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Greening the Canvas: How ESG Investing and Green Finance Can Paint a Sustainable Future for Culture-Led Development

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ABSTRACT

The core relationship between environmental sustainability and culture-led development though the effectiveness of ESG investment and green finance is the main purpose of this paper. By employing panel data from 42 countries in Europe, Asia and Latin America from 2005 to 2023, this study attempts to evaluate the impact of ESG investing and green finance on culture sector CO_2 emission activities, alongside culture-led development's emission-offsetting mechanisms. After applying econometric methods that capture cross-section dependence and slope heterogeneity, results show that culture-led development is associated with a substantial increase in CO_2 emissions per capita, thereby confirming the culture development issues that pertain to the environmental sustainability of the development model. However, ESG investing and green finance can, in isolation, and in combination, attenuate these emissions by moderating the culture-development-emissions nexus. Other emission reduction factors such as the quality of institutions, renewable resources, and technological development, juxtaposed with tourism concentration and the growth of urban cultural infrastructure, which increases emission margins, are noted. Sensitivity tests underscore regional and income level differences within these relationships. These findings offer relevant cultural policies for financing mechanisms that embrace culture sustainable development targets to the level of United Nations SDG 11 and SDG 13.

INTRODUCTION

Culture-led development has become a dominant strategy for urban renewal and social inclusion, yet its environmental implications remain insufficiently understood. Cities across developed and developing regions increasingly invest significant financial and human resources in museums, theatres, festivals, cultural districts, and creative infrastructures to stimulate economic growth and improve social well-being. However, while the cultural sector enhances local economies, its resource-intensive activities raise important environmental concerns that are often overlooked. Cultural production, heritage-site management, festivals, and creative industries consume large amounts of energy and materials, generate waste, require transportation, and depend on environmentally demanding infrastructure. As culture-led development expands, so does its carbon footprint creating a "lose–lose" scenario where cultural growth intensifies environmental harm. This contradiction has become more pronounced as countries pursue carbon-neutral goals alongside post-pandemic cultural revival strategies (Gillan, 2021; Sachs *et al*., 2019). This tension highlights the need to explore mechanisms capable of balancing cultural development with environmental sustainability.

Sustainable finance particularly ESG investing and green finance offers potential tools to reconcile the environmental costs of culture-led development. ESG investing incorporates environmental, social, and governance principles into investment decisions, enabling funding for sustainable cultural projects, while green finance provides targeted mechanisms to lower ecological impact. Research shows that ESG integration guides investors toward environmentally responsible cultural initiatives (Berg *et al*., 2022), while green finance instruments such as green bonds, sustainability-linked loans, and climate funds support eco-friendly cultural activities (Tolliver *et al*., 2020). These innovations allow cultural organisations to pursue growth while reducing emissions and ecological footprints. These mechanisms may therefore help resolve the underlying conflict between cultural expansion and environmental objectives. Despite these opportunities, the environmental dimension of culture-led development and the role of sustainable finance in mitigating cultural-sector emissions remain largely underexplored.

While extensive literature examines culture-led development's economic and social outcomes, far less is known about its ecological consequences or how ESG and green finance interact with cultural activities to influence environmental performance. Existing studies mostly analyse aggregate emissions or economic growth, leaving the culture-development-emissions nexus under-researched. No known studies have jointly examined culture-led development, ESG financing, and environmental outcomes in a comparative global context. Addressing these gaps is essential for designing cultural policies aligned with global sustainability commitments such as the SDGs and Paris Climate Agreement.

This study contributes new evidence by examining whether ESG investing and green finance can reduce

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the environmental impact of culture-led development across countries. The study investigates how ESG finance interacts with cultural activities to influence carbon emissions, and whether these effects vary across regions and income groups. Using advanced panel estimation methods that account for cross-sectional dependence and slope heterogeneity, the study evaluates 42 countries and conducts regional (Europe, Asia, Latin America) and income-level (high vs. middle income) analyses to ensure robust and generalisable findings. These contributions enhance theoretical understanding and offer practical insights for policymakers, cultural managers, and investors seeking to transition cultural economies toward sustainability.

The remaining sections outline the theoretical, methodological, and empirical components of the study. Section 2 reviews literature on culture-led development, ESG investing, green finance, and environmental impacts; Section 3 presents the theoretical and empirical framework; Section 4 explains the data; Section 5 describes the estimation strategy; Section 6 discusses results. Section 7 concludes with policy implications and future research directions

Literature Review

Culture-led development takes into account the strategic use of creative industries, cultural heritage, arts institutions, and cultural activities to promote economic growth, foster social cohesion, and revitalise cities (Evans, 2023). From Bilbao to Singapore, it is evident that cities around the globe are investing billions into cultural infrastructure for transformative developments (Plaza *et al.*, 2022). Nevertheless, new research indicates that culture is potentially a significant source of environmental cost. Lucchi (2023) notes that museums' climate control systems, necessary for the preservation of their collections, consume energy at a rate considerably higher than that of residential buildings, thereby classifying museums as some of the most inefficient energy-residential building operations. Mair and Smith (2021) note that major cultural festivals and events have significant carbon footprints associated with audience travel, infrastructure and catering, as well as the generated waste. González (2024) critiques the "Bilbao Effect", which is the phenomenon of urban regeneration associated with the construction of a museum, on the embodied carbon found in the 'Bilbao Effect' architecture and the carbon emissions associated with the increased tourism.

Recent studies have conducted research on certain cultural industries and have sociological studies around cultural trends, specifically to point out environmental trends. (Smith *et al.*, 2024) explains that some of the most prominent international art fairs are able to emit, on average, 3,500 tonnes of CO_2 due to the mass air travel and logistics for attending the event. Chen and Liu (2024) demonstrate that the increase in designated UNESCO World Heritage Sites experience increased emissions of 8-12% annually due to the tourism that follows post designation. As described in Hadley *et al.* (2022), performing arts venues in European cities account for 2.3% of urban emissions while only representing 0.8% of the urban built environment floor area. Despite this growing evidence, the culture-development-emissions relationship has yet to be examined in depth across multiple countries. Most studies in this area tend to be case studies or focus on one cultural subsector, which diminishes the relevance of the findings to policy. ESG investments grew rapidly, exceeding $35 trillion in global assets in 2023 (Global Sustainable Investment Alliance, 2024). This form of investment uniquely assesses the environmental, social, and governance (ESG) policies of firms and projects in addition to the conventional financial analysis (see Friede *et al.* 2015).

