RIETI Discussion Paper Series 26-E-061

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RIETI Discussion Paper Series 26-E-061
August 2026

Urban Planning and Vertical Urbanization[*]

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Abstract

This study examines how urban planning is associated with vertical urbanization in Tokyo by using a unique building-level PLATEAU 3D City Model dataset from Japan. While urban economics has traditionally conceptualized density in two-dimensional terms, this study directly measures building height to capture the vertical dimension of urban development. Using OLS and quantile regression, we examine the relationship between floor area ratio (FAR) and residential and commercial building heights across use districts. The results show that FAR is positively associated with building height, but that this relationship is highly heterogeneous across the height distribution. In commercial districts, for both residential and commercial buildings, the FAR coefficient generally increases across quantiles, suggesting that FAR is more strongly associated with taller buildings than with buildings around the median of the height distribution. The study further reveals the coexistence of vertical and horizontal urbanization: inner and near-center areas accommodate density through taller buildings, whereas suburban areas remain more horizontally developed. Beyond market mechanisms, the findings suggest that long-standing residential zoning designed primarily for detached housing has constrained vertical intensification and may have contributed to a more horizontally oriented pattern of urban development.

JEL classification: R11, R12, R32
Keywords: Vertical city, 3D city model, Floor area ratio, Economics of density, Micro-geographic data

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[*] We would like to thank Masahisa Fujita, Kyoji Fukao, Toshitaka Gokan, Hiroshi Goto, Nobuaki Hamaguchi, Hiroshi Ikari, Eichi Tomiura, and the participants of the RIETI DP Seminar for their helpful comments and suggestions. Any remaining errors are our own. This study is an outcome of the research conducted under the RIETI Project "Revitalization of the Japanese Non-metropolitan Economies." This study was supported by JSPS KAKENHI Grant Numbers 21K01497 and 26K04880.
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1. Introduction

Cities have long been understood as places where economic activity becomes more productive through spatial concentration, and the economic logic underlying compact urban development remains deeply rooted in the concept of agglomeration economies and economics of density (Ciccone and Hall 1996; Combes et al. 2008, 2012; De La Roca and Puga 2017; Duranton and Puga 2020; Marshall 1890; Rosenthal and Strange 2020). However, the conventional empirical literature on density has largely treated cities as two-dimensional spaces. Modern metropolitan areas increasingly accommodate people and firms not only by expanding outward but also by building upward. High-rise residential buildings, office towers, mixed-use complexes, and vertically integrated commercial centers fundamentally change how density is produced and experienced. As Liu et al. (2018) emphasize, the vertical structure of cities is closely related to rent gradients, spatial structure, and agglomeration economies. Three-dimensional spaces are also intended to be incorporated into urban economic analysis in recent studies (Jedwab et al. 2021, 2022; Esch et al. 2025). Understanding density therefore requires direct attention to vertical urbanization.

This distinction is particularly important for urban policy. In many large cities, housing affordability and spatial misallocation are closely linked to the regulation of land and building supply. Hsieh and Moretti (2019) show that housing constraints in highly productive cities can generate substantial aggregate economic losses through spatial misallocation. Related studies examine how land-use regulations affect housing supply, land values, and the cost of living (Gyourko and Krimmel 2021; Larson et al. 2022; Büchler and Lutz 2024; Baum-Snow Nathaniel and Han Lu 2024; Baum-Snow and Duranton 2025; Elmendorf et al. 2025). These studies highlight the importance of supply-side constraints, but they often focus on housing quantity, land prices, or regulatory stringency rather than the physical vertical form of the built environment. The economics of skyscrapers literature has begun to address this gap by emphasizing the economic logic of tall buildings and the role of height regulation (Ahlfeldt and McMillen 2018; Brueckner and Singh 2020; Ahlfeldt and Barr 2022; Yamasaki et al. 2023; Nakajima and Takano 2023). Yet empirical evidence on how land-use regulation shapes actual building height across an entire metropolitan area remains limited.

Tokyo provides a valuable setting for studying these issues and combines extremely high population density with strong institutional regulation of land use. Historically, Tokyo's urban structure has been shaped by repeated shocks and institutional changes, including the 1919 City Planning Act and Urban Building Act, the Great Kanto Earthquake, wartime destruction, rapid postwar growth, and subsequent reforms of the Building Standards Act. Historical studies of Japanese urban planning and land problems emphasize that these institutional arrangements left persistent spatial imprints on Tokyo's urban form (Ishida 1987, 1990; Numajiri 2002; Kikkawa and Kasuya 2007). A particularly important transition was the shift from direct height controls to FAR regulation. Whereas early regulations controlled building form through absolute height limits, postwar reforms increasingly regulated development capacity through the ratio of total floor area to site area. This institutional shift made floor area ratio (FAR) one of the central instruments governing urban density and vertical development.

The contemporary Japanese zoning system therefore provides a useful institutional framework for analyzing the relationship between regulation and vertical urbanization. As shown in Figure 1, mapping the contemporary distribution of use districts in Tokyo, use districts define the broad categories of land use, including residential, commercial, and industrial zones, while FAR regulates the amount of developable floor space. Low-rise residential zones preserve detached-house environments through strict height and intensity controls, whereas commercial zones allow much higher development intensity. Quasi-residential and quasi-industrial zones occupy intermediate positions, permitting more mixed and flexible forms of development. As a result, Tokyo's vertical urbanization cannot be understood only as a market response to land scarcity or accessibility. It is also mediated by zoning regimes that channel density into different physical forms.

This institutional background of use district motivates our empirical focus on FAR as a key measure of regulatory development intensity. By examining how FAR is associated with building height across use districts and across quantiles of the height distribution, this study provides the first evidence on how Japan's regulatory shift from direct height control to development-capacity control has shaped the vertical dimension of Tokyo's urban form. To answer these questions, we estimate both ordinary least squares and quantile regression models. While OLS captures the average relationship between FAR and building height, quantile regression allows us to examine whether this relationship differs between median buildings and buildings in the upper tail of the height distribution. This distinction is crucial because vertical urbanization is reflected not only in average building height but also in the emergence of high-rise buildings.

Our empirical analysis combines new building-level three-dimensional data with conventional spatial and regulatory datasets. We use the 3D City Model PLATEAU developed by the Ministry of Land, Infrastructure, Transport and Tourism (2026b), which provides detailed building-level information on height and geometry. Recent advances in geospatial data have created new opportunities for empirical urban research (Donaldson and Storeygard 2016; Harari 2020)[1], and PLATEAU allows us to directly observe the vertical structure of Tokyo at a fine spatial resolution. We combine these data with FAR information from National Land Numerical Information, population data from the 2020 Population Census, employment data from the 2021 Economic Census for Business Activity, railway accessibility measures, and distance from

[1] Harari (2020) provides a particularly influential contribution using the data from India by showing that cities with more compact geographic shapes exhibited stronger long-run growth of population. While Harari (2020) focuses on the horizontal compactness of cities, we emphasize their vertical structure.

Tokyo Station.

This study advances the literature in two key ways. First, it offers new empirical evidence focused on Tokyo, a major global city whose built environment reflects the interplay of market forces and long-term planning institutions. By connecting 3D building data with zoning and FAR regulations, this research bridges urban economics and urban planning, providing fresh insight into how regulatory institutions shape the physical structure of cities. Second, it enriches the literature on land-use regulation and housing markets by demonstrating that FAR is not uniformly associated with all buildings, but is particularly relevant to the upper tail of the building-height distribution. For comparison, Nakajima and Takano (2023) examine changes in aviation-related height restrictions in Fukuoka, showing that deregulation leads to significant increases in land prices in affected areas, although they do not directly observe building height. Yamasaki et al. (2023), meanwhile, investigate the transaction costs of constructing tall buildings, noting that such projects require larger lot sizes under FAR regulations. This study also sets a direction for future research by highlighting the direct connection between land use regulation and vertical urbanization.

The remainder of this paper is organized as follows. Section 2 describes the institutional background of vertical urbanization in Tokyo, with particular attention to the historical transition from height regulation to FAR regulation. Section 3 introduces the data and presents descriptive evidence on building heights, zoning, population, employment, railway accessibility, and distance from Tokyo Station. Section 4 explains the empirical strategy, including OLS and quantile regression. Section 5 reports the estimation results and discusses the relationship between vertical and horizontal urbanization. Section 6 concludes.

[Figure 1]

2. Institutional Background on Vertical Urbanization

Understanding the spatial structure of contemporary Tokyo requires an appreciation of the city's long and distinctive history of urban planning and land-use regulation. Tokyo's planning institutions evolved through a sequence of major historical disruptions, including earthquakes, war damage, rapid postwar growth, and repeated regulatory reforms (Ishida 1987). These episodes shaped not only the functional organization of the city but also the physical form of its built environment, particularly with respect to building height.

Japan's regulation of building form historically relied heavily on direct height controls. Modern urban planning in Japan began with the enactment of the City Planning Act and the Urban Building Act in 1919. These laws introduced the foundational framework for regulating urban development, including the designation of urban planning areas, the classification of land into broad use categories, and the imposition of controls on building form. Height restrictions were imposed in this early regulatory regime. Residential zones were subject to strict absolute height limits, typically around 20 meters (65-*shaku*), while non-residential zones allowed somewhat taller structures, up to approximately 31 meters (100-*shaku*). These height standards shaped the mid-rise urban form of Japanese cities during the prewar and early postwar periods.

The urban planning in 1925 formally divided the Tokyo metropolitan area into residential, commercial, and industrial zones, as shown in Figure 2(a). This early zoning map already reflected a spatial logic that continues to shape the city today: residential areas concentrated in the western uplands (the so-called Yamanote area), commercial districts clustered around traditional centers and transport hubs, and industrial zones located primarily in the eastern lowlands and along the waterfront (The Tokyo Institute for Municipal Research 2026). Figure 2(b) shows the spatial distribution of population density, which was first surveyed by the 1920 Population Census (The Tokyo Institute for Municipal Research 2026). Unlike the current population distribution, the population concentration was observed on the east side of Tokyo.

A major institutional turning point occurred with the 1963 amendment to the Building Standards Act, which was implemented in 1964. Following World War II, Tokyo experienced rapid population growth and industrial expansion. This amendment introduced the system of volume districts and replaced direct height limits with regulation based on the ratio of total floor area to site area, namely the FAR (Tokyo Metropolitan Government 2020). The purpose of the reform was to ensure an appropriate building scale in response to urban development, and that buildings in designated volume districts would be regulated by FAR rather than height limits.

This institutional shift was further consolidated through the 1970 amendment to the Building Standards Act. The amendment introduced Article 52, which specified FAR limits according to land-use zones. For example, lower limits were assigned to exclusive residential zones, while higher limits were allowed in commercial zones. The law thereby transformed development control from a simple restriction on physical height into a broader regulation of development capacity, defined by the amount of floor space that could be supplied on a given parcel of land.

Table 1 presents the current Urban Planning Act classifies land into twelve distinct use zones, broadly grouped into residential, commercial, and industrial categories. Within residential zones, further distinctions are made between low-rise, mid-rise, and general residential areas, each associated with different height, FAR, and use restrictions. For instance, low-rise residential zones impose strict height limits of 10 or 12 meters, explicitly prioritizing a detached-house urban form. Mid-rise zones permit taller structures. Commercial zones, by contrast, are subject to much looser restrictions on building form. In central districts, FAR allowances can be extremely high, making vertical intensification the primary mechanism through which density is realized. Industrial and quasi-industrial zones occupy an intermediate position, often allowing mixed uses and moderate building heights.

