Extended Abstract

Urbanization is one of the defining structural transformations of modern economies. The verticalization of cities, the concentration of economic activity in dense cores, and the spatial reconfiguration of infrastructure and services have reshaped not only productivity and land markets but also environmental exposure and health outcomes. While regional science has extensively studied the economic consequences of density—agglomeration economies, land rents, labor productivity, innovation—its implications for population health remain comparatively underexplored. This paper contributes to the regional science literature by examining how vertical urban density, as a structural characteristic of territorial development, is associated with lung and bronchus cancer mortality across U.S. states from 1999 to 2022, with particular attention to gender heterogeneity and nonlinear spatial effects.

The analysis is grounded in the premise that the built environment constitutes a persistent regional structure that shapes long-term exposure to environmental risk, access to healthcare infrastructure, and behavioral patterns. Rather than focusing on conventional measures of population density, this study introduces a structural proxy for vertical urban development: the number of skyscrapers in each state (buildings exceeding 150 meters in height). In urban economics, vertical construction reflects extreme realizations of floor-area intensity and arises where land rents, accessibility, and agglomeration forces are strongest. Skyscrapers therefore capture the presence and scale of highly vertical urban cores and represent a durable manifestation of territorial development patterns. Because long-run, comparable measures of fine-grained urban density are unavailable at the state level, skyscraper counts offer a theoretically grounded and observable indicator of structural urban intensity.

From a regional science perspective, vertical density may influence mortality through competing mechanisms. On one side, agglomeration and spatial concentration may intensify environmental externalities. Dense built forms can reduce air circulation, trap pollutants, amplify traffic congestion, and reinforce urban heat island effects. These dynamics increase exposure to fine particulate matter and other carcinogens associated with lung cancer. Moderately dense metropolitan systems may thus experience heightened environmental risk due to concentrated industrial and transportation activity. On the other side, dense urban cores typically host advanced medical facilities, specialized oncology centers, screening infrastructure, and higher-quality healthcare services. Agglomeration economies in healthcare provision—shorter travel times, thicker provider markets, technological diffusion—may enhance early detection and survival outcomes. Consequently, vertical density may simultaneously generate environmental risk and institutional protection.

These opposing forces suggest that the relationship between urban verticalization and mortality is unlikely to be monotonic. Instead, regional development theory implies the possibility of nonlinear effects: mortality may initially increase with density due to environmental exposure, but decline at high density levels where healthcare access and institutional capacity dominate. Moreover, regional heterogeneity is likely to interact with demographic structure. Gender differences in smoking behavior, occupational exposure, healthcare utilization, and biological response imply that both baseline mortality and the marginal impact of density may differ systematically between men and women. Understanding these interactions is essential for territorial policy design, particularly in the context of sustainable and resilient urban development.

To investigate these questions, the study constructs a state–year panel dataset covering 48 U.S. states over the period 1999–2022, yielding 2,304 observations (1,152 male and 1,152 female). Age-adjusted lung and bronchus cancer mortality rates are obtained from the Centers for Disease Control and Prevention. Age-adjusted smoking prevalence, derived from the Behavioral Risk Factor Surveillance System, captures persistent cross-state differences in smoking culture and exposure. Skyscraper counts are measured as the cumulative number of buildings exceeding 150 meters as of 2021 and are treated as time-invariant structural characteristics. While skyscraper counts do not vary over time within states, they capture enduring territorial differences in vertical development patterns that are central to the research question.

Descriptive statistics reveal pronounced regional and gender heterogeneity. Average mortality is substantially higher among males than females, and smoking prevalence also differs significantly by gender. Skyscraper distribution is highly skewed across states, reflecting the uneven geography of vertical urbanization in the United States. These disparities underscore the importance of a regional framework that exploits cross-sectional structural variation rather than relying exclusively on within-state temporal changes.

The empirical strategy estimates a fully interacted quadratic regression model in which mortality depends on skyscraper counts, their squared term, smoking prevalence, a linear time trend, and interactions with a female indicator. This specification allows both intercepts and slopes to differ by gender and enables identification of nonlinear density effects. Quadratic terms test explicitly for U-shaped or inverted U-shaped relationships between vertical development and mortality. The model is estimated using pooled ordinary least squares. From a methodological standpoint, the pooled specification is appropriate because the key explanatory variable—skyscraper count—is time-invariant. Fixed-effects approaches would absorb this structural variable and eliminate the cross-sectional variation necessary to identify territorial density effects. Diagnostic tests show no statistically meaningful correlation between skyscraper counts and regression residuals, supporting the exogeneity assumption required for identification.