Several theoretical arguments posit that emissions can be reduced through ESG investments. First, the owners of the assets in our investment portfolios would, that is, allocationally, be economically encouraged to invest in activities with lower emissions (Pastor *et al.*, 2021) or sustainable activities. Second, rather than targeting companies that do not emanate or do not have significant air emissions, ESG investors tend to actively engage with their portfolio companies to encourage the adoption of low-emission strategies (Dimson *et al.*, 2022). Third, ESG screening may be able to increase the cost of capital for polluting firms while decreasing it for firms with responsible environmental practices, thereby creating financial incentives for firms to encourage more rapid decarbonisation (Bolton & Kacperczyk, 2021).

The effectiveness at which ESG investing achieves its environmental objectives remains a subject of mixed empirical assessment. Li *et al.* (2023) found a positive correlation between the growing allocation of ESG funds in the OECD countries and the annual rate of industrial CO_2 emission reduction by 3.2%. On the other hand, Kim and Park (2024) argued that the actual impact of ESG investing on emissions is negligible, and that much of the observed impact is simply a result of portfolio reallocation in what has been termed the "green portfolio illusion." Most importantly, in which sectors emissions are concentrated, and what the relationship is with ESG investing, particularly with the cultural and creative industries, has not been researched. Most cultural organizations are structured as nonprofit organizations or small and medium enterprises and are likely to operate under very restrictive environments, the implication being that access to mainstream ESG investments is highly unlikely. These factors raise the issue of whether the findings reached in ESG investing carry significant weight in a cultural context.

In contrast to ESG investing, green finance is more precise and focused on achieving environmental goals due to the strict use-of-proceeds rules and impact verification protocols (Taghizadeh-Hesary & Yoshino, 2019). The theoretical rationale for green finance's capacity to reduce emissions supports its advocacy as a mechanism to finance investment market failures. Conventional finance systematically underinvests in sustainable projects by underpricing the environmental externalities, applying exorbitantly high discount rates to a value of the environmental benefits, and projecting them over an extended period (Polzin *et al*., 2017). These failures are attributed to insufficient green finance, including dedicated capital pools, technical aid, and risk-mitigation instruments strategically designed for environmental projects (Sachs *et al*., 2019). Nonetheless, the application of green finance within the culture sector is still in the early stages. While some of the largest museums have started to issue sustainability-linked bonds (British Museum, 2023) and some cultural festivals have been able to access green finance for the installation of renewable energy (Edinburgh Festival, 2024), the systematic literature on the effectiveness of green finance within the culture sector is practically non-existent. This is a major gap in the literature, especially as cultural policymakers have been actively looking for financing structures which are more environmentally sustainable. The above literature has highlighted several important issues. Firstly, the development of the culture sector and the economic impact associated with it have been thoroughly documented. However, the environmental impact has been very poorly analysed, especially in a cross-national comparative framework. Secondly, research on ESG financing and green finance has largely focused on the industry, energy, and finance, while cultural and creative industries have been largely overlooked.

In their separate studies, culture, finance, and emissions 'phenomena' have not been studied interdependently and the impact of sustainable finance on the environmental effects of cultural growth remains largely unexplored. Thus, this study aims to fill the gaps by: (1) estimating the relationship between culture-led development and CO_2 emissions for a wide range of countries: (2) evaluating the impact of ESG investing and green finance on emissions from the cultural sector and the extent to which cultural emissions are fossilised financing; (3) determining the extent to which these financial instruments offset the emissions derived from culture-led development activities; (4) assessing the emissions from and the development features of these countries; (5) constructing the provision of policy counsel on cross-country culture development while improving sustainable development considering the gaps in available literature.

Theoretical Framework and Empirical Model

This study builds on the Stochastic Impacts by Regression on Population, Affluence and Technology (STIRPAT) impact framework, which Dietz and Rosa (1997) first applied to assess environmental impacts. The STIRPAT model suggests that the environmental impact equates to the weighted population, affluence (economic activities) and technology factor within a specified region. In this case, we modify this framework by adding culture-driven development, ESG investing, and green finance as primary variables influencing environmental impact.

The general STIRPAT specification is:

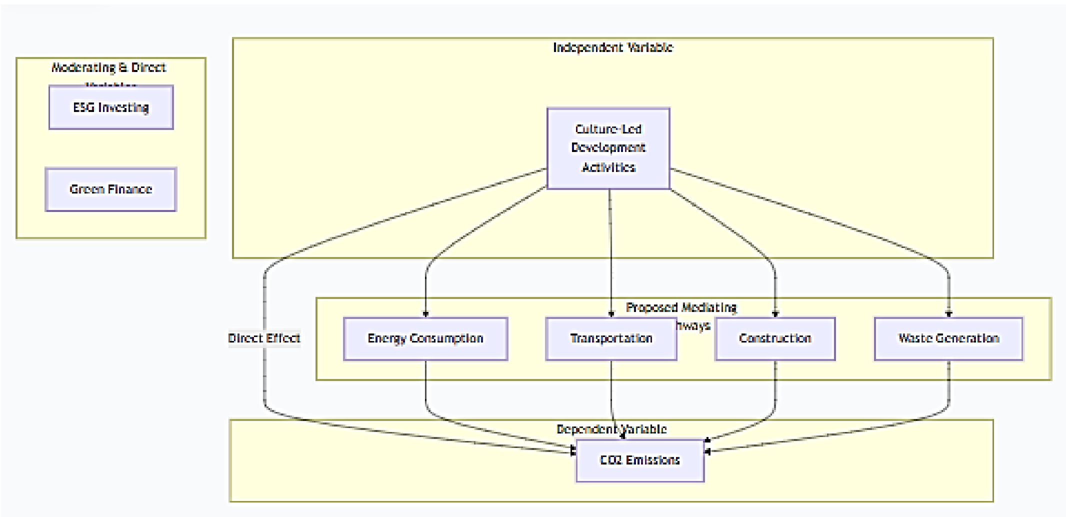
Environmental Impact = *f* (Population, Affluence, Technology, Institutional Factors)