This institutional architecture implies that vertical urbanization in Tokyo is not simply the result of land scarcity or agglomeration pressures. It is also a product of deliberate regulatory choices that channel development into specific physical forms. In low-rise residential zones, density must be achieved horizontally, through small lots and closely spaced buildings. In commercial zones, density is primarily realized vertically, through high-rise towers. In intermediate zones, hybrid forms emerge.

These regulatory distinctions provide a natural framework for analyzing vertical urbanization. If building height were purely a market outcome, one would expect it to be determined primarily by land prices and demand for floor space. However, if zoning regimes exert a strong influence, then patterns of vertical development should differ systematically across categories, even after accounting for population concentration.

[Figure 2 and Table 1]

3. Data

This study constructs a building-level dataset for Tokyo Prefecture to examine the relationship between FAR and vertical urbanization in each use district. The empirical analysis combines building height information, use district, FAR, population and employment agglomeration, railway accessibility, and distance from the Tokyo station. These variables are used to characterize how vertical urban development differs across residential, commercial, and industrially mixed urban environments.

3.1. 3D City Model PLATEAU

The high-resolution three-dimensional building dataset is provided by the PLATEAU project, developed by the Ministry of Land, Infrastructure, Transport and Tourism (2026b). In Japan, the Ministry of Land, Infrastructure, Transport and Tourism (MLIT) has launched the PLATEAU project, an ambitious initiative to create open-access 3D city models for municipalities nationwide. These data provide building-level information on height, footprint, and geometry, making it possible to analyze vertical urbanization at an unprecedented spatial resolution. Unlike conventional GIS datasets, which typically represent buildings as two-dimensional footprints, PLATEAU provides explicit geometric information about building volumes, including height, roof shape, and spatial orientation. This feature makes it particularly well suited for analyzing vertical urbanization.

Figure 3 visualizes the landscape around the Shinjuku station using the 3D City model PLATEAU. This study uses Level of Detail 1 (LOD1) data, which represent buildings as simple extruded polygons with flat roofs. Although this level of detail does not capture architectural nuances, it provides information on building height, which is sufficient for our purposes. Higher levels of detail (LOD2 and above) include more complex geometries, but they are not consistently available across all municipalities and are therefore less suitable for metropolitan-scale analysis.

Figure 4 illustrates how the building-level information from the 3D City Model PLATEAU is represented on a map focusing on Shinjuku and Hachioji stations. Each building is displayed as an individual spatial object based on its footprint and geometric information. Because the PLATEAU data include building height, location, and shape, the map enables visual identification of fine-grained differences in the built environment.

[Figures 3–4]

3.2. Building Height

This study covers the Tokyo prefecture, excluding island territories. The temporal coverage of the PLATEAU data is based on 2023 surveys. Although the version of 3D City model varies across municipalities, we consider it acceptable given the relatively slow pace of change in the built environment.

We extract the height of each structure from the original building-level dataset. We exclude buildings with heights below 2.4 meters, which typically correspond to small auxiliary structures or measurement artifacts. We also drop observations for which the number of floors or height information is missing or implausible. To remove potentially erroneous observations, we use the information on the number of floors and exclude buildings with implausible floor heights, defined as those with a height per floor of less than 1 meter or more than 5 meters. To mitigate the influence of outliers, we exclude buildings in the upper 1% of the building-height distribution.

Based on the building-use classification in the original data, we split the sample into two subsamples: residential buildings and commercial buildings. Residential buildings are defined as buildings classified in the original data as mixed residential-commercial buildings, mixed residential-factory buildings, detached houses, or apartment buildings. Commercial buildings are defined as buildings classified in the original data as office buildings, mixed residential-commercial buildings, commercial facilities, accommodation facilities, or amusement/entertainment facilities. Mixed residential-commercial buildings are included in both the residential and commercial samples because they contain both residential and commercial uses.

To make the data compatible with the mesh statistics and to facilitate spatial analysis, we aggregate building-level information to a regular grid of 500m mesh grid, following the standard Japanese spatial coding system. For each mesh grid, we compute summary statistics of building height, including the mean, median, and selected percentiles.

As a first step of our empirical analysis, we show aggregate building heights across the Tokyo metropolitan area at the 500m mesh grid level, both for the full sample and separately by zoning category. These maps serve two purposes. First, they allow us to identify spatial clusters of vertical development. Rather than assuming a monocentric structure, we can observe whether tall buildings concentrate exclusively in the historical core or whether they form multiple subcenters. Second, these maps make it possible to visually assess how use districts correspond to different vertical profiles. For instance, we can examine whether low-rise residential zones are indeed characterized by uniformly low heights, or whether they exhibit pockets of vertical intensification. This cartographic approach is not merely illustrative. It plays an important analytical role by revealing spatial structures that might otherwise be obscured by summary statistics.

Figures 5 and 6 present the spatial distribution of residential and commercial building heights, respectively. Each figure maps the mean, median, and 90th-percentile height, allowing us to distinguish between general vertical intensity and the upper tail of the building-height distribution. Railway and subway routes are overlaid to relate vertical development to transport infrastructure. The eastern part of Tokyo, particularly in quasi-industrial zones, exhibits relatively high population density combined with moderate vertical development. These areas have evolved into mixed-use neighborhoods that accommodate residential growth through mid-rise buildings. The central wards display intense vertical development in commercial zones with high employment density. These areas function primarily as business centers rather than as residential neighborhoods. Verticality here reflects economic centrality rather than residential crowding. In contrast, the western part of Tokyo and much of the Tama region remain characterized by low-rise residential environments. Even when embedded in the metropolitan core, these areas preserve a horizontally oriented urban form.

Figures 7 and 8 further disaggregate the 90th-percentile building height by use district. These maps show how the upper tail of the height distribution differs across residential, commercial, quasi-residential, and quasi-industrial zones. This is particularly important because the 90th percentile captures high-rise development more clearly than the mean or median. Several striking patterns emerge. First, when the maps are stratified by use district, the imprint of regulatory regimes becomes clearly visible. In low-rise exclusive residential zones, 90th percentile building heights rarely exceed 10 meters. These areas form large contiguous regions, particularly in the western part of Tokyo and in the Tama region. The spatial continuity of these low-rise zones underscores the effectiveness of absolute height limits in preserving a horizontally oriented urban form. In contrast, mid- and high-rise residential zones display greater heterogeneity. While many mesh grids remain relatively low, pockets of taller buildings emerge, especially near railway stations. This pattern is consistent with the institutional logic of these zones, which are designed to accommodate moderate vertical densification while maintaining a predominantly residential character.

Commercial zones exhibit the most pronounced vertical development. In central districts, 90th percentile building heights frequently exceed 30 meters, and in some mesh grids they are substantially higher. Notably, vertical urbanization is highly uneven across space. Rather than forming a smooth gradient from the city center outward, tall buildings are clustered into distinct nodes. These clusters correspond closely to major commercial centers, transport hubs, and redevelopment zones. The traditional central business districts, such as the areas around Tokyo Station, Shinjuku, Shibuya, and Ikebukuro, exhibit the highest average building heights. Significant vertical development is also observed in subcenters and along major railway corridors, indicating a polycentric structure. This pattern contrasts with the monocentric density gradients often assumed in classical urban models. Instead of a single peak, Tokyo displays multiple vertical peaks, reflecting its long-standing reliance on rail-based transit and its history of decentralized subcenter formation.

Quasi-industrial zones display intermediate characteristics. While historically associated with low-rise manufacturing facilities, many of these areas have undergone gradual transformation. Our maps reveal clusters of mid-rise and, in some cases, high-rise development, particularly in eastern Tokyo and along waterfront areas. These patterns reflect the increasing residentialization and commercialization of formerly industrial land.

Summing up, these spatial patterns provide initial evidence that vertical urbanization in Tokyo is not simply a function of centrality or land scarcity. Rather, it is deeply structured by zoning regimes that impose distinct regulatory logics on different parts of the city.

[Figures 5−8]

3.3. Floor Area Ratio

To measure regulatory development intensity, we use the FAR assigned to each location. Floor-area ratio data are derived from use-district information in the National Land Numerical Information provided by the Ministry of Land, Infrastructure, Transport and Tourism (2026a).

Figure 9 maps the spatial distribution of FARs by use district across Tokyo, showing substantial spatial variation in permitted development intensity. The map indicates that commercial use districts generally allow higher FARs, reflecting their role in accommodating intensive land use, whereas Category 1 low-rise exclusive residential districts are characterized by relatively low FARs.

[Figure 9]

3.4. Population, Employment, and Accessibility Measures

Although the main empirical variable is based on the building level, several spatial variables are assigned using 500m mesh grid and 2 km buffer measures. This design allows us to combine fine-grained building information with broader neighborhood characteristics.

We construct local population and employment agglomeration measures at the 500m mesh grid level. Population data are obtained from the Mesh Statistics of the 2020 Population Census, and this is one of the finest spatial resolutions available for nationwide demographic statistics in Japan. We compute both population within each 500m mesh grid and surrounding population within a 2-km radius. Employment data are obtained from the Mesh Statistics of the 2021 Economic Census for Business Activity. Similar to the population variables, we construct both employment within each 500m mesh grid and surrounding employment within a 2-km radius. We compute population and employees within a 2-km radius by summing those of all mesh grids whose centroids lie within a 2-kilometer radius. Importantly, this calculation includes mesh grids in neighboring prefectures, ensuring that boundary effects do not distort the results near the edges of Tokyo. This geographical variable was created by the spgen command in Stata (Kondo 2017).

Figures 10 maps the population variables, showing the spatial distribution of residential concentration in Tokyo. Figure 11 shows that employment is highly concentrated in central and subcentral areas, providing an important measure of economic agglomeration. The distinction between these two measures is crucial. A location may have low residential density but be embedded in a dense metropolitan core. Such areas often host commercial or office towers, where vertical development is driven not by local population but by regional accessibility. By considering both local density and surrounding population potential, we can better differentiate between residential and non-residential mechanisms of vertical urbanization.

Railway accessibility is measured using railway network data from National Land Numerical Information (Ministry of Land, Infrastructure, Transport and Tourism 2026b). We construct the number of railway lines and the number of railway lines within a 2-km radius of each 500m mesh grid. In addition, the regression dataset includes a station dummy indicating whether a station exists within the 500m mesh grid. Figure 12 maps railway accessibility across Tokyo.

Finally, we measure centrality using distance from Tokyo Station. This variable captures the spatial gradient from the metropolitan core to peripheral areas. Figure 13 maps distance from Tokyo Station at the 500m mesh grid level.

[Figure 10–13]

3.5. Descriptive Statistics

Tables 2 and 3 present summary statistics for residential and commercial buildings, respectively. The dependent variable in the empirical analysis is the logarithm of building height. Based on the building-use classification in the original data, we split the building-level sample into two subsamples: residential buildings and commercial buildings.

The residential building sample contains 2,232,007 observations, whereas the commercial building sample contains 274,669 observations. The mean log building height is 2.09 for residential buildings and 2.37 for commercial buildings. The 99th percentile of log building height is 3.25 for residential buildings and 3.68 for commercial buildings, indicating that commercial buildings tend to be taller not only on average but also in the upper tail of the height distribution.

These descriptive patterns provide initial evidence of substantial heterogeneity in building-height distributions. However, they do not reveal how building height is systematically related to geographical characteristics, land-use regulation, or transport accessibility. To explore these relationships, we next turn to a more systematic spatial analysis.