The results confirm that smoking prevalence remains a powerful determinant of lung cancer mortality across regions. A one-percentage-point increase in smoking prevalence increases mortality substantially for both genders, with a larger marginal effect among males. Mortality declines over time for both sexes, reflecting nationwide improvements in prevention and treatment, though the rate of decline differs by gender. These findings align with existing epidemiological evidence but are embedded here within a regional structural framework.

The central contribution concerns the nonlinear association between vertical urban density and mortality. For both men and women, the relationship exhibits an inverted U-shaped pattern. At low levels of vertical development, increases in skyscraper counts are associated with rising mortality. Beyond a threshold—approximately 125 skyscrapers for males and 136 for females—additional vertical development is associated with declining mortality. This turning point represents a structural transition in which healthcare and institutional advantages appear to outweigh environmental exposure effects.

From a regional science perspective, this finding is significant. It suggests that territorial development follows distinct phases in its health implications. In moderately vertical states—those transitioning from dispersed to concentrated urban forms—environmental externalities may intensify faster than healthcare infrastructure expands, generating elevated mortality risk.

In highly vertical states, however, the agglomeration of medical services, screening facilities, and technological innovation may create protective effects that reduce mortality despite dense built environments. Thus, vertical density is neither uniformly harmful nor uniformly beneficial; its health impact depends on the stage and scale of territorial development.

Gender heterogeneity persists across the entire density distribution. Even after controlling for smoking prevalence and time trends, males exhibit higher mortality than females at every level of vertical development. Confidence interval analysis confirms that the female–male mortality gap remains statistically significant across density levels. These persistent differences suggest that structural regional factors interact with gender-specific behavioral and biological mechanisms in shaping mortality outcomes. For regional policymakers, this implies that density-related health policies cannot adopt a one-size-fits-all approach; demographic composition must be integrated into territorial planning.

Robustness checks strengthen the internal validity of the findings. Median (quantile) regression results replicate the inverted U-shaped density effect and the magnitude of gender differences, indicating that conclusions are not driven by highly urbanized outlier states. The nonlinear pattern remains stable under alternative estimation strategies, reinforcing the structural interpretation.

The implications for regional and urban policy are multifaceted. First, environmental regulation should be particularly attentive to moderately dense urban systems, where pollution exposure may peak relative to healthcare capacity. Second, investments in medical infrastructure and screening access in less vertically developed states may help offset structural disadvantages. Third, gender-sensitive public health interventions remain critical, given the differential marginal effects of smoking and persistent mortality gaps. More broadly, the results underscore that sustainable regional development must consider health outcomes as endogenous to urban form rather than as external byproducts.

In the broader context of ERSA themes—urban resilience, territorial cohesion, and sustainable development—this study highlights the importance of integrating health metrics into regional development analysis. Vertical urbanization is often evaluated in terms of productivity, housing markets, and environmental efficiency. However, its implications for mortality and long-term population well-being are equally central to territorial resilience. Regions that combine high density with robust healthcare infrastructure may achieve both economic and health resilience, while those in intermediate stages of verticalization may face heightened vulnerability.

Several limitations warrant caution. Skyscraper counts are a coarse proxy for vertical density and do not capture intra-state spatial heterogeneity or micro-level environmental conditions. Smoking prevalence is measured cross-sectionally and should be interpreted as a structural rather than temporal determinant. Omitted variables such as occupational risk or socioeconomic inequality may also influence mortality patterns. Nonetheless, the robustness of the nonlinear density effect and the consistency of gender disparities support the broader structural conclusions.

In conclusion, this study demonstrates that vertical urban density is associated with lung cancer mortality in a nonlinear, gender-differentiated manner across U.S. states. Mortality initially increases with vertical development but declines at high density levels, reflecting a structural tradeoff between environmental exposure and healthcare access. Smoking remains a central determinant, yet gender disparities persist beyond behavioral differences alone. By embedding

epidemiological outcomes within a regional science framework, the paper advances understanding of how territorial development patterns shape population health and contributes to the growing literature linking urban structure, sustainability, and regional resilience.