For this study's purposes, we specify a modified STIRPAT model as:

$$\ln Cit = \beta + \delta_1 CDIit + \delta_2 \ln ESGit + \delta_3 \ln GFit + \delta_4 (\ln ESGit \times CDIit) + \delta_5 (\ln GFit \times CDIit) + \delta_6 REit + \delta_7 TIit + \delta_8 IQit + \delta_9 TINTit + \delta_{10} UCIit + \varepsilon it \quad (1)$$

Conceptual Framework

The conceptual relationships explored in this research are depicted in Figure 1. The framework argues that development activities pertaining to culture in the field are capable of causing multiple pathways to an increase in the CO_2 emissions of a country (in energy use, transport, construction, as well as in waste produced). In contrast, ESG investing and green finance, in addition to CO_2 emission reduction, also sustain the relationship between culture sector emissions by indirectly and directly moderating CO_2 emissions in the cultural sectors. There is also CO_2 emission reduction by financing CO_2 emission reduction, low carbon infrastructure, and sustainable CO_2 emission reduction practices.



Data Sources and Estimation Methodology

The present study examines balanced panel datasets from 42 nations in Europe, Asia, and Latin America for the period from 2005 to 2023, resulting in 798 country-year records. The sample comprises 23 European, 12 Asian, and 7 Latin American nations. The selected countries meet the following criteria: (a) the existence of reasonably comprehensive and dependable cultural sector data, (b) the presence of reasonably well-developed ESG investing markets, (c) availability of relevant data concerning the provision of green financing, and (d) the existence of relevant and comprehensive environmental and economic data.

Table 1: Data Sources and Measurement

Variable	Measurement Unit	Primary Source
lnC	Metric tons CO2 per capita (log)	World Bank World Development Indicators; EDGAR Database
CDI	Index (0-100 scale)	Author's calculations based on UNESCO Institute for Statistics; OECD Culture Statistics; National statistical offices
lnESG	Percentage of total investment (log)	Bloomberg ESG Database; Refinitiv ESG Index; National financial regulatory authorities
lnGF	USD per capita, constant 2021 prices (log)	Climate Bonds Initiative; World Bank Green Bond Database; National development banks
RE	Percentage of total energy consumption	International Energy Agency (IEA); International Renewable Energy Agency (IRENA)
TI	Index (0-100 scale)	Author's calculations based on World Bank; WIPO Statistics; ITU ICT Development Index
IQ	Index (0-100 scale)	Author's calculations based on World Bank Worldwide Governance Indicators
TINT	Percentage of GDP	World Bank World Development Indicators; UNWTO Statistics
UCI	Annual percentage growth	Author's calculations based on national construction statistics; urban planning databases
	p-value	0.00
Middle-Income	CD Stat.	22.34α
	p-value	0.00

Estimation Methodology

The estimation methodology follows a systematic two-stage approach designed to ensure the reliability and robustness of the empirical results. First, a series of pre-estimation diagnostic tests is conducted to identify the statistical properties of the dataset. These include tests for stationarity, cross-sectional dependence, slope heterogeneity, serial correlation, and multicollinearity. The outcomes of these diagnostics guide the selection of appropriate estimators that align with the structure and characteristics of the panel data. Second, the core regression analysis is performed using econometric techniques that are robust to the issues identified in the preliminary diagnostics. Depending on the results from the pre-estimation tests, suitable panel estimators such as the Pooled Mean Group (PMG), Dynamic Fixed Effects (DFE), Common Correlated Effects (CCE), or other second-generation panel methods are applied to ensure consistent and efficient parameter estimates. This structured approach enhances the accuracy of the empirical assessment and strengthens the validity of the conclusions drawn from the analysis.

Pre-Estimation Diagnostic Tests

Cross-Sectional Dependence (CD) Test

Country panel datasets within a region may likely have cross-sectional dependence due to physical proximity, economic ties, policy similarities, and shared cultures. Cross-sectional dependence, or CD, violates assumptions made in panel regression and results in biased and inconsistent estimates (Pesaran, 2015). We apply the CD test developed in (Pesaran, 2004) that is most appropriate to panels with large N (number of cross-sections) over T (time periods). The test checks if the residuals from the regression of a given country's outcomes are dependent. The CD test statistic is:

$$CD = \sqrt{2T/(N(N-1))} \times \Sigma_{i=1}^{N-1} \Sigma_{j=i+1}^{N} \hat{\rho}_{ij} \quad (2)$$

where $\hat{\rho}_{ij}$ is the estimated correlation of country residuals i and j. The test statistic, given the null hypothesis of no Cross-Sectional Dependence (weak CD), is standard normally distributed. Thus, the failure to accept the null hypothesis indicates strong CD, or strong cross-sectional dependence, suggesting estimation techniques that deal with cross-sectional correlation are needed.

Slope Heterogeneity (SH) Test

In cross-section panel datasets, it is common to find different degrees of association between dependent and independent variables across a cross-section; this is termed slope heterogeneity. The assumption of uniform slope coefficients or slope homogeneity in the presence of heterogeneity is a violation of the model that leads to biased and inconsistent estimates (Pesaran and Yamagata, 2008). The slope heterogeneity test developed by Pesaran and Yamagata (2008), also called panel data slope heterogeneity test, provides two test statistics: Delta and adjusted Delta. These two statistics calculate the fifth moments of the distributions by testing the null hypothesis of slope homogeneity and the alternative hypothesis of slope heterogeneity. The test is also robust to cross-sectional dependence and can be used for either $N > T$ or $T > N$ for panel data.

Panel Unit Root Test

Non-stationarity or the presence of unit roots is common in time series data, which refers to the tendency of a variable to stray from the mean and never return to it. The use of non-stationary data in a regression equation is highly prone to erroneous conclusions, also known as spurious results (Granger & Newbold, 1974). Hence, it is essential to test and prove that the data is stationary. The Pesaran (2007) second generation panel unit root test, the cross-sectionally augmented Im-Pesaran-Shin CIPS test, will be used. This test accounts for cross-sectional dependence by adding standard unit root regression with cross-sectional averages of lagged levels and first differences. The CIPS statistic is given by:

$$CIPS = N^{-1} \Sigma_{i=1}{}^{N} CIPS_i \quad (3)$$

Where $CIPS_i$ denotes the cross-sectionally augmented Dickey-Fuller, i statistic for country i. The test is used to determine the null hypothesis with regards to unit root or non-stationarity and the alternative hypothesis which is that the data is stationary. Tests are conducted at both level [I(0)] and first difference [I(1)] to determine the order of integration for each variable.

