

Study on the Evolution and Driving Mechanism of Spatial Polarization in Tokyo Metropolitan Area

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Abstract of Dissertation

Spatial polarization denotes the bipolarized concentration and segregation of socio-economic groups or resource endowments within urban space, such that certain districts become richly endowed with wealth and services while others descend into resource scarcity and social isolation. Western scholarship has long examined this phenomenon through lenses of class, ethnicity, and territorial fragmentation, East Asian contexts—marked by accelerated urban growth, sharply falling birthrates, and closed migration systems—present a distinct setting in which to isolate the demographic drivers of spatial polarization. Japan's Tokyo Metropolitan Area (TMA), as the world's most mature megacity, epitomizes these dynamics: half a century of “unipolar concentration” in the metropolis contrasts starkly with depopulation and aging across over 60% of the nation's landmass. Yet prior studies have largely foregrounded macro-economic and neoliberal policy factors, leaving the roles of life-course migration, built-environment change, and urban greening underexamined—particularly across nested spatial scales.

Therefore, this doctoral dissertation analyzes 25 years of data from the TMA to examine the interaction between population dynamics and urban environmental factors, thereby elucidating the distinctive patterns and driving mechanisms of spatial polarization in East Asian megacities. By positioning the TMA as a paradigmatic case, it offers transferable insights for the sustainable planning of global cities confronting complex demographic shifts. The research aims to address three core themes: (i) Diverse spatial evolution trajectories. How do urban cores and peripheral zones diverge in their developmental pathways? (ii) Environmental implications of polarization patterns. What lessons do emergent spatial bifurcations hold for green and resilient urban design? (iii) Interaction between population migration and the built environment. In what ways do net migration flows and built - environment attributes jointly shape the evolution of spatial polarization?

First, the study introduces the Normalized Difference Index (NDI) to quantify the change degree in population (P) and built-up areas (B) over the past 25 years across three periods, and conceptualizes five urban development dynamics with nine sub-categories: Steady (B-P-), Expand ($B \uparrow P-$; $B \uparrow P \uparrow$), Sprawl shrinkage($B \uparrow P \downarrow$), Shrink ($B \downarrow P \downarrow$; $B \downarrow P-$; $B-P \downarrow$), and Intensive ($B \downarrow P \uparrow$; $B-P \uparrow$). Results are discussed from two aspects: (i) Over the past 25 years, how have built-up areas and population in the TMA evolved? (ii) What spatiotemporal patterns do these evolutions exhibit? As result, this chapter revealed the “central concentration, peripheral shrinkage” driven by population changes.

Second, the changes in the Normalized Difference Vegetation Index (NDVI) during each period are calculated using Landsat satellite imagery through the Google Earth Engine (GEE) and GIS platforms. Based on the NDI and NDVI changes, three greenness trends are categorized:

Greening (NDVI $\uparrow$), Browning (NDVI $\downarrow$), and Stable Greenspace (high NDVI-). The Kruskal-Wallis H Test (KWT) is then applied to analyze the differences in the impact of urban development dynamics on each greenness change trend. The research results are discussed from three perspectives: (i) What are the spatiotemporal characteristics of greenness trends in TMA over the past 25 years? (ii) Which urban dynamic has the greatest influence on each greenness trend? (iii) What role do changes in population and built-up areas play in the greenness change process? This chapter further revealed the impact of population (density) changes on greenness trends and potential “center-periphery” ecological polarization.

Third, Factor analysis is applied to categorize the net migration population of ten age groups into three life-course migration intensity (MPI): young adults(Y), young nuclear family (C), and older seniors (S). Then, eight migration patterns are identified by combining population inflow (+) and outflow (–) for each migration trend: Y–C–S+, Y–C–S–, Y–C+S+, Y–C+S–, Y+C+S+, Y+C+S–, Y+C–S–, and Y+C–S+. Robust Multiple Linear Regression (MLR) is then used to analyze the impact of 44 urban environmental factors related to multiple housing choices (housing characteristic, neighborhood condition, accessibility) on MPI across three life-course groups. Random Forest is introduced to select the most influential housing choice factors for each life-course migration trend. Subsequently, Geographically Weighted Regression (GWR) is used to examine the spatial variations in the impact of key influencing factors on the corresponding migration trends at regional and local scales. This chapter aims to answer four questions: (i) Which life-course groups are migrating? (ii) To which areas do these life-course groups tend to migrate from and to? (iii) What housing choices do these life-course groups make? Do housing choices associated with life-course migration vary significantly across regions? (iv) How do migration and housing choices across different life stages contribute to spatial polarization in a shrinking megacity? As a result, this chapter revealed driving mechanism of spatial polarization through life-course migration and associated housing choices.

In conclusion, this dissertation demonstrates that demographic forces—more than land - cover change alone—have orchestrated Tokyo’ s shift toward a compact core and hollowed periphery, imprinting distinct ecological signatures across its urban fabric. It reveals that emerging “sprawl - shrinkage” dynamics can both curb vegetation loss and sustain greenspace where population declines outpace development, while greening initiatives concentrated in central wards risk deepening a center-periphery ecological divide. Through a life - course lens, the work shows how cohort-specific housing choices underpin a “Youthful Centers - Favored Inner Suburbs - Aging Periphery” geography, challenging the assumption that polycentric planning inherently diffuses spatial pressure. By integrating demographic, spatial, and ecological dimensions, the study not only enriches our conceptualization of metropolitan polarization but also points toward tailored greening, land-use, and housing strategies that can foster more equitable, green, and resilient megacities under demographic decline.