How Does Urban Sustainability Look From Above?

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1 Introduction

The UNESCO Creative Cities Network (UCCN), established in 2004, promotes sustainable urban development by encouraging cities to harness cultural heritage and creative industries in line with the 2030 Agenda. Applicants must demonstrate how creativity fosters long-term progress across economic, social, cultural, and environmental dimensions. However, it remains unclear whether UCCN membership actively drives greater sustainability or simply recognizes cities already on a sustainable path—an important distinction for assessing its transformative potential.

Urban vegetation, essential to sustainable urban systems, regulates climate, mitigates pollution, and enhances well-being. Yet, vegetation trends vary under urbanization pressures. Recent studies show that while suburban vegetation often declines, urban cores may experience gains through proactive management (Zhong and Li, 2024; Guo et al., 2024).

This study applies satellite remote sensing methods, using Landsat imagery and standardized NDVI measures, to assess changes in urban greenness across a global sample of cities. Employing a staggered difference-in-differences approach and quantile analysis, we examine whether UCCN designation correlates with increased green space, providing evidence on whether the initiative catalyzes or merely codifies sustainable urban development.

2 Data

This study covers the period 2004–2023, coinciding with the launch of the UCCN and the availability of consistent satellite imagery. Two main data sources are used: (i) the official UCCN website, providing the list of member cities and their declaration dates across seven creative fields, and (ii) satellite imagery from the Landsat program, accessed via the Google Earth Engine (GEE) platform. Landsat's long-term, global coverage with 30-meter resolution and a 16-day revisit cycle enables reliable monitoring of urban vegetation dynamics. Imagery from Landsat 5, 8, and 9 is used depending on the year.

Cities were geolocated using OpenStreetMap's Nominatim API, with a 5-kilometre buffer applied around each urban center to capture both core and peri-urban green spaces. Socio-economic controls—annual GDP growth, population growth, and urban population share growth—are incorporated at the country level, acknowledging the limitation of assuming intra-country homogeneity in the absence of consistent city-level data.

3 NDVI Methodology

To quantify vegetation cover over time, this study calculates the Normalized Difference Vegetation Index (NDVI) from the Landsat imagery. NDVI is a widely used index that captures the density and greenness of vegetation and is defined by the following formula:

$$\text{NDVI} = \frac{\text{NIR} - \text{RED}}{\text{NIR} + \text{RED}} \tag{1}$$

where **NIR** represents the reflectance in the near-infrared band, and **RED** represents

the reflectance in the red band of the electromagnetic spectrum[1]. Healthy vegetation absorbs most visible light (particularly red) and reflects a significant portion of near-infrared light, leading to high NDVI values. The resulting index ranges from -1 to 1. Higher positive values typically indicate healthy, dense vegetation, with tropical and temperate forests often falling in the range of 0.6 to 0.8. Intermediate values around 0.2 to 0.3 are associated with grasslands or shrubs, while values near zero or negative are characteristic of non-vegetated surfaces such as built-up areas, water bodies, snow, or bare soil.

To ensure temporal and geographic consistency, NDVI was calculated over the summer period, when vegetation is typically most dense and green. This corresponds to April to September in the Northern Hemisphere and October to March in the Southern. This seasonal focus reduces the effects of short-term weather fluctuations and seasonal dormancy, providing a more accurate reflection of annual green cover.

However, this approach has limitations. Cities near the equator often lack clearly defined seasonal cycles, so applying a fixed seasonal window may misrepresent peak vegetation levels. Further, summer periods often coincide with increased cloud cover in some regions, particularly tropical or monsoonal climates, which may limit the availability of clear satellite imagery.

For each city-year combination, all images available within the summer period were averaged to create a single NDVI value for each year. Observations were included only if at least one valid NDVI image was available in the target period.

4 Empirical Strategy

This study employs a staggered difference-in-differences (DID) approach, following Callaway and Sant'Anna (2021), to estimate the impact of UNESCO Creative City designation on urban sustainability, proxied by changes in urban green space from satellite imagery. Treatment is defined as the year a city is officially designated, with later-designated cities serving as controls. The empirical model is specified as:

$$Y_{it} = \alpha_i + \sum_g \delta_{gt} D_i(g) + \beta X_{it} + \epsilon_{it} \tag{2}$$

where:

- Y_{it} represents the indicator of urban green space for city i at time t,

- $D_i(g)$ is an indicator for whether city i was treated in cohort g at time t,

- X_{it} is a vector of time-varying control variables,

- α_i captures city-specific fixed effects,

- ϵ_{it} is the error term.