Panel Cointegration Test

There are many reasons why two variables might be integrated of different orders. That said, the presence of cointegration means there are stable long run relationships, even if the variables deviate from equilibrium in the short run. In long run analyses of regressed variables, the output must be validated through cointegration. In this paper, we employ the Westerlund (2007) panel cointegration test, which is based on error-correction models, and is robust to cross-sectional dependence through bootstrap methods. This test yields four statistics: G_t, G_a, P_t and P_a. G_t and G_a check to see if there is cointegration in at least one panel unit, while P_t and P_a check to see if there is cointegration in the whole panel. The null hypothesis of these tests states there is no cointegration, while the ability to reject the null hypothesis implies the existence of long run equilibrium relations, thus justifying long run regression analysis.

Feasible Generalised Least Squares (FGLS)

Because we expect to find cross-sectional dependence along with heteroskedasticity (the 'a' in 'FGLS' where there are differing errors across observations) we use the Feasible Generalised Least Squares (FGLS) estimator in the core regression analysis. Legendre FGLS refinement and enhancements through the years have been able to settle most challenges while working with panel data sets simultaneously. In relation to panels, Cross-sectional dependence FGLS gives direct attention to the time-linear intertwining of disruptions along and across cross-sectional strata of the framework. Heteroskedasticity is the module which permits the disparate error variances across the common geo-political boundaries among federating units. And the last component, Serial correlation FGLS has the capacity to handle spatial autocorrelation in panel disruptions. When CDL, heteroskedasticity and/or correlation of errors of the same order of the estimation exists, it has been demonstrated that FGLS is, in any case, more efficient in the sense of lower variance of the estimators, while the estimators remain consistent and asymptotically normally distributed, given 'reasonable' requirements are satisfied (Baltagi, 2013).

In the FGLS estimation, there are two stages to the setup: The initial stage, referred to as First Stage, predicts an initial model leveraging OLS and derives residuals associated with the model which are employed to generate estimates of the variance-covariance matrix $\hat{\Omega}$ which exhibits heteroskedastic, cross-sectional dependence, and autocorrelation. The Second Stage involves transforming the model through the application of $\hat{\Omega}^{-1/2}$ and estimating using the generalized least squares, which has the associated FGLS coefficient estimates on record:

$$\epsilon\,\hat{}\,gls = (X'\hat{\Omega}^{-1}X)^{-1}X'\Omega\,\hat{}^{-1}y \quad (4)$$

where X stands for the dependent variable vector while y represents independent matrices and $\hat{\Omega}$ holds the outcome of the estimators of the matrix.

Although powerful, FGLS is based on a number of assumptions, such as: the regressors' strict exogeneity (independent variables at every time period are not correlated with the errors); specifying the error variance-covariance structure correctly; and asymptotic sufficient N or T properties. Other limitations include bias on the computed standard errors in finite sample sizes and error structure misspecification by Beck and Katz (1995). These issues are alleviated by conducting robustness checks with the different estimators.

Analytical Strategy

The analytical strategy is empirical and unfolds in three phases. First, the baseline analysis employs the full sample of 42 countries (798 observations) to estimate the primary model and test the core hypotheses concerning culture-led development, the role of ESG investing, and the influence of green finance on CO_2 emissions. This stage provides the main empirical foundation for understanding the relationships among the study variables. Second, regional sensitivity analyses are conducted by estimating separate models for Europe, Asia, and Latin America. This allows the study to assess whether the effects of ESG investing and green finance vary across geographic regions with different institutional structures, cultural dynamics, and environmental policy regimes. Similarly, income-based sensitivity analyses are performed by separating the sample into high-income and middle-income countries to capture heterogeneity associated with varying levels of economic development. Third, robustness checks are implemented to validate the consistency of the findings. These include using alternative dependent variables using CO_2 emission growth rates and total CO_2 emissions to ensure that results are not driven by a single measurement of environmental performance. Additionally, the analysis applies the Panel Corrected Standard Errors (PCSE) estimator as an alternative estimation method to address potential heteroskedasticity and contemporaneous correlation in the panel. Further robustness checks use alternative operationalizations of the principal independent variables to test the stability of the main results.

Table 2: Descriptive Statistics

Sample	Variable	Mean	Std. Dev.	Skewness	Kurtosis	Obs.
Full Sample (N=42)	lnC	1.845	0.682	-0.156	2.445	798
	CDI	42.367	18.542	0.327	2.186	798
	lnESG	2.456	0.834	-0.412	2.678	798
	lnGF	3.124	1.245	0.289	2.334	798
	RE	24.567	15.893	0.634	2.456	798
	TI	56.234	22.178	-0.187	2.567	798
	IQ	64.892	19.456	-0.345	2.234	798
	TINT	8.345	5.678	1.234	4.567	798
	UCI	3.456	2.123	0.567	3.234	798
Europe (N=23)	lnC	1.956	0.523	-0.234	2.345	437
	CDI	51.234	16.234	0.123	2.456	437
	lnESG	2.789	0.678	-0.345	2.567	437
	lnGF	3.567	1.123	0.234	2.234	437
Asia (N=12)	lnC	1.678	0.789	-0.123	2.567	228
	CDI	35.678	19.345	0.456	2.123	228
	lnESG	2.234	0.923	-0.234	2.789	228
	lnGF	2.789	1.345	0.345	2.456	228
Latin America (N=7)	lnC	1.789	0.634	-0.089	2.456	133
	CDI	28.456	15.234	0.567	2.234	133
	lnESG	1.987	0.876	-0.456	2.345	133
	lnGF	2.456	1.234	0.278	2.567	133
High-Income (N=28)	lnC	2.034	0.567	-0.187	2.456	532
	CDI	48.567	17.234	0.234	2.345	532
	lnESG	2.678	0.756	-0.345	2.567	532
	lnGF	3.456	1.134	0.256	2.345	532
Middle-Income (N=14)	lnC	1.456	0.712	-0.098	2.378	266
	CDI	32.456	17.892	0.456	2.123	266
	lnESG	2.123	0.892	-0.234	2.678	266
	lnGF	2.567	1.312	0.312	2.456	266

RESULTS AND DISCUSSION

Pre-Estimation Test Results

Descriptive Statistics

Table 2 presents comprehensive descriptive statistics for the full sample and subsamples disaggregated by region and income level.