[Tables 2–3]

4. Method

To characterize the horizontal and vertical dimensions of urbanization in Tokyo, this study investigates how FAR designated in the use district has shaped the city's vertical development. While much of the existing literature on urban economics focuses on density, far less attention has been paid to the vertical dimension of cities, despite its increasing importance in land-constrained metropolitan areas.

As a baseline model, this study estimates the linear regression as follows:

$$\log(H_{idg}) = \alpha \mathrm{FAR}_{d(i)} + \boldsymbol{X}_{ig}\boldsymbol{\beta} + \eta_m D_m + u_{idgm}, \tag{1}$$

where is H_{idg} is the height of building i in use district d in mesh grid g, $\mathrm{FAR}_{d(i)}$ is the floor area ratio in use district d where the building i is located, $\boldsymbol{X}_{ig}$ is the vector of control variables (population, employee, railway station dummy, number of railway lines, distance from the Tokyo station), η_m is the municipality fixed effect, D_m is the dummy variable for municipality m and u_{idgm} is the error term.

The parameter of our interest is α, which captures the extent to which the FAR affects the building height. The positive sign of α is expected because the higher FAR allows a vertical development.

The parameter of interest is α, which captures the effect of the FAR on building height. We expect α to be positive, because a higher FAR permits more intensive land use and thereby encourages vertical development.

To examine heterogeneity in the relationship between land-use regulation and building height, we employ quantile regression in addition to OLS. While OLS estimates the conditional mean of building height, quantile regression allows us to estimate the conditional quantiles of the building-height distribution. This is particularly useful in the present context because vertical urbanization is not only reflected in average building height but also in the upper tail of the height distribution, where high-rise development is observed.

In a linear parametric framework, the τth conditional quantile is specified as a linear combination of the covariates as follows:

$$Q_{\tau}\left(\log\left(H_{idg}\right)\middle|\mathrm{FAR}_{d}, \boldsymbol{X}_{ig}, \boldsymbol{D}_{m}\right) = \alpha_{\tau}\mathrm{FAR}_{d} + \boldsymbol{X}_{ig}\boldsymbol{\beta}_{\tau} + \eta_{\tau,m}D_{m}, \tag{2}$$

where $\boldsymbol{D}_m$ is the matrix of municipal dummies, and $\boldsymbol{\theta}_{\tau} = (\alpha_{\tau},\ \boldsymbol{\beta}_{\tau},\ \boldsymbol{\eta}_{\tau})$ are the quantile-specific parameters. For a given quantile $\tau \in (0, 1)$, the quantile regression estimator is obtained by minimizing the asymmetrically weighted absolute deviations:

$$\min_{\boldsymbol{\theta}_{\tau}} \sum_{i;\,u_i \geq 0} \tau|u_i| + \sum_{i;\,u_i < 0} (1-\tau)|u_i|, \tag{3}$$

where u_i is the residual in the quantile regression model of Equation (2).

The parameter of interest is α_{τ}, which captures the association between the FAR and the τth conditional quantile of building height. The conditional quantile represents the value below which a fraction τ of buildings fall in the conditional distribution of log building height, given observed local characteristics. This framework allows us to examine whether the association between FAR and building height differs between median buildings and buildings in the upper tail of the height distribution. We compare how the quantile regression estimates differ from the OLS estimate.

Although this study does not strictly aim to identify the causal effect of FAR on building height, the quantile regression approach allows us to examine how the relationship between FAR and building height differs across the conditional distribution of building height. Since FAR is one of the central instruments of land-use regulation, our findings provide useful implications for urban planning and land-use policy.

5. Results and Discussion

5.1. Estimation Results for Vertical Urbanization

Tables 4–6 report the estimation results for residential buildings, while Tables 7–9 present the corresponding results for commercial buildings. Tables 4 and 7 provide the OLS estimates, and Tables 5, 6, 8, and 9 report the quantile regression estimates at the median and the 90th percentile. Figures 14 and 15 summarize the quantile-specific coefficients on FAR and compare them with the corresponding OLS estimates.

For residential buildings, the OLS results in Table 4 show that FAR is positively and significantly associated with building height across all use-district groups. The coefficient is relatively small in Category 1 and 2 low-rise exclusive residential districts, where it is 0.0122 in Column (1) of Table 4, but larger in Category 1 and 2 residential districts, quasi-residential districts, and quasi-industrial districts. The largest OLS coefficient is observed in neighborhood commercial and commercial districts, where the coefficient is 0.1427 in Column (5) of Table 4. This indicates that, on average, residential buildings tend to be taller in locations where higher FARs are permitted, but the strength of this relationship differs substantially across zoning categories.

The quantile regression results in Tables 5 and 6 reveal that this relationship is much stronger in the upper tail of the residential building-height distribution than around the median. At the median, the coefficient on FAR is positive and statistically significant in all use-district groups, but its magnitude is generally smaller than the OLS estimate. For example, in neighborhood commercial and commercial districts, the median coefficient is 0.1144 in Column (5) of Table 5, compared with the OLS coefficient of 0.1427 in Column (5) of Table 4.

By contrast, at the 90th percentile, the coefficients on FAR become substantially larger than the OLS estimates in all residential zoning groups. The coefficient rises to 0.3097 in neighborhood commercial and commercial districts, in Column (5) of Table 6. Even in Category 1 and 2 low-rise exclusive residential districts, where the average relationship is weak, the 90th-percentile coefficient is 0.0487 in Column (1) of Table 6, much larger than the OLS estimate. These results suggest that floor are ratio is particularly associated with high-rise residential buildings rather than with residential buildings uniformly across the entire height distribution.

Figure 14 reinforces this interpretation. The coefficient plots show that the FAR coefficient generally increases as the quantile rises, especially in neighborhood commercial and commercial districts, quasi-industrial districts, and quasi-residential districts. The OLS estimate therefore masks important distributional heterogeneity: it summarizes an average relationship, while the quantile estimates show that the association between FAR and residential building height is concentrated in the upper part of the height distribution.

For commercial buildings, the results display a similar but even clearer pattern. The OLS estimates in Table 7 show that FAR is positive and statistically significant across all use-district groups. The coefficient is largest in neighborhood commercial and commercial districts, at 0.1178, followed by Category 1 and 2 residential districts, at 0.0959, quasi-industrial districts, at 0.0707, and Category 1 and 2 medium-to-high-rise exclusive residential districts, at 0.0601. These results indicate a positive average association between permitted development intensity and commercial building height.

The median quantile estimates in Table 8 are broadly similar to the OLS estimates, although the relative magnitudes differ across zoning categories. In neighborhood commercial and commercial districts, the median coefficient is 0.1286 in Column (5) of Table 8, slightly larger than the OLS estimate. In Category 1 and 2 residential districts and quasi-industrial districts, the median coefficients are also larger than the corresponding OLS estimates. In quasi-residential districts, however, the median coefficient is small and statistically insignificant, suggesting that the FAR–height relationship is weaker around the center of the commercial building-height distribution in this category.

At the 90th percentile, the FAR coefficient increases markedly for commercial buildings. The coefficient reaches 0.1943 in neighborhood commercial and commercial districts, in Column (5) of Table 9. In all use-district groups, the 90th-percentile estimate exceeds the corresponding OLS estimate. This indicates that FAR is more strongly associated with the upper tail of the commercial building-height distribution than with average commercial building height.

Figure 15 visually confirms this pattern for commercial buildings. The coefficient plots show that the estimated FAR coefficient generally rises across quantiles, with the upper-quantile estimates exceeding the OLS estimates in most zoning categories. This pattern is especially pronounced in neighborhood commercial and commercial districts and quasi-industrial districts. As in the residential sample, the OLS estimate captures only the average relationship, while the quantile regression results show that FAR is particularly relevant for explaining taller commercial buildings.

Overall, the results suggest that FAR plays an important role in shaping high-rise buildings for both residential and commercial development. This finding is consistent with the institutional role of FAR as a regulatory instrument that determines the maximum allowable floor space on a site. Higher FAR does not necessarily increase the height of all buildings uniformly, but it appears to be especially relevant for buildings located in neighborhood commercial and commercial districts, where developers are more likely to exploit the regulatory capacity for vertical development.

[Tables 4–9; Figures 14–15]

5.2. Discussions on Horizontal and Vertical Urbanization

The coefficients on distance from Tokyo Station provide additional evidence on the relationship between vertical and horizontal urbanization. Since distance from Tokyo Station captures the radial gradient from the metropolitan core to the suburban fringe, a negative coefficient indicates that buildings tend to be taller closer to the center, whereas a weak or insignificant coefficient suggests that building height does not systematically decline with distance from the center.

For residential buildings, the OLS results in Table 4 show negative and statistically significant coefficients on distance from Tokyo Station in most use-district groups, including Category 1 and 2 low-rise exclusive residential districts, Category 1 and 2 medium-to-high-rise exclusive residential districts, Category

1 and 2 residential districts, quasi-residential districts, and quasi-industrial districts. The magnitude is especially large in quasi-residential districts and quasi-industrial districts, suggesting that residential buildings in these zones are taller in locations closer to the metropolitan center. By contrast, the coefficient is not statistically significant in neighborhood commercial and commercial districts, implying that residential building height in these zones is not explained solely by distance from Tokyo Station.

The quantile regression results further clarify this pattern. At the median, the negative distance gradient remains strong in low-rise residential, medium-to-high-rise residential, quasi-residential, and quasi-industrial districts. At the 90th percentile, the negative coefficient becomes particularly large in quasi-residential districts and remains sizable in low-rise residential and quasi-industrial districts. This indicates that distance from Tokyo Station is especially relevant for explaining the upper tail of residential building height in certain zoning categories. In other words, high-rise residential development is more concentrated in inner-city or near-center locations, while suburban areas are more likely to accommodate population and urban expansion through horizontal development rather than vertical stacking.

For commercial buildings, the distance coefficients also reveal an urban gradient, although the pattern differs across use districts. In the OLS estimates, distance from Tokyo Station is negative and statistically significant in Category 1 and 2 residential districts, quasi-residential districts, and quasi-industrial districts. This suggests that, within these zones, commercial buildings tend to be taller closer to the urban core. At the median and 90th percentile, the negative distance gradient remains especially pronounced in quasi-industrial districts and quasi-residential districts. However, in neighborhood commercial and commercial districts, the 90th-percentile coefficient becomes positive and statistically significant. This suggests that tall commercial buildings in commercial zones are not concentrated only around Tokyo Station, but may also appear in other commercial centers located farther from the metropolitan core. As shown in Figure 13, this finding can be confirmed around the railways stations in suburban areas.

Figure 16 provides a visual complement to these regression results by plotting the 90th-percentile residential building height in each municipality against distance from Tokyo Station. This figure helps describe how the vertical structure of residential buildings changes with distance from the metropolitan center. The baseline is the category 1 and 2 low-rise exclusive residential zones, which impose strict height limits of 10 or 12 meters.

Figure 16 shows that, in quasi-residential districts and neighborhood commercial/commercial districts, municipalities closer to central Tokyo tend to have substantially taller buildings in the upper tail of the height distribution. The height of these upper-tail buildings declines as distance from Tokyo Station increases, especially when moving from inner areas to suburban municipalities. In contrast, Category 1 and 2 residential districts and medium-to-high-rise exclusive residential districts show a much flatter relationship, with building heights remaining relatively low and stable across distance. Although there is no fixed height limit, we cannot see huge gap in building height in the residential zones. One possible reason for Category 1 and 2 medium-to-high-rise exclusive residential districts is that the FAR is capped at 200 percent in our dataset, limiting the scope for vertical development.