We conduct a robust parallel trends test following Rambachan and Roth (2023) to validate the DID assumptions. To account for potential heterogeneity, we perform a quantile analysis based on the historical growth rate of urban population shares, clustering

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[1]NIR is Band 4 for Landsat 5 and Band 5 for Landsat 8 or 9; RED is Band 3 for Landsat 5 and Band 4 for Landsat 8 or 9.

cities into four groups. This approach, informed by Banquet et al. (2022), allows us to control for underlying urban expansion trends and assess differential effects across varying urban growth contexts.

5   Background and Descriptive Statistics

Among the top ten countries with the most UNESCO Creative City nominations—China, Japan, Mexico, Brazil, the United Kingdom, France, Spain, Italy, the United States, and Australia—Gastronomy, Design, and Literature are the leading creative fields. Urbanization patterns vary across these countries, with China showing the highest average urban population growth (2.91%) and Australia the lowest (0.11%). These differences underscore the need to control for baseline urban growth when analyzing sustainability impacts.

The mean NDVI across all cities shows a gradual upward trend between 2004 and 2023, with more pronounced improvements from 2010 onward, peaking in 2023. This suggests increasing urban greenness over time, consistent with broader global trends toward sustainable urban development.

For further details, please refer to the interactive map attached, which visualizes the nominated cities, their creative fields, and the years of their nomination.

6   Results

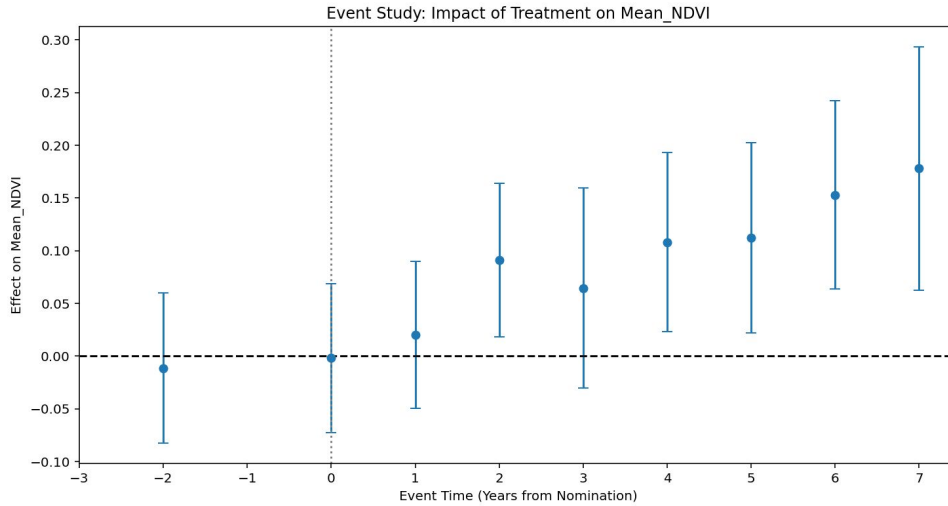## 6.1   Overall Impact of Nomination on NDVI

Figure 1: Event Study: Impact of Treatment on Mean NDVI

The event study plot (Figure 1) shows the dynamic effects of UNESCO Creative City designation on urban vegetation, measured through standardized NDVI. Before nomination (Event Time 0), NDVI trends are flat and statistically indistinguishable from zero, supporting the validity of the parallel trends assumption.

Following nomination, a positive trend emerges, with NDVI increasing steadily from year two onward and peaking around six to seven years after designation. This suggests

that UCCN membership is associated with gradual improvements in urban greenness, likely reflecting both direct greening initiatives and broader shifts in urban planning practices.

These findings align with prior research emphasizing the delayed impacts of cultural and urban policy interventions (Evans, 2009; Baycan and Girard, 2012), reinforcing the view that creative city policies can act as long-term catalysts for sustainable urban transformation rather than delivering immediate effects.

6.2 Heterogeneity Analysis: Urban Population Growth Quartiles

To further explore heterogeneity in treatment effects, cities were stratified into quartiles based on their average annual urban population growth rates. The event study results reveal important differences across these groups.