The "Regional Clusters" section begins with the presentation of striking findings for European countries, which have the highest means for both the Culture-led Development Index (51.234) and ESG investment intensity (2.789). This suggests that these countries have comparatively more sophisticated strategies for cultural development and more developed sustainable finance markets. The means for Asian countries are moderate for cultural development intensity (35.678), but these countries have the most rapidly growing ESG adoption.

Latin American countries, on the other hand, have the lowest cultural development and the least penetration of sustainable finance, suggesting the greatest potential for development. Regarding income, the emissions per capita for high-income countries are disproportionately high, and are accompanied by more intense cultural development, ESG finance, and green finance (mean lnC = 2.034 versus 1.456 for middle-income). This is indicative of a "sustainability paradox" whereby more developed cultural economies are paradoxically more sustainable, despite having more sustainable finance mechanisms. With regard to the "variance and dispersion," the scores of the standard deviations on the variables suggest a degree of heterogeneity in the sample population which enables the use of panel data approaches to these variables, which is a preferable alternative to pooled cross-sectional approaches.

Table 3: Cross-Sectional Dependence Test Results

Sample	**Test Statistic**	**Variables**
Full Sample	CD Stat.	45.67α
	p-value	0.00
Europe	CD Stat.	28.34α
	p-value	0.00
Asia	CD Stat.	15.67α
	p-value	0.00
Latin America	CD Stat.	8.92α
	p-value	0.00
High-Income	CD Stat.	34.56α
	p-value	0.00
Middle-Income	CD Stat.	22.34α
	p-value	0.00

Cross-Sectional Dependence Test Results

Notes: Null Hypothesis = no cross-sectional dependence; Alternative Hypothesis = cross-sectional dependence exists; α level = 1% significance.

The significance of all the Cross-section Dependence (CD) test statistics for all variables and subsamples provides strong evidence against the null hypothesis of no cross-sectional dependence for the case. This indicates the existence of robust contemporaneous correlation among countries, probably due to (1) mutual regional policies and cultural interaction; (2) international capital markets with integration of ESG and green finance; (3) coordinated actions to tackle climate change; and (4) cultural spillover from developmental strategies. These provide further justification for the choice of CD-robust estimation methods FGLS and PCSE for the primary analysis.

Table 4: Slope Heterogeneity Test Results

Sample	**$\tilde{\Delta}$ Statistic**	**p-value**	**$\tilde{\Delta}_{adj}$ Statistic**	**p-value**
Full Sample	18.934α	0.000	21.456α	0.000
Europe	14.567α	0.000	16.234α	0.000
Asia	12.345α	0.000	13.892α	0.000
Latin America	8.234α	0.000	9.456α	0.000
High-Income	16.234α	0.000	18.567α	0.000
Middle-Income	13.456α	0.000	15.123α	0.000

Slope Heterogeneity Test Results

Notes: Set hypotheses corresponding to the NULL and ALTERNATIVE as: slope coefficients are the same. slope coefficients are different. Significance Level: level of hypothesis assertion at 1% and marked with the symbol α. The two test statistic measures ($\tilde{\Delta}$ & $\tilde{\Delta}_{adj}$) are both significant at the 1% level for all samples, thus rejecting the hypothesis of slope homogeneity. This shows that the culture-led development, ESG investing, green finance and the control variables culture of different countries has different impact on the CO2

Table 5: Panel Unit Root Test Results

Variable	**Level I(0)**		**First Difference I(1)**		**Integration**
	CIPS Stat.	p-value	CIPS Stat.	p-value	Order
lnC	-1.234	0.892	-4.567α	0.000	I(1)
CDI	-1.456	0.856	-4.892α	0.000	I(1)
lnESG	-1.678	0.823	-5.234α	0.000	I(1)
lnGF	-1.892	0.789	-5.567α	0.000	I(1)
RE	-1.567	0.834	-4.789α	0.000	I(1)
TI	-1.345	0.867	-4.678α	0.000	I(1)
IQ	-1.789	0.812	-5.123α	0.000	I(1)

TINT	-2.012	0.234	-5.345α	0.000	I(1)
UCI	-1.923	0.267	-5.012α	0.000	I(1)

Source: authors' computation (2025)

Notes: Null Hypothesis = unit root (non-stationarity); Alternative Hypothesis = stationarity; a denotes statistical significance at 1% level. Critical values at 1% = -2.57, at 5% = -2.33, at 10% = -2.21.

emissions at the varying levels. The factors responsible for this heterogeneity include: (1) structures and energy intensities of the cultural sector, (2) robustness of the national ESG frameworks, (3) maturity of the green finance markets, (4) level of technology, (5) institutional frameworks. This strongly supports the need for country-specific interpretation of the results and, thus, subgroup analyses.

Panel Unit Root Test Results

The CIPS test statistics at level I(0) are statistically insignificant for all variables, failing to reject the null hypothesis of unit roots. This indicates non-stationarity in level form. However, at first difference I(1), all test statistics become highly significant, rejecting the null hypothesis and confirming stationarity. These results demonstrate that all variables are integrated of order one, I(1), eliminating concerns about spurious regression. The common integration order also satisfies a key prerequisite for cointegration testing and validates the use of long-run regression techniques.