These findings suggest that Tokyo's urban expansion has both vertical and horizontal dimensions. Near the metropolitan center, high land values, accessibility, and regulatory capacity are associated with taller buildings, especially in quasi-residential, quasi-industrial, and commercial-related zones. In suburban areas, however, urbanization appears to be accommodated more through horizontal expansion, with relatively lower building heights even when residential development is widespread. Thus, the distance gradient highlights an important spatial division: vertical intensification is concentrated in inner and near-center areas, whereas peripheral urbanization is more strongly characterized by horizontal development.

[Figure 16]

6. Conclusion

This study examined vertical urbanization in Tokyo by combining building-level 3D City Model PLATEAU data with land-use regulation, FAR information, population and employment agglomeration, railway accessibility, and distance from Tokyo Station. The purpose of the analysis was to document systematic empirical patterns in how Tokyo's vertical urban form is structured across space and across regulatory environments. By doing so, the study contributes to the economics of density by showing that urban density cannot be fully understood in two-dimensional terms.

A central finding is that FAR is positively associated with building height for both residential and commercial buildings, but this relationship differs substantially across the building-height distribution. The OLS results show a positive average association between FAR and building height across use districts. However, the quantile regression results reveal that the FAR coefficient is generally larger at the 90th percentile than at the median or in the OLS specification. This indicates that FAR is especially related to high-rise development in the upper tail of the building-height distribution, rather than uniformly raising the height of all buildings. The coefficient plots further confirm this pattern for both residential and commercial buildings.

The difference between residential and commercial buildings is also important. For residential buildings, the FAR–height relationship is strongest in neighborhood commercial and commercial districts, quasi-industrial districts, and quasi-residential districts, while it remains relatively limited in low-rise exclusive residential zones. This reflects the regulatory logic of Japanese zoning: low-rise residential zones are designed to preserve horizontally oriented residential environments, whereas commercial and mixed-use zones provide greater scope for vertical intensification. For commercial buildings, the positive association between FAR and building height is even more pronounced in the upper tail, suggesting that commercial developers are more likely to use permitted floor space through vertical construction when market demand and accessibility support high-intensity development.

The analysis of distance from Tokyo Station further clarifies the relationship between vertical and horizontal urbanization. Negative coefficients on distance from Tokyo Station indicate that, in many zoning categories, buildings tend to be taller closer to the metropolitan core. This pattern is especially visible for the upper tail of residential building height in quasi-residential and commercial-related zones. It is suggested that inner and near-center areas accommodate density partly through vertical intensification, whereas peripheral areas accommodate urbanization more through horizontal expansion.

This study has several implications for broader debates on land-use regulation, housing supply, and urban productivity. Recent studies have emphasized that restrictive land-use regulations can limit housing supply, raise land values, and generate spatial misallocation. Our results complement this literature by showing that the relevant margin of supply is not only the amount of land or housing units but also the vertical structure of buildings. In cities where developable land is scarce, the ability to build upward becomes a crucial channel for accommodating demand. However, the Tokyo case also shows that verticalization is not simply a market outcome. It depends on zoning, FAR, height-related controls, road conditions, railway accessibility, and the historical evolution of urban planning institutions.

This study has several limitations. One of them is that this study does not estimate the causal effect of FAR or zoning regulations on building height. Future research could exploit regulatory changes, boundary discontinuities, or natural experiments to identify causal effects.

Despite some limitations, this study demonstrates the value of integrating 3D city models into empirical urban research. By directly observing the vertical structure of the built environment, researchers can move beyond conventional two-dimensional measures of density and better understand how urban form is shaped by the interaction between market forces and planning institutions. In an era of population decline, aging, and growing pressure for compact urban development, such evidence is increasingly important. The Tokyo case shows that the long-run evolution of cities depends not only on how far they expand outward, but also on where and under what institutional conditions they grow upward.

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CRediT Authorship Contribution Statement

Keisuke Kondo: Conceptualization, Methodology, Formal analysis, Investigation, Data Curation, Writing - Original Draft, Writing - Review & Editing, Visualization, Funding acquisition.

Toshihiro Okubo: Writing - Review & Editing, Supervision, Project administration, Funding acquisition.

Funding

This study was supported by JSPS KAKENHI Grant Numbers 21K01497.

Declaration of Competing Interest

The authors have no competing interests to declare.

Data Availability

Codes and data are available upon request.

Generative AI Usage Disclosure

During the preparation of this work, the authors used ChatGPT 5.5 (https://chatgpt.com/) in order to reorganize the content and to enhance clarity and readability. After using this service, the authors reviewed and edited the content as needed and took full responsibility for the content of the publication.

Table 1. Definition of Use Districts in City Planning Act

Type	Category	Explanation
Residence	Category 1 low-rise exclusive residential districts	Districts designated to conserve a favorable dwelling environment for low-rise housing.
	Category 2 low-rise exclusive residential districts	Districts designated primarily to conserve a favorable dwelling environment for low-rise housing.
	Category 1 medium-to-high-rise exclusive residential districts	Districts designated to conserve a favorable dwelling environment for medium-to-high-rise housing.
	Category 2 medium-to-high-rise exclusive residential districts	Districts designated primarily to conserve a favorable dwelling environment for medium-to-high-rise housing.
	Category 1 residential districts	Districts designated to conserve the dwelling environment.
	Category 2 residential districts	Districts designated primarily to conserve the dwelling environment.
	Quasi-residential districts	Districts designated to conserve the dwelling environment concordant with the promotion of convenience to conduct business suitable to the roadside characteristics of the region.
Commerce	Neighborhood commercial districts	Districts designated to promote the convenience to conduct commercial business and other businesses whose primary concern is the provision of daily necessities to residents of residential areas in the neighborhood.
	Commercial districts	Districts designated primarily to promote the convenience to conduct commercial business and other businesses.
Industry	Quasi-industrial districts	Districts designated primarily to promote convenience for industries that are not likely to degrade the environment.
	Industrial districts	Districts designated primarily to promote convenience for industries.
	Exclusive industrial districts	Districts designated to promote convenience for industries.

Note: Use Districts in City Planning Act define the broad framework for land use in urban areas, such as residential, commercial, and industrial. There are 13 types of Use Districts. The Rural Residential District was added in 2017 Amendment Act. Once a Use District is designated, the types of buildings that can be built there are regulated.

Table 2. Descriptive Statistics for Residential Buildings

Variable	Mean	S.D.	Min	P1	P25	Median	P75	P99	Max
log(Building Height)	2.09	0.29	0.88	1.34	1.96	2.04	2.20	3.25	4.21
Floor-Area-Ratio in Location	1.91	1.10	0.50	0.80	1.00	2.00	2.00	6.00	10.00
log(Population within a 2km-radius circle)	12.06	0.53	6.68	10.25	11.81	12.19	12.45	12.68	12.75
log(Employees within a 2km-radius circle)	11.11	0.85	6.43	9.21	10.63	11.04	11.47	13.44	14.24
Station Dummy within a 500m Grid	0.15	0.36	0.00	0.00	0.00	0.00	0.00	1.00	1.00
Number of Railways within a 2km-radius circle	11.42	12.06	0.00	0.00	4.00	7.00	14.00	62.00	98.00
log(Distance from Tokyo Station)	2.67	0.64	−1.18	1.04	2.27	2.58	3.20	3.83	4.01
Dummy(1=Category 1 low-rise exclusive residential districts)	0.41	0.49	0.00	0.00	0.00	0.00	1.00	1.00	1.00
Dummy(1=Category 2 low-rise exclusive residential districts)	0.01	0.10	0.00	0.00	0.00	0.00	0.00	0.00	1.00
Dummy(1=Category 1 medium-to-high-rise exclusive residential districts)	0.16	0.37	0.00	0.00	0.00	0.00	0.00	1.00	1.00
Dummy(1=Category 2 medium-to-high-rise exclusive residential districts)	0.02	0.15	0.00	0.00	0.00	0.00	0.00	1.00	1.00
Dummy(1=Category 1 residential districts)	0.14	0.34	0.00	0.00	0.00	0.00	0.00	1.00	1.00
Dummy(1=Category 2 residential districts)	0.01	0.09	0.00	0.00	0.00	0.00	0.00	0.00	1.00
Dummy(1=Quasi-residential districts)	0.01	0.08	0.00	0.00	0.00	0.00	0.00	0.00	1.00
Dummy(1=Neighborhood commercial districts)	0.08	0.26	0.00	0.00	0.00	0.00	0.00	1.00	1.00
Dummy(1=Commercial districts)	0.05	0.21	0.00	0.00	0.00	0.00	0.00	1.00	1.00
Dummy(1=Quasi-industrial districts)	0.11	0.32	0.00	0.00	0.00	0.00	0.00	1.00	1.00
Dummy(1=Industrial districts)	0.01	0.09	0.00	0.00	0.00	0.00	0.00	0.00	1.00
Dummy(1=Exclusive industrial districts)	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	1.00

Note: The number of observations is 2,232,007. The unit of observations is the building for residence.

Table 3. Descriptive Statistics for Commercial Buildings

Variable	Mean	S.D.	Min	P1	P25	Median	P75	P99	Max
log(Building Height)	2.37	0.50	0.88	1.28	2.01	2.26	2.63	3.68	4.38
Floor-Area-Ratio in Location	3.47	1.79	0.50	0.80	2.00	3.00	5.00	8.00	13.00
log(Population within a 2km-radius circle)	12.18	0.46	1.79	10.54	11.98	12.27	12.52	12.69	12.75
log(Employees within a 2km-radius circle)	11.77	1.16	6.43	9.59	10.95	11.45	12.63	14.15	14.29
Station Dummy within a 500m Grid	0.34	0.47	0.00	0.00	0.00	0.00	1.00	1.00	1.00
Number of Railways within a 2km-radius circle	22.19	21.62	0.00	0.00	6.00	13.00	33.00	84.00	98.00
log(Distance from Tokyo Station)	2.21	0.84	−1.74	0.04	1.78	2.27	2.66	3.79	4.01
Dummy(1=Category 1 low-rise exclusive residential districts)	0.08	0.28	0.00	0.00	0.00	0.00	0.00	1.00	1.00
Dummy(1=Category 2 low-rise exclusive residential districts)	0.01	0.07	0.00	0.00	0.00	0.00	0.00	0.00	1.00
Dummy(1=Category 1 medium-to-high-rise exclusive residential districts)	0.09	0.28	0.00	0.00	0.00	0.00	0.00	1.00	1.00
Dummy(1=Category 2 medium-to-high-rise exclusive residential districts)	0.03	0.17	0.00	0.00	0.00	0.00	0.00	1.00	1.00
Dummy(1=Category 1 residential districts)	0.10	0.31	0.00	0.00	0.00	0.00	0.00	1.00	1.00
Dummy(1=Category 2 residential districts)	0.02	0.12	0.00	0.00	0.00	0.00	0.00	1.00	1.00
Dummy(1=Quasi-residential districts)	0.01	0.12	0.00	0.00	0.00	0.00	0.00	1.00	1.00
Dummy(1=Neighborhood commercial districts)	0.23	0.42	0.00	0.00	0.00	0.00	0.00	1.00	1.00
Dummy(1=Commercial districts)	0.32	0.47	0.00	0.00	0.00	0.00	1.00	1.00	1.00
Dummy(1=Quasi-industrial districts)	0.10	0.30	0.00	0.00	0.00	0.00	0.00	1.00	1.00
Dummy(1=Industrial districts)	0.01	0.08	0.00	0.00	0.00	0.00	0.00	0.00	1.00
Dummy(1=Exclusive industrial districts)	0.00	0.03	0.00	0.00	0.00	0.00	0.00	0.00	1.00

Note: The number of observations is 274,669. The unit of observations is the building for business.

