examines political corruption using an aggregated measure from the V-Dem Political Corruption Index, which, although comprehensive, does not disentangle specific types of corruption such as clientelism, patronage, rent-seeking, or state capture. This limitation constrains our ability to determine how distinct corruption mechanisms affect environmental policy design and enforcement. Future research could address this issue by developing a disaggregated cross-national corruption dataset that distinguishes between different forms, channels, and institutional contexts of corruption. Combining such measures with sector-specific environmental indicators could yield deeper insights into the mechanisms through which corruption influences environmental outcomes. Additionally, qualitative approaches such as process tracing could be employed to uncover the causal sequences linking specific corruption practices to policy formulation, regulatory capture, and enforcement failures within particular institutional settings. By integrating such in-depth case studies with cross-national quantitative evidence, future research can better illuminate the contextual dynamics and causal pathways through which corruption shapes environmental governance.

Fourth, while the study focuses on the effect of corruption on environmental policy stringency, the possibility of reverse causality should also be acknowledged. It is plausible that more stringent and transparent environmental regulations may themselves reduce opportunities for corruption by limiting discretionary decision-making, enhancing public scrutiny, and promoting procedural transparency in permitting, monitoring, and enforcement processes. In this sense, environmental policy and corruption may be jointly determined through a feedback loop, where strong governance norms reinforce both cleaner politics and more effective regulation. Although we employed multiple regression techniques—including 2WFE, PCSE, FGLS, and System GMM—to mitigate potential biases, reverse causality, cross-sectional dependence, and other endogeneity concerns cannot be entirely ruled out. Because cross-sectional dependence is a common characteristic of macro-panel data—where unobserved global or regional shocks can simultaneously affect multiple countries—future research could use second-generation

Table 6 Variance inflation factor for Table 3 model 7

	VIF	1/VIF
Corruption	4.94	0.2024
Democracy	3.72	0.2684
Election	1.01	0.9950
Economic development	4.41	0.2267
Economic globalization	2.52	0.3975
Manufacturing sector	1.46	0.6841
Population density	2.09	0.4901

Mean VIF = 2.88

panel estimators or spatial econometric approaches designed to explicitly model such interdependencies. Moreover, future studies could employ instrumental-variable techniques, longitudinal causal modeling, or extended dynamic panel frameworks to further capture and test the bidirectional and cross-linked dynamics between corruption and environmental policy stringency over time. Addressing these econometric challenges would yield a more robust and comprehensive understanding of the co-evolution between institutional integrity, spatial interdependence, and environmental governance.

Appendix

See Table 6.

Authors contributions
CX: Data curation, Formal analysis, Methodology, Writing—original draft, Writing—review& editing; JK: Conceptualization, Data curation, Formal analysis, Methodology, Validation, Visualization, Writing—original draft, Writing–review & editing; MR: Methodology, Validation, Writing—original draft, Writing—review& editing; CG: Conceptualization, Resources, Validation, Writing—original draft, Writing—review& editing.

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Data availability
Data will be made available on request.

Declarations

Ethics approval and consent to participate
Not applicable, as it only uses secondary data.

Consent for publication
Not applicable.

Competing interest
The authors declare no competing interests.

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