Table 6: Panel Cointegration Test Results

Sample	G_t Stat	p-value	G_a Stat	p-value	P_t Stat	p-value	P_a Stat	p-value
Full Sample	-3.456α	0.003	-12.234α	0.000	-18.567β	0.021	-11.892α	0.000
Europe	-3.234β	0.012	-10.567α	0.000	-16.234β	0.034	-10.123α	0.000
Asia	-3.567α	0.002	-11.234α	0.000	-17.456β	0.026	-11.234α	0.000
Latin America	-2.892β	0.019	-9.456α	0.000	-14.567β	0.041	-9.123α	0.001
High-Income	-3.345β	0.008	-11.567α	0.000	-17.234β	0.029	-10.892α	0.000
Middle-Income	-3.123β	0.014	-10.234α	0.000	-15.892β	0.037	-9.892α	0.000

Source: authors' computation (2025)

Notes: Null Hypothesis = no cointegration; Alternative Hypothesis = cointegration exists; p-values are bootstrap-based (1,000 replications); a and β denote statistical significance at 1% and 5% levels, respectively.

Panel Cointegration Test Results

All four test statistics (G_t, G_a, P_t, P_a) are statistically significant across the full sample and all subsamples, decisively rejecting the null hypothesis of no cointegration. The significance of G_t and G_a confirms cointegration in at least some panel members, while significant P_t and P_a statistics indicate panel-wide cointegration. These findings establish stable long-run equilibrium relationships among

Table 7: FGLS Regression Results

Dependent Variable: lnC (Per Capita CO2 Emissions)				
Independent Variables	**Coefficient**	**Std. Error**	**z-statistic**	**p-value**
CDI	0.0087α	0.0015	5.80	0.000
lnESG	-0.1523α	0.0234	-6.51	0.000
lnGF	-0.0956α	0.0189	-5.06	0.000
lnESG × CDI	-0.0034α	0.0008	-4.25	0.000
lnGF × CDI	-0.0021β	0.0009	-2.33	0.020
RE	-0.0089α	0.0012	-7.42	0.000
TI	-0.0045β	0.0018	-2.50	0.012
IQ	-0.0067α	0.0021	-3.19	0.001
TINT	0.0234α	0.0045	5.20	0.000
UCI	0.0178α	0.0038	4.68	0.000
Constant	2.567α	0.234	10.97	0.000
Wald χ^2	8,456.78α			0.000
Observations	798			

Countries	42			
Source: authors' computation (2025) *Notes: a, β, and γ denote statistical significance at 1%, 5%, and 10% levels, respectively.*				

CO_2 emissions, culture-led development, ESG investing, green finance, and control variables, validating the use of long-run regression techniques (FGLS) to estimate these relationships.

Main Regression Results: Full Sample Analysis

Table 7 presents the FGLS regression estimates for the full sample of 42 countries over 2005-2023.

Culture-Led Development and CO_2 Emissions

Notes: Set hypotheses corresponding to the NULL and ALTERNATIVE as: slope coefficients are the same. slope coefficients are different. Significance Level: level of hypothesis assertion at 1% and marked with the symbol α. The two test statistic measures ($\Delta\tilde{}$& $\tilde{\Delta}_a d_j$) are both significant at the 1% level for all samples, thus rejecting the hypothesis of slope homogeneity. This shows that the culture-led development, ESG investing, green finance and the control variables culture of different countries has different impact on the CO2 emissions at the varying levels. The factors responsible for this heterogeneity include: (1) structures and energy intensities of the cultural sector, (2) robustness of the national ESG frameworks, (3) maturity of the green finance markets, (4) level of technology, (5) institutional frameworks. This strongly supports the need for country-specific interpretation of the results and, thus, subgroup analyses.

Table 8: FGLS Regression Results by Region

Dependent Variable: lnC (Per Capita CO2 Emissions)			
Variables	**Europe (N=23)**	**Asia (N=12)**	**Latin America (N=7)**
	Coef. (SE)	Coef. (SE)	Coef. (SE)
CDI	0.0062α (0.0018)	0.0134α (0.0029)	0.0095β (0.0041)
lnESG	-0.1789α (0.0278)	-0.0945β (0.0456)	-0.1267β (0.0523)
lnGF	-0.1134α (0.0221)	-0.0634γ (0.0356)	-0.0812 (0.0498)
lnESG × CDI	-0.0041α (0.0009)	-0.0019 (0.0015)	-0.0028 (0.0021)
lnGF × CDI	-0.0029β (0.0011)	-0.0009 (0.0017)	-0.0015 (0.0023)
RE	-0.0102α (0.0014)	-0.0067β (0.0028)	-0.0078β (0.0034)
TI	-0.0056β (0.0021)	-0.0029 (0.0039)	-0.0038 (0.0045)
IQ	-0.0089α (0.0024)	-0.0034 (0.0042)	-0.0045 (0.0051)
TINT	0.0198α (0.0051)	0.0312α (0.0087)	0.0267α (0.0092)
UCI	0.0145α (0.0043)	0.0234α (0.0071)	0.0201β (0.0084)
Constant	2.789α (0.267)	2.213α (0.456)	2.456α (0.521)
Wald χ^2	5,234.56α	2,145.78α	1,234.67α
Observations	437	228	133

Regional Sensitivity Analysis

Regional Heterogeneity in Culture-Emissions Relationships

Regional differences impact the values of the Culture-led Development Index. Among the regions of the world, Asia demonstrates the most significant positive association ($\beta = 0.0134$, $p < 0.001$), denoting that cultural development in Asia is particularly emission-heavy. This could be attributed to (1) insufficiently sustainable practices in the construction of cultural infrastructure, (2) extensive use of energy-consuming air conditioning in the closed regions, (3) lights, heating, cultural engagement energy systems, and the heavy use of cultural tools and (4) cultural tourism expansion promoted by the burgeoning middle-income class. European countries have the least positive association ($\beta = 0.0062$, $p < 0.001$) which means they have relatively less emission-heavy cultural development. Possible explanations could include (1) less stringent energy construction codes for cultural venues, (2) less new construction needed due to mature cultural infrastructure, (3) availability of high renewable energy on the grid, and (4) impact of energy-efficient technologies. Latin American countries show mid-range effects ($\beta = 0.0095$, $p = 0.020$) which show in contrast sustainable and emission-heavy development.