Table 4. OLS Estimation Results of Residential Buildings

	Dependent Variable: log(Building Height)					
	Category 1 & 2 low-rise exclusive residential districts	Category 1 & 2 medium-to-high-rise exclusive residential districts	Category 1 & 2 residential districts	Quasi-residential districts	Neighborhood commercial and commercial districts	Quasi-industrial districts
Variables	(1)	(2)	(3)	(4)	(5)	(6)
Floor Area Ratio in Location	0.0122***	0.0264***	0.0655***	0.0645***	0.1427***	0.0632***
	(0.0009)	(0.0011)	(0.0011)	(0.0058)	(0.0011)	(0.0016)
log(Population within a 2km-radius Circle)	0.0267***	0.0017	−0.0096***	0.0495**	0.0724***	−0.0347***
	(0.0013)	(0.0027)	(0.0031)	(0.0198)	(0.0060)	(0.0048)
log(Employees within a 2km-radius Circle)	−0.0150***	−0.0148***	0.0003	−0.0190	0.0243***	0.0459***
	(0.0007)	(0.0015)	(0.0021)	(0.0117)	(0.0036)	(0.0029)
Station Dummy within a 500m Grid	0.0008	−0.0020*	0.0015	0.0199	−0.0036*	−0.0107***
	(0.0006)	(0.0011)	(0.0012)	(0.0124)	(0.0019)	(0.0015)
Number of Railways within a 2km-radius Circle	0.0005***	0.0006***	−0.0001	−0.0009	0.0003*	−0.0000
	(0.0001)	(0.0001)	(0.0001)	(0.0011)	(0.0002)	(0.0002)
log(Distance from Tokyo Station)	−0.0172***	−0.0354***	−0.0090**	−0.1567***	0.0110	−0.1032***
	(0.0020)	(0.0035)	(0.0040)	(0.0361)	(0.0073)	(0.0061)
Municipality Fixed Effect	Yes	Yes	Yes	Yes	Yes	Yes
Number of Observations	932,416	417,888	323,691	14,783	273,822	251,960
Adjusted R^2	0.0374	0.0726	0.0880	0.0948	0.1948	0.1172

Notes: Heteroskedasticity-consistent standard errors are in parentheses. * denotes statistical significance at the 10 % level, ** at the 5 % level, and *** at the 1 % level.

Table 5. Quantile Regression Estimation Results of Residential Buildings (Quantile = 0.5)

	Dependent Variable: log(Building Height)					
	Category 1 & 2 low-rise exclusive residential districts	Category 1 & 2 medium-to-high-rise exclusive residential districts	Category 1 & 2 residential districts	Quasi-residential districts	Neighborhood commercial and commercial districts	Quasi-industrial districts
Variables	(1)	(2)	(3)	(4)	(5)	(6)
Floor Area Ratio in Location	0.0033***	0.0243***	0.0507***	0.0294***	0.1144***	0.0440***
	(0.0006)	(0.0010)	(0.0012)	(0.0041)	(0.0013)	(0.0017)
log(Population within a 2km-radius Circle)	0.0044***	−0.0073***	0.0005	−0.0167	0.0222***	−0.0362***
	(0.0009)	(0.0022)	(0.0027)	(0.0136)	(0.0057)	(0.0038)
log(Employees within a 2km-radius Circle)	−0.0122***	−0.0029**	−0.0006	0.0140*	0.0216***	0.0332***
	(0.0006)	(0.0014)	(0.0021)	(0.0083)	(0.0036)	(0.0025)
Station Dummy within a 500m Grid	0.0012**	−0.0002	0.0000	0.0342***	0.0059***	−0.0182***
	(0.0005)	(0.0011)	(0.0012)	(0.0106)	(0.0020)	(0.0017)
Number of Railways within a 2km-radius Circle	0.0004***	0.0003***	−0.0000	0.0001	0.0012***	0.0006***
	(0.0000)	(0.0001)	(0.0001)	(0.0009)	(0.0002)	(0.0002)
log(Distance from Tokyo Station)	−0.0168***	−0.0089***	0.0005	−0.1516***	−0.0031	−0.0583***
	(0.0016)	(0.0033)	(0.0041)	(0.0274)	(0.0081)	(0.0058)
Municipality Fixed Effect	Yes	Yes	Yes	Yes	Yes	Yes
Number of Observations	932,416	417,888	323,691	14,783	273,822	251,960
Pseudo R^2	0.0252	0.0557	0.0531	0.0408	0.0834	0.0652

Notes: Heteroskedasticity-consistent standard errors are in parentheses. * denotes statistical significance at the 10 % level, ** at the 5 % level, and *** at the 1 % level.

Table 6. Quantile Regression Estimation Results of Residential Buildings (Quantile = 0.9)

	Dependent Variable: log(Building Height)					
	Category 1 & 2 low-rise exclusive residential districts	Category 1 & 2 medium-to-high-rise exclusive residential districts	Category 1 & 2 residential districts	Quasi-residential districts	Neighborhood commercial and commercial districts	Quasi-industrial districts
Variables	(1)	(2)	(3)	(4)	(5)	(6)
Floor Area Ratio in Location	0.0487***	0.0520***	0.1162***	0.1213***	0.3097***	0.1439***
	(0.0014)	(0.0018)	(0.0024)	(0.0099)	(0.0016)	(0.0037)
log(Population within a 2km-radius Circle)	0.0084***	−0.0216***	−0.0459***	−0.0092	0.0495***	−0.1223***
	(0.0013)	(0.0044)	(0.0050)	(0.0321)	(0.0105)	(0.0078)
log(Employees within a 2km-radius Circle)	−0.0138***	−0.0093***	0.0096***	0.0136	0.0358***	0.1120***
	(0.0009)	(0.0024)	(0.0036)	(0.0233)	(0.0072)	(0.0048)
Station Dummy within a 500m Grid	0.0066***	0.0018	0.0083***	0.0364	−0.0021	−0.0029
	(0.0009)	(0.0016)	(0.0019)	(0.0300)	(0.0036)	(0.0030)
Number of Railways within a 2km-radius Circle	0.0009***	0.0004***	−0.0005***	0.0014	−0.0006**	0.0004*
	(0.0001)	(0.0001)	(0.0002)	(0.0021)	(0.0003)	(0.0003)
log(Distance from Tokyo Station)	−0.0592***	−0.0265***	0.0052	−0.3974***	0.0214	−0.0842***
	(0.0028)	(0.0053)	(0.0067)	(0.0734)	(0.0136)	(0.0086)
Municipality Fixed Effect	Yes	Yes	Yes	Yes	Yes	Yes
Number of Observations	932,416	417,888	323,691	14,783	273,822	251,960
Pseudo R^2	0.0471	0.0851	0.1105	0.1460	0.2462	0.1359

Notes: Heteroskedasticity-consistent standard errors are in parentheses. * denotes statistical significance at the 10 % level, ** at the 5 % level, and *** at the 1 % level.

Table 7. OLS Estimation Results of Commercial Buildings

	Dependent Variable: log(Building Height)					
	Category 1 & 2 low-rise exclusive residential districts	Category 1 & 2 medium-to-high-rise exclusive residential districts	Category 1 & 2 residential districts	Quasi-residential districts	Neighborhood commercial and commercial districts	Quasi-industrial districts
Variables	(1)	(2)	(3)	(4)	(5)	(6)
Floor Area Ratio in Location	0.0183***	0.0601***	0.0959***	0.0544***	0.1178***	0.0707***
	(0.0063)	(0.0051)	(0.0045)	(0.0158)	(0.0011)	(0.0046)
log(Population within a 2km-radius Circle)	0.0524***	0.0634***	−0.0012	0.0159	−0.0062	0.0218**
	(0.0088)	(0.0105)	(0.0111)	(0.0479)	(0.0072)	(0.0085)
log(Employees within a 2km-radius Circle)	−0.0134**	0.0010	0.0084	0.0228	0.0773***	0.0326***
	(0.0063)	(0.0068)	(0.0082)	(0.0285)	(0.0050)	(0.0098)
Station Dummy within a 500m Grid	0.0154***	0.0166***	0.0068	0.0583**	0.0031	−0.0073
	(0.0048)	(0.0046)	(0.0047)	(0.0262)	(0.0025)	(0.0055)
Number of Railways within a 2km-radius Circle	0.0021***	0.0013***	0.0006	−0.0016	−0.0002	0.0024***
	(0.0004)	(0.0003)	(0.0004)	(0.0023)	(0.0002)	(0.0005)
log(Distance from Tokyo Station)	−0.0225	0.0158	−0.0594***	−0.1787**	−0.0079	−0.1551***
	(0.0170)	(0.0150)	(0.0153)	(0.0823)	(0.0083)	(0.0206)
Municipality Fixed Effect	Yes	Yes	Yes	Yes	Yes	Yes
Number of Observations	24,687	31,275	32,763	3,793	151,896	28,141
Adjusted R^2	0.0731	0.1601	0.1945	0.1682	0.3059	0.1593

Notes: Heteroskedasticity-consistent standard errors are in parentheses. * denotes statistical significance at the 10 % level, ** at the 5 % level, and *** at the 1 % level.

Table 8. Quantile Regression Estimation Results of Commercial Buildings (Quantile = 0.5)

	Dependent Variable: log(Building Height)					
	Category 1 & 2 low-rise exclusive residential districts	Category 1 & 2 medium-to-high-rise exclusive residential districts	Category 1 & 2 residential districts	Quasi-residential districts	Neighborhood commercial and commercial districts	Quasi-industrial districts
Variables	(1)	(2)	(3)	(4)	(5)	(6)
Floor Area Ratio in Location	0.0170***	0.0563***	0.1028***	0.0185	0.1286***	0.0817***
	(0.0047)	(0.0056)	(0.0053)	(0.0171)	(0.0015)	(0.0050)
log(Population within a 2km-radius Circle)	0.0284***	0.0331***	−0.0099	0.0086	−0.0505***	0.0112*
	(0.0073)	(0.0111)	(0.0122)	(0.0500)	(0.0086)	(0.0063)
log(Employees within a 2km-radius Circle)	−0.0195***	−0.0060	−0.0039	0.0124	0.0727***	0.0284***
	(0.0050)	(0.0074)	(0.0092)	(0.0303)	(0.0062)	(0.0103)
Station Dummy within a 500m Grid	0.0073	0.0216***	0.0165***	0.0525*	0.0075**	−0.0151**
	(0.0045)	(0.0057)	(0.0056)	(0.0316)	(0.0031)	(0.0069)
Number of Railways within a 2km-radius Circle	0.0011***	0.0017***	0.0001	−0.0001	0.0002	0.0013**
	(0.0004)	(0.0004)	(0.0004)	(0.0027)	(0.0003)	(0.0006)
log(Distance from Tokyo Station)	−0.0443***	0.0167	−0.0633***	−0.1081	−0.0094	−0.1968***
	(0.0140)	(0.0188)	(0.0184)	(0.0921)	(0.0105)	(0.0236)
Municipality Fixed Effect	Yes	Yes	Yes	Yes	Yes	Yes
Number of Observations	24,687	31,275	32,763	3,793	151,896	28,141
Pseudo R^2	0.0218	0.0891	0.0999	0.0865	0.1870	0.0905

Notes: Heteroskedasticity-consistent standard errors are in parentheses. * denotes statistical significance at the 10 % level, ** at the 5 % level, and *** at the 1 % level.