- **Q1 (Lowest Urban Population Growth):**

Cities with slow or declining urban growth exhibit modest improvements in NDVI following UCCN nomination. While point estimates are positive post-treatment, confidence intervals remain wide, suggesting substantial uncertainty. The limited effect may reflect weaker investment dynamics or a lack of urban expansion pressures that typically drive large-scale greening initiatives.
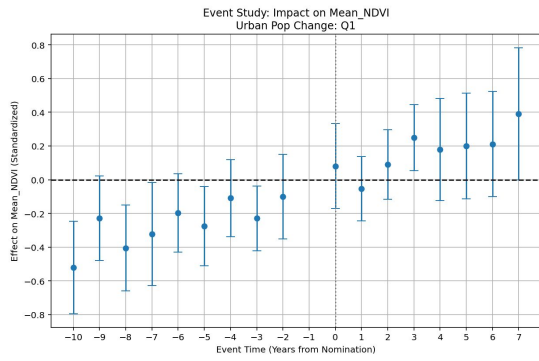
- **Q2 (Moderate-Low Growth):**

In Q2, a stronger and clearer positive NDVI response emerges, becoming statistically distinguishable from zero approximately two years after nomination. This suggests that moderately growing cities might be particularly well-positioned to integrate sustainability policies and leverage UCCN recognition to enhance urban greenness.

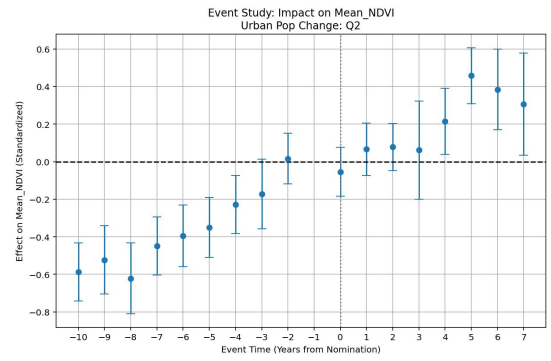- **Q3 (Moderate-High Growth):**

Cities in Q3 experience the most pronounced and consistent NDVI gains post-nomination. The results indicate that in contexts of moderate-to-high urban expansion, cities are able to balance growth with the implementation of green urban strategies, potentially amplified by the visibility and resources linked to Creative City status.

- **Q4 (Highest Urban Population Growth):**

Rapidly growing cities in Q4 also display positive NDVI trends, although the effects are more volatile compared to Q3. This pattern suggests that while opportunities for greening exist amid high urban expansion, they may be partially offset by competing development pressures that challenge the implementation of sustainable land use policies.
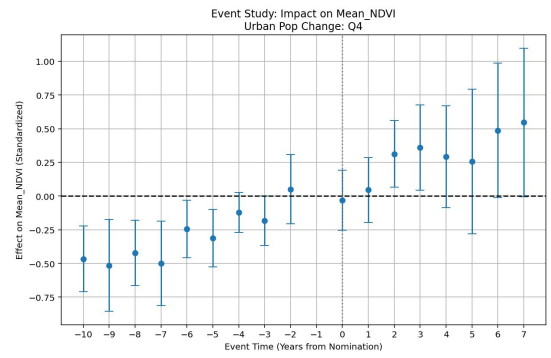
(a) Quartile 1 (Lowest Growth)

(b) Quartile 2 (Moderate-Low Growth)
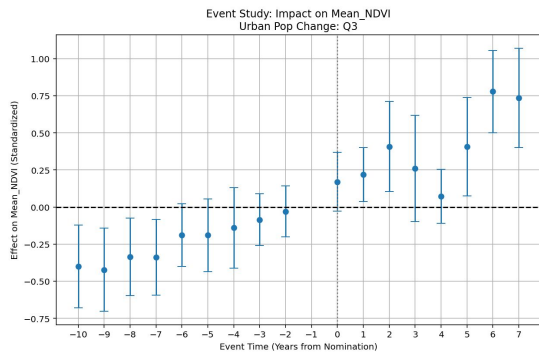
(c) Quartile 3 (Moderate-High Growth)

(d) Quartile 4 (Highest Growth)

Figure 2: Event Study Plots: Impact of UCCN Designation on NDVI Across Urban Growth Quartiles

7 Conclusion

This study investigates the impact of UNESCO Creative City designation on urban sustainability, proxied by changes in urban green space as measured through satellite-derived NDVI. Using a staggered difference-in-differences approach complemented by quantile analysis, we find that UCCN membership is associated with gradual and positive increases in urban vegetation over time. The effects are heterogeneous across cities, with the most pronounced gains observed in contexts of moderate to high urban population growth, suggesting that baseline urbanization dynamics mediate the sustainability outcomes of cultural policy interventions.

Our findings contribute to the growing body of evidence that cultural initiatives can support broader sustainable development goals. Nevertheless, the lagged and uneven nature of the observed effects points to the need for complementary policies to maximize the environmental benefits of UCCN participation.

Future research should expand the analysis to other dimensions of urban sustainability, including energy use, mobility patterns, and social inclusion, to offer a more comprehensive assessment of the transformative potential of creative city policies.

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