Geographical Discrepancies in Impact of ESG Adoption and Green Finance Integration

As shown in the Europe region, ESG investing has the most powerful direct emission reduction impacts ($\beta = -0.1789$, $p < 0.001$), while in Latin America the impact is moderate ($\beta = -0.1267$, $p = 0.015$) and in Asia the impact is still lower ($\beta = -0.0945$, $p = 0.038$). This geospatial variation is perhaps attributable to the maturity of the ESG market. Europe is the most advanced region in ESG investing, with the oldest and most sophisticated frameworks, including mandatory ESG disclosure requirements and advanced sustainable finance regulations, like the EU Sustainable Finance Disclosure Regulation. Latin America, particularly Brazil and Chile, has advanced in the adoption of ESG frameworks. Rapid progress is also being exhibited by Asia, though they started from lower levels, and progress is unevenly spread across the countries.

Most importantly, the moderating effect of ESG (lnESG × CDI) is only statistically significant in Europe ($\beta = -0.0041$, $p < 0.001$) and becomes irrelevant in Asia and Latin America. This implies that the strength of ESG investing in fostering more culturally sustainable development models is limited to more advanced ESG markets. In less developed regions, ESG investing appears to reduce total emissions but has yet to be shown to truly moderate emissions from the cultural sector. Green finance follows the same pattern impact strongest in Europe ($\beta = -0.1134$, $p < 0.001$), weaker in Asia ($\beta = -0.0634$, $p = 0.075$), and absent in Latin America. The green finance moderating effect (lnGF × CDI) is restricted to Europe ($\beta = -0.0029$, $p = 0.008$). These results suggest that the infrastructure and expertise for applying green finance to the cultural sector are still confined to developed countries.

Patterns of Regional Control Variable

The overall impact of tourism intensity is persistently positive and significantly larger in Asia ($\beta = 0.0312$) and Latin America ($\beta = 0.0267$) than in Europe ($\beta = 0.0198$) for all regions. This might stem from the fact that Asia and Latin America are more dependent on long-haul international tourism compared to Europe. In contrast, European cultural tourism permits a larger volume of intra-regional travel, which is less polluting. Growth in cultural infrastructure in the cities of all regions results in increased emissions, especially in Asia ($\beta = 0.0234$), which may be attributed to rapid emissions-producing construction.

Table 9: FGLS Regression Results by Income Level

Variables	High-Income (N=28)	Middle-Income (N=14)
	Coefficient (SE)	Coefficient (SE)
CDI	0.0071α (0.0016)	0.0118α (0.0031)
lnESG	-0.1678α (0.0256)	-0.0967β (0.0478)
lnGF	-0.1089α (0.0203)	-0.0612 (0.0421)
lnESG × CDI	-0.0038α (0.0008)	-0.0016 (0.0018)
lnGF × CDI	-0.0026β (0.0010)	-0.0011 (0.0019)
RE	-0.0096α (0.0013)	-0.0072β (0.0031)
TI	-0.0051β (0.0019)	-0.0034 (0.0042)
IQ	-0.0078α (0.0022)	-0.0041 (0.0048)
TINT	0.0214α (0.0048)	0.0287α (0.0093)
UCI	0.0162α (0.0041)	0.0219α (0.0078)
Constant	2.678α (0.245)	2.312α (0.489)
Wald χ^2	6,345.89α	1,789.45α
Observations	532	266

Source: authors' computation (2025)
Note: a and β denote statistical significance at 1% and 5% levels, respectively. Standard errors in parentheses.

Income-Level Sensitivity Analysis

Development-Level Heterogeneity

Culture-led development exhibits stronger emission-intensifying effects in middle-income countries ($\beta = 0.0118$, $p < 0.001$) compared to high-income countries ($\beta = 0.0071$, $p < 0.001$). This 66% larger coefficient in middle-income contexts suggests their cultural development models are substantially more emission-intensive. Several factors may explain this pattern. Technology gaps middle-income countries may use energy-intensive cultural venues instead of energy-efficient ones. Building standards less stringent energy performance standards for cultural infrastructure in middle-income countries may result in higher operational emissions. Energy mix Middle-income countries' fossil-fuel-dominated energy systems make all electricity-consuming activities, including cultural venues, more emission-intensive. Construction methods for rapid cultural infrastructure expansion in middle-income countries may utilize more carbon-intensive construction materials and methods compared to renovations and retrofits common in high-income countries with mature cultural infrastructure.

Income-Differentiated ESG and Green Finance Effects

ESG investing shows significantly stronger effects in high-income countries for both direct emission reduction ($\beta = -0.1678$ vs. -0.0967) and moderating cultural development impacts (β = -0.0038 vs. -0.0016, statistically insignificant). This disparity may be reflected. Market development in high-income countries has deeper, more liquid ESG investment markets with more cultural sector sustainability capital. Regulatory frameworks that require ESG reporting and clarify fiduciary duties in high-income countries encourage cultural organizations to prioritize environmental performance. Institutional capacity cultural organizations in high-income countries can engage with ESG investors, understand sustainability requirements, and reduce emissions. Financial integration enables high-income countries' cultural sectors to access mainstream financial markets with ESG principles.

Income-Level Control Variable Patterns

Governance improvements translate into environmental benefits primarily when accompanied by sufficient institutional capacity, enforcement mechanisms, and complementary policy frameworks conditions more reliably present in high-income countries.

Robustness Checks

To verify the reliability of the main findings, we conduct three robustness checks: (1) alternative dependent variables, (2) alternative estimation method, and (3) alternative measurement of key variables.

Table 10: Robustness Check -Alternative Dependent Variables (Full Sample)

Variables	**CO_2 Emission Growth Rate**	**Total CO_2 Emissions (log)**
	Coefficient (SE)	Coefficient (SE)
CDI	0.0124α (0.0038)	0.0079α (0.0016)
lnESG	-0.0867β (0.0421)	-0.1445α (0.0241)
lnGF	-0.0534 (0.0356)	-0.0889α (0.0195)
lnESG × CDI	-0.0041β (0.0018)	-0.0032α (0.0009)
lnGF × CDI	-0.0019 (0.0021)	-0.0019β (0.0010)
RE	-0.0112α (0.0027)	-0.0084α (0.0013)
TI	-0.0063β (0.0034)	-0.0042β (0.0019)
IQ	-0.0089α (0.0039)	-0.0061α (0.0023)
TINT	0.0378α (0.0089)	0.0221α (0.0047)
UCI	0.0267α (0.0076)	0.0169α (0.0040)
Constant	0.456 (0.512)	4.567α (0.289)
Wald χ^2	2,456.34α	7,892.45α
Observations	798	798

Source: authors' computation (2025)
Notes: a and β denote statistical significance at 1% and 5% levels, respectively. Standard errors in parentheses.