Table 9. Quantile Regression Estimation Results of Commercial Buildings (Quantile = 0.9)

	Dependent Variable: log(Building Height)					
	Category 1 & 2 low-rise exclusive residential districts	Category 1 & 2 medium-to-high-rise exclusive residential districts	Category 1 & 2 residential districts	Quasi-residential districts	Neighborhood commercial and commercial districts	Quasi-industrial districts
Variables	(1)	(2)	(3)	(4)	(5)	(6)
Floor Area Ratio in Location	0.0389***	0.0839***	0.1410***	0.0756**	0.1943***	0.1239***
	(0.0072)	(0.0072)	(0.0069)	(0.0300)	(0.0019)	(0.0085)
log(Population within a 2km-radius Circle)	0.0105	0.0179	−0.0242	−0.1591*	0.0679***	−0.1157***
	(0.0106)	(0.0137)	(0.0197)	(0.0846)	(0.0100)	(0.0411)
log(Employees within a 2km-radius Circle)	−0.0161**	0.0134	0.0023	0.0739	0.1117***	0.0928***
	(0.0065)	(0.0105)	(0.0135)	(0.0501)	(0.0078)	(0.0198)
Station Dummy within a 500m Grid	0.0158***	0.0188***	−0.0016	0.0311	0.0174***	−0.0020
	(0.0056)	(0.0070)	(0.0072)	(0.0620)	(0.0037)	(0.0096)
Number of Railways within a 2km-radius Circle	0.0015***	0.0004	0.0017***	−0.0008	−0.0022***	0.0030***
	(0.0004)	(0.0005)	(0.0006)	(0.0043)	(0.0002)	(0.0008)
log(Distance from Tokyo Station)	−0.0319*	0.0147	−0.0291	−0.2906*	0.0235**	−0.1515***
	(0.0194)	(0.0218)	(0.0256)	(0.1564)	(0.0114)	(0.0348)
Municipality Fixed Effect	Yes	Yes	Yes	Yes	Yes	Yes
Number of Observations	24,687	31,275	32,763	3,793	151,896	28,141
Pseudo R^2	0.0478	0.1335	0.1831	0.1414	0.2752	0.1464

Notes: Heteroskedasticity-consistent standard errors are in parentheses. * denotes statistical significance at the 10 % level, ** at the 5 % level, and *** at the 1 % level.

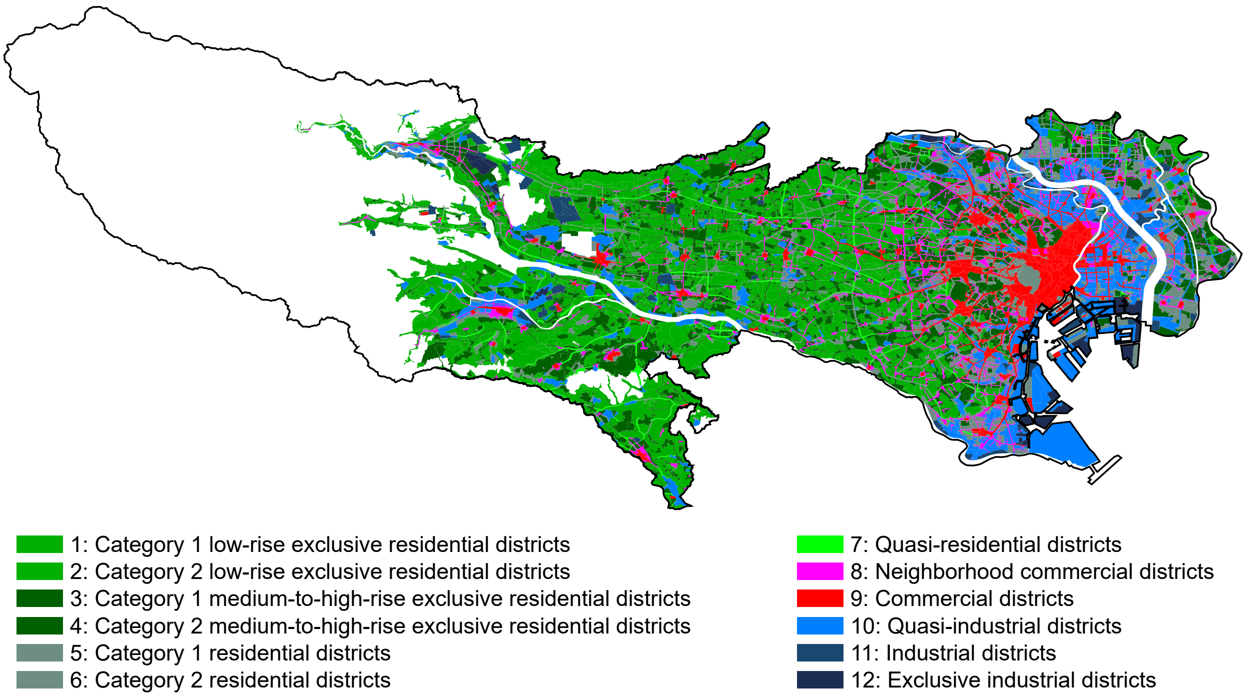
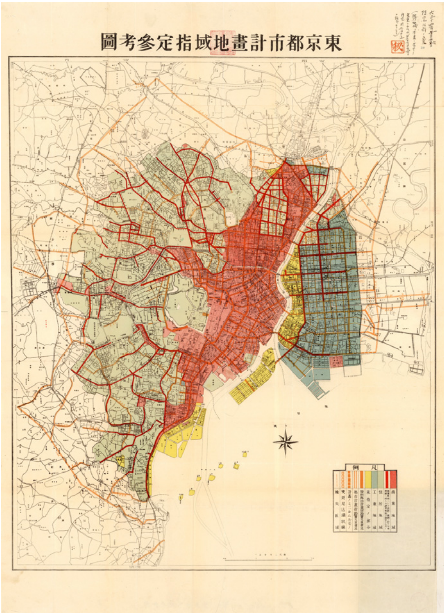
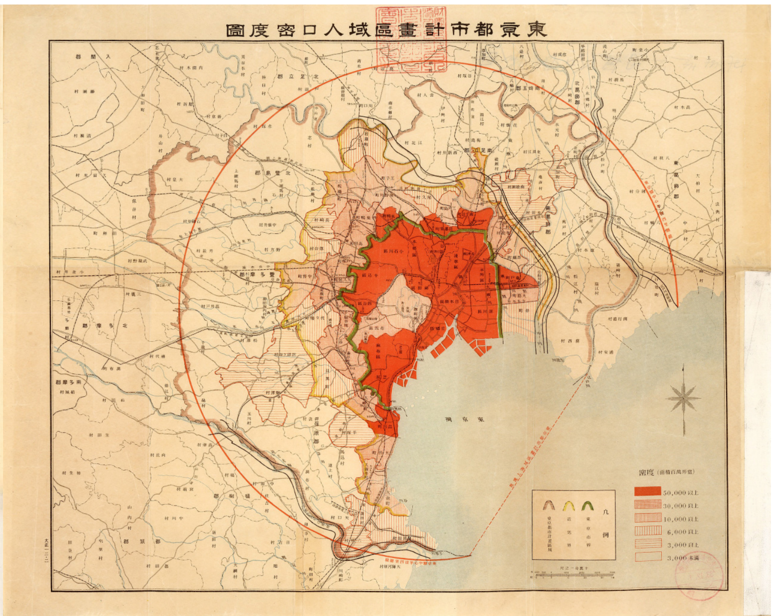


Figure 1. Use Districts in City Planning Act in 2010s

Note: Authors' creation using the use district Shapefiles (Ministry of Land, Infrastructure, Transport and Tourism, 2026).



(a) Use District in 1925



(b) Population Density in 1923

Figure 2. Urban Planning and Population Density in 1920s

Note: Maps on the left hand side (Code: OY, No. 1-089) and the right hand side (Code: OY, No. 1-092) are cited from The Tokyo Institute for Municipal Research (2026).

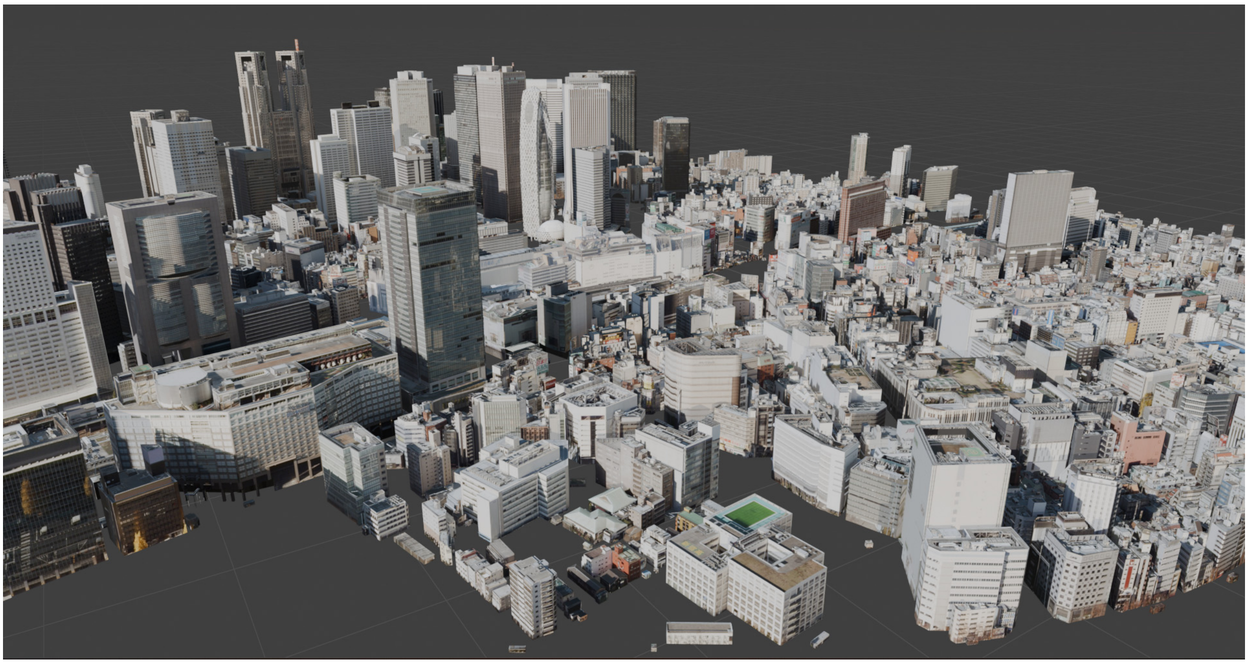


Figure 3. Landscape around Shinjuku Station in 3D City Model PLATEAU

Note: Authors' creation using 3D City Model PLATEAU (Ministry of Land, Infrastructure, Transport and Tourism).

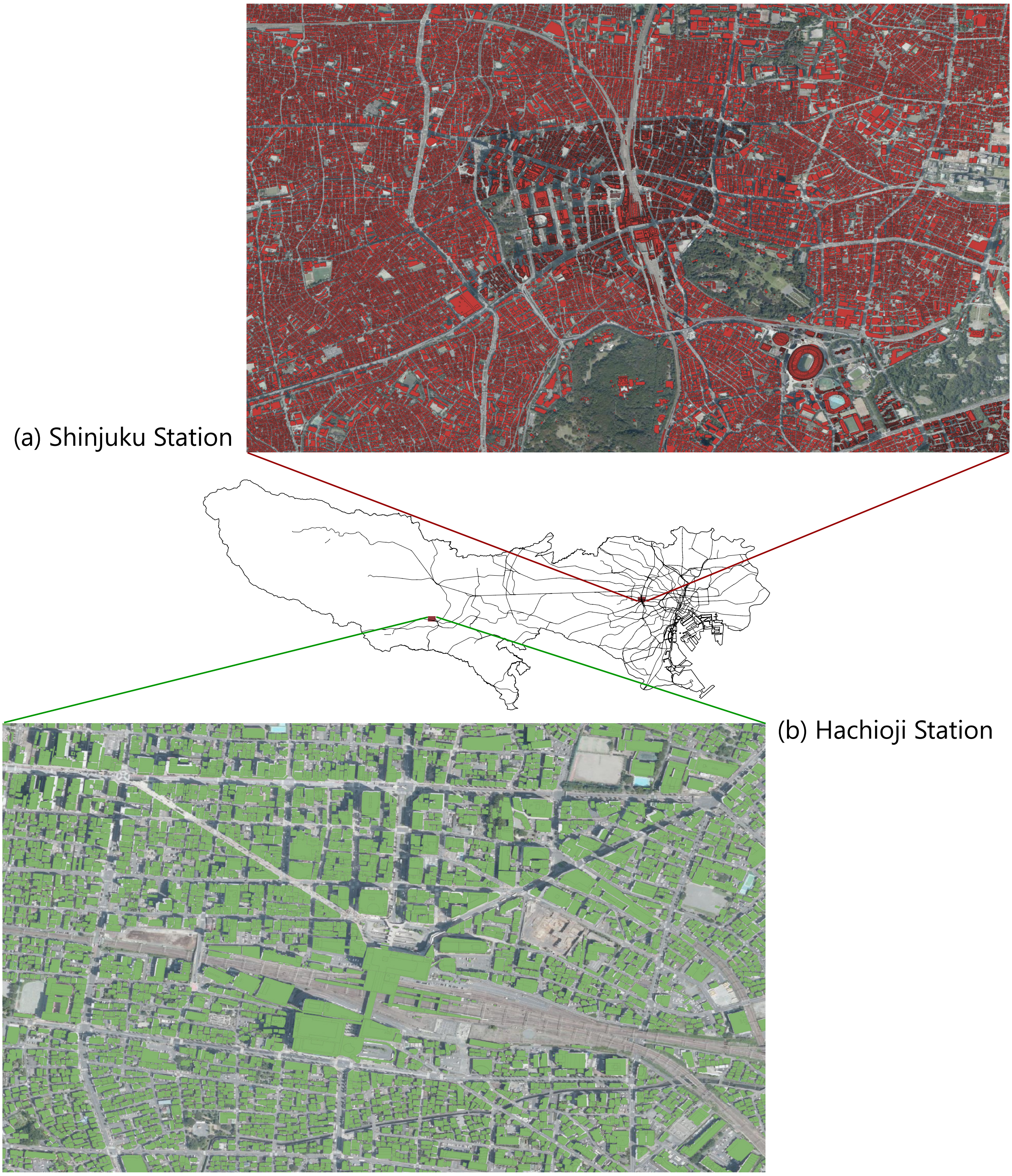
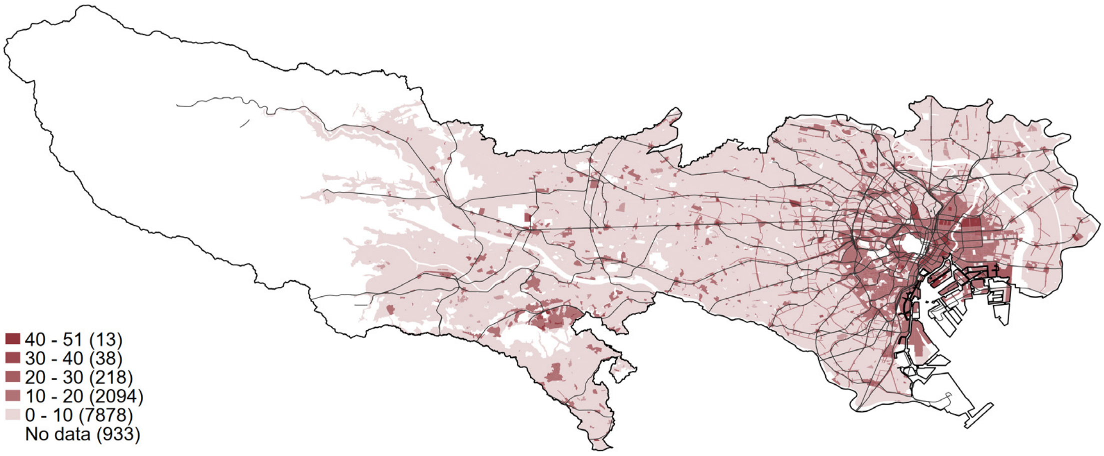
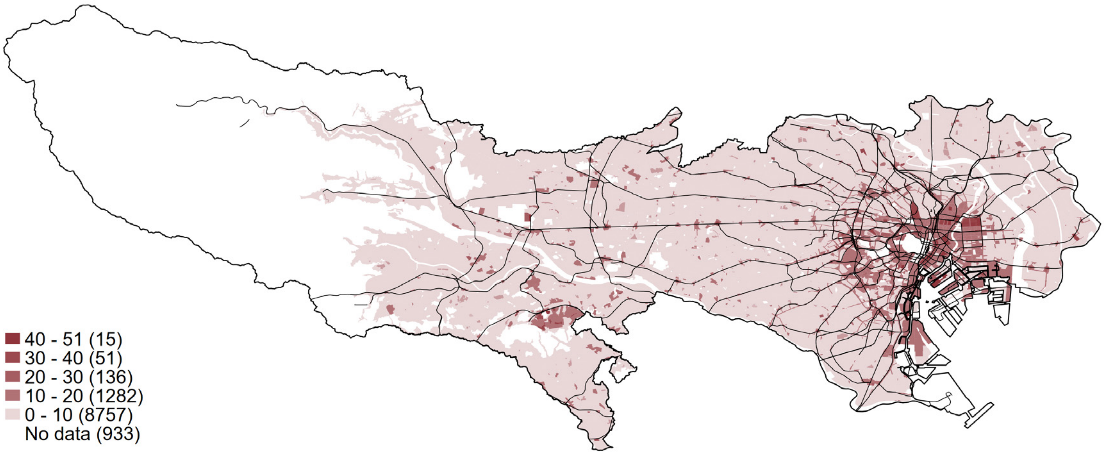


Figure 4. Building-Level Data in 3D City Model PLATEAU

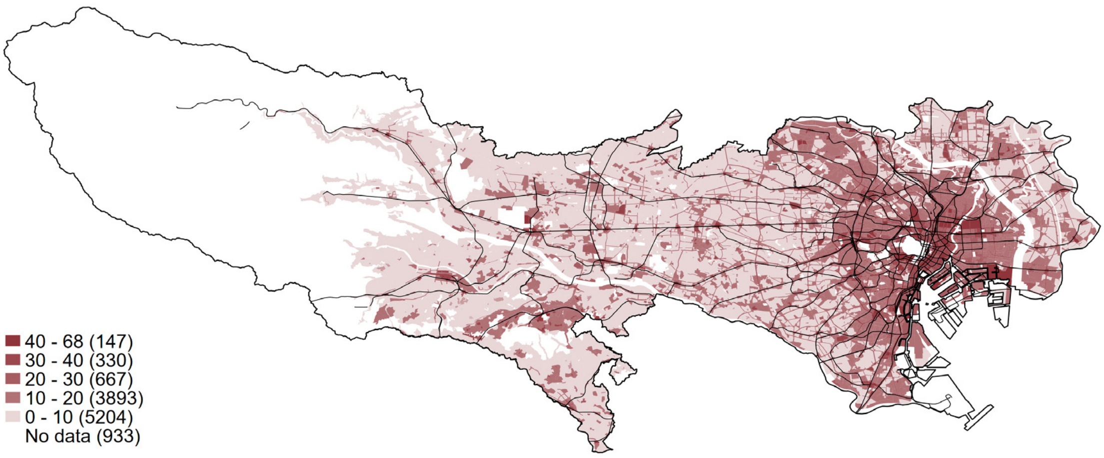
Note: Authors' creation using 3D City Model PLATEAU (Ministry of Land, Infrastructure, Transport and Tourism). Polygons on the map indicates the buildings included in the 3D City Model.