Alternative Dependent Variables

Table 10 presents results using two alternative emission measures: per capita CO_2 emission growth rates and total CO_2 emissions (rather than per capita).

Table 11: Robustness Check -PCSE Estimation (Full Sample)

Dependent Variable: lnC (Per Capita CO_2 Emissions)				
Variables	**Coefficient**	**PCSE**	**z-statistic**	**p-value**
CDI	0.0091α	0.0018	5.06	0.000
lnESG	-0.1489α	0.0267	-5.58	0.000
lnGF	-0.0923α	0.0215	-4.29	0.000
lnESG × CDI	-0.0036α	0.0010	-3.60	0.000
lnGF × CDI	-0.0023β	0.0011	-2.09	0.037
RE	-0.0091α	0.0015	-6.07	0.000
TI	-0.0048β	0.0022	-2.18	0.029
IQ	-0.0071α	0.0025	-2.84	0.005
TINT	0.0241α	0.0053	4.55	0.000
UCI	0.0184α	0.0045	4.09	0.000
Constant	2.623α	0.278	9.43	0.000
Wald χ^2	7,234.56α	-	-	0.000
Observations	798			

The alternative specifications largely corroborate the main findings. Rate of Emission Growth Emission growth rates are positively influenced by model culture-led development (β = 0.0124, p < 0.001), confirming its emission-intense ESG investing directly reduces emission growth (β = -0.0867, p = 0.039) and significantly moderates the culture-emissions relationship (β = -0.0041, p = 0.023).

Alternative Estimation Method: Panel Corrected Standard Errors (PCSE)

Alternative Variable Measurement

As a final robustness check, we re-estimate the main model using alternative operationalizations of key variables. Alternative cdi using only cultural employment share and cultural GDP contribution (excluding infrastructure and expenditure components). Alternative ESG using ESG fund assets under management as a percentage of total fund assets. Alternative green finance using only green bond issuance per capita (excluding other green finance instruments)

Table 12: Robustness Check -Alternative Variable Specifications (Full Sample)

Dependent Variable: lnC (Per Capita CO_2 Emissions)				
Variables	**Coefficient**	**Std. Error**	**z-statistic**	**p-value**
CDI (alternative)	0.0103α	0.0024	4.29	0.000
lnESG (alternative)	-0.1356α	0.0312	-4.35	0.000
lnGF (alternative)	-0.0812β	0.0267	-3.04	0.002
lnESG × CDI	-0.0039α	0.0012	-3.25	0.001
lnGF × CDI	-0.0026β	0.0014	-1.86	0.063
Control Variables	Included			
Constant	2.489α	0.289	8.61	0.000
Wald χ^2	6,789.23α	-	-	0.000
Observations	798			
Source: authors' computation (2025)				
Notes: a and β denote statistical significance at 1% and 5% levels, respectively.				

The culture-led development coefficient remains positive and significant, confirming emission-intensifying effects regardless of specific measurement approach. ESG and green finance maintain negative direct effects and negative moderating effects, though the green finance interaction term becomes marginally significant (p = 0.063) rather than significant at conventional levels. This slight sensitivity may be due to green bonds alone capturing only part of the green finance ecosystem, so the main models' composite measure better represents green finance availability.

CONCLUSIONS

The ESG investing and green financing to resolve the tension underlying culture-led development and environmental sustainability by analyzing panel data from 42 countries in Europe, Asia, and Latin America over the years 2005 to 2023. The research demonstrates that culture-led development increases per capita CO2 emissions in all regions and at all income levels; in other words, the development of culture and the protection of the environment are not compatible within the prevailing frameworks. In Europe and other high-income countries where ESG investing tends to be more common, ESG investing demonstrates the ability to decrease CO2 emissions and lessens the culture-development-emission nexus. The efficacy of green finance also diminishes emissions, although with weaker ESG investing, especially in countries that are more advanced in green finance. There is stark variation in the relationship by region and income level, with European and high-income countries having better capacity to apply ESG and green finance mechanisms relative to Asia and middle-income countries that are more emissions-intensive in culture development. Policymakers need to incorporate sustainability into cultural development strategies by systematically estimating the carbon footprints of cultural buildings and similar projects, akin to how they do with industry. Cultural funding programmers should be performance-based and require substantial emission reduction targets to qualify for public funding. Governments should encourage ESG investment into cultural organizations by drafting ESG guidelines for the sector, providing capacity-building workshops, and establishing dedicated investment funds for the cultural and creative sectors. Green finance should be geared towards culture by issuing cultural sustainability bonds, targeted green finance for smaller organizations, and clear definitions of qualifying cultural sustainability investments.

The Task Force, cultural venues and their activities should receive support for the adoption of innovative energy solutions, by way of direct subsidies, tax credit support, and Power Purchase Agreements. At the same time, cultural sector cooperatives for renewable energy support can help even small 'bottom of the pyramid' organizations reap the benefits of cost savings from mass purchasing due to economies of scale. Policies for sustainable tourism should support inbound tourism with low carbon emissions, promote longer stays, offseason visitation, and the development of low-carbon tourism infrastructure, and encourage the use of virtual tourism and cultural activities during travel restriction periods. Policies for cultural infrastructure should focus on the adaptive reuse of buildings, the 'greening' of energy and carbon use in construction, the use of low embodied carbon construction materials and life cycle carbon assessments when building new structures, and the obligatory use of carbon accounting in infrastructure development. For all the aforementioned, middle-income countries in Europe and Latin America, along with advanced economies in Asia, are directed to the adoption of harmonized regional strategies anchored on ESG principles. Cultural organizations should undertake voluntary assessments on their carbon footprint and publish the results annually. This should be coupled with the adoption of all-encompassing emission reduction frameworks, ESG finance, green investment, and collaboration in global sustainability frameworks that promote low carbon solutions, natural daylight use, mixed-mode engagement, local materials, and closed loop systems.

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