(a) Mean Building Height



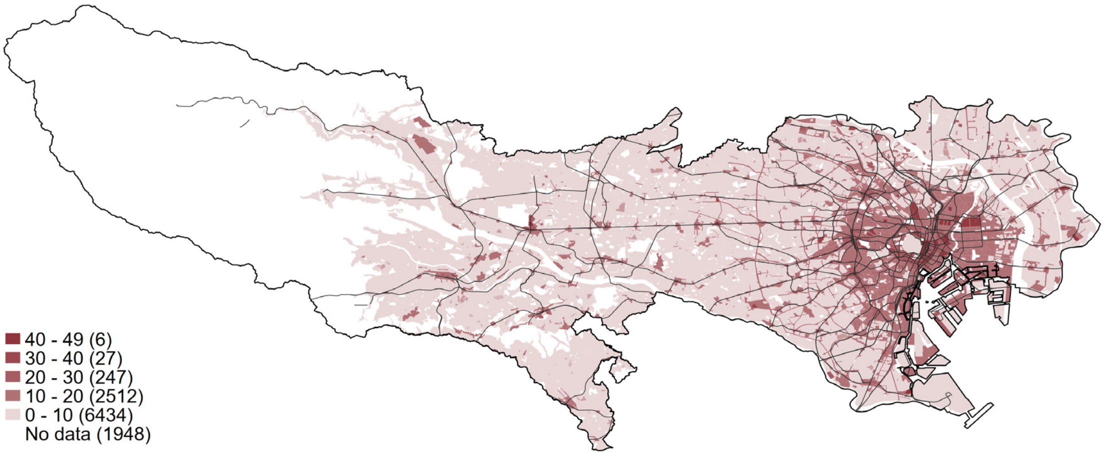
(b) Median Building Height



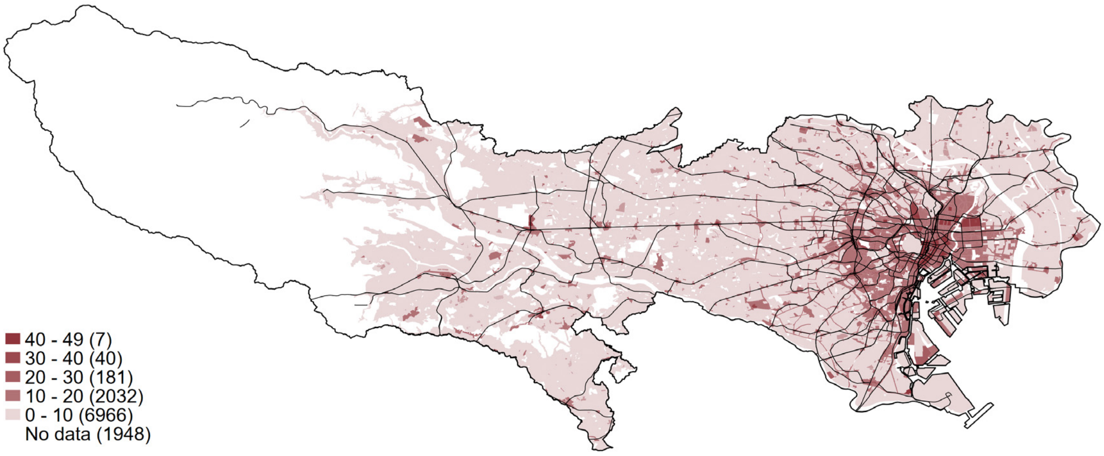
(c) 90th-Percentile Building Height

Figure 5. Spatial Distribution of Residential Building Heights in Tokyo

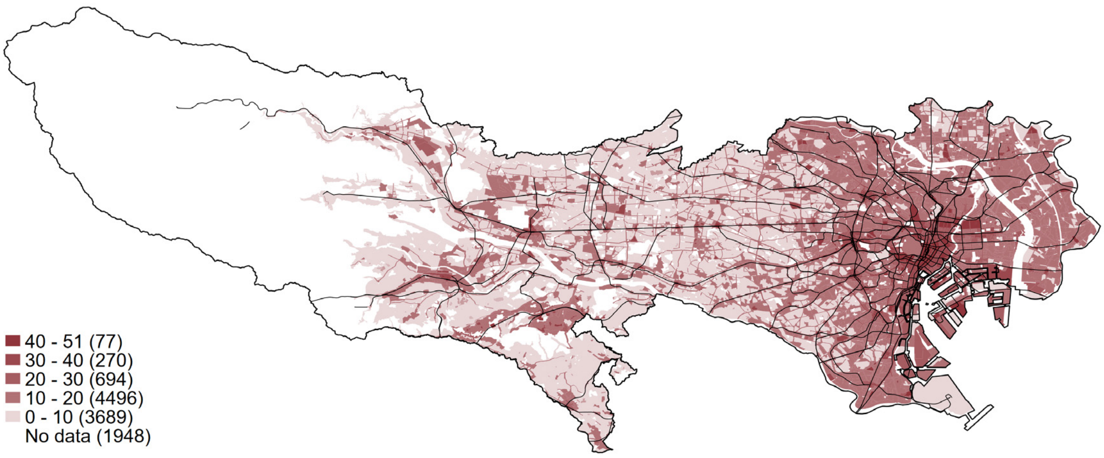
Note: Authors' creation using 3D City Model PLATEAU (Ministry of Land, Infrastructure, Transport and Tourism). The lines indicate railway and subway routes.



(a) Mean Building Height



(b) Median Building Height

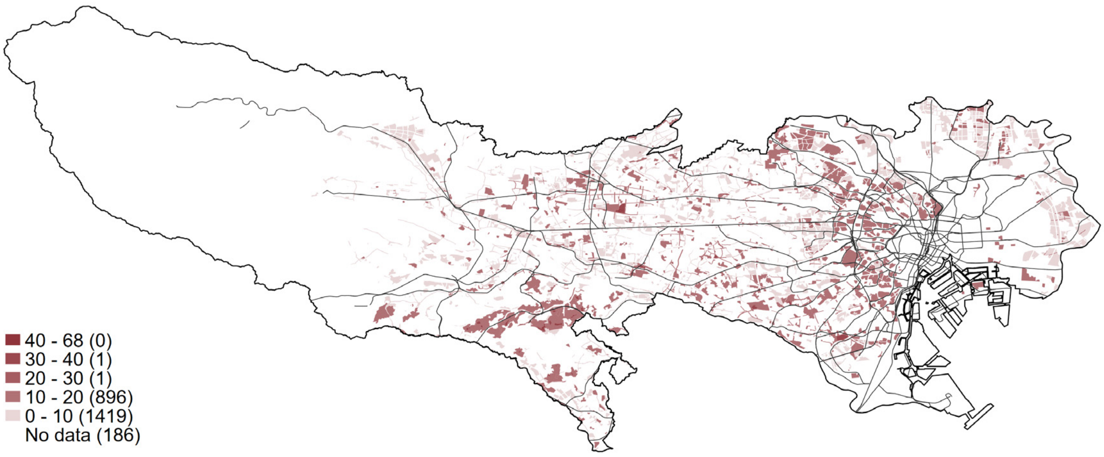


(c) 90th-Percentile Building Height

Figure 6. Spatial Distribution of Commercial Building Heights in Tokyo

Note: Authors' creation using 3D City Model PLATEAU (Ministry of Land, Infrastructure, Transport and Tourism). The lines indicate railway and subway routes.

(a) Category 1 and 2 low-rise exclusive residential districts



(b) Category 1 and 2 medium-to-high-rise exclusive residential districts

(c) Category 1 and 2 residential districts

Figure 7. Distribution of the 90th Percentile of Residential Building Heights

Note: Authors' creation using 3D City Model PLATEAU (Ministry of Land, Infrastructure, Transport and Tourism). The lines indicate railway and subway routes.

(d) Quasi-residential district

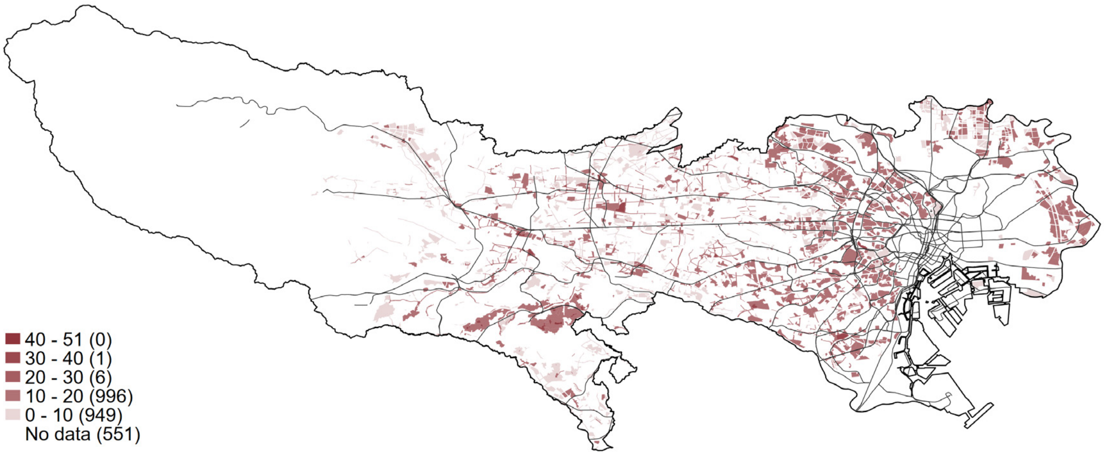
(e) Neighborhood commercial and commercial districts

(f) Quasi-industrial district

Figure 7. Distribution of the 90th Percentile of Residential Building Heights (*Continued*)

Note: Authors' creation using 3D City Model PLATEAU (Ministry of Land, Infrastructure, Transport and Tourism). The lines indicate railway and subway routes.

(a) Category 1 and 2 low-rise exclusive residential districts



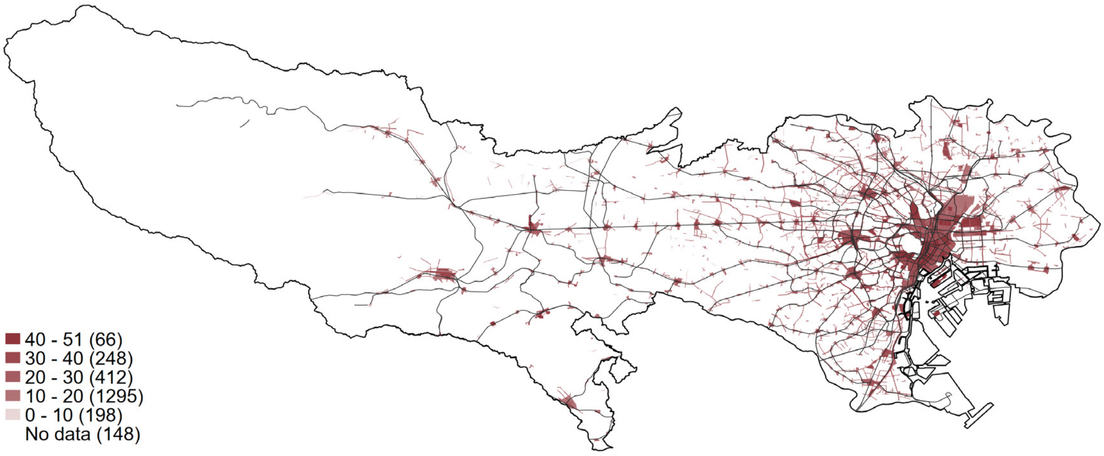
(b) Category 1 and 2 medium-to-high-rise exclusive residential districts

(c) Category 1 and 2 residential districts

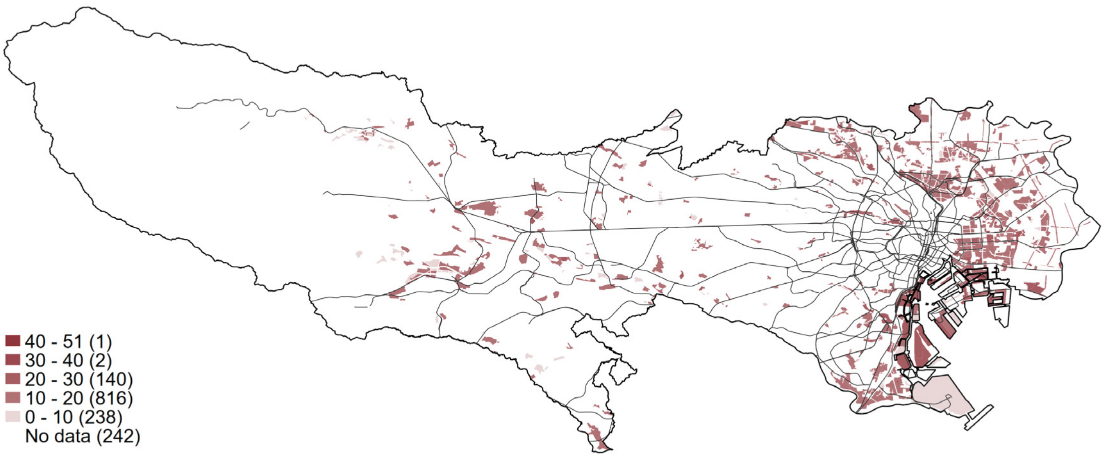
Figure 8. Distribution of the 90th Percentile of Commercial Building Heights

Note: Authors' creation using 3D City Model PLATEAU (Ministry of Land, Infrastructure, Transport and Tourism). The lines indicate railway and subway routes.

(d) Quasi-residential district



(e) Neighborhood commercial and commercial districts



(f) Quasi-industrial district

Figure 8. Distribution of the 90th Percentile of Commercial Building Heights (*Continued*)

Note: Authors' creation using 3D City Model PLATEAU (Ministry of Land, Infrastructure, Transport and Tourism). The lines indicate railway and subway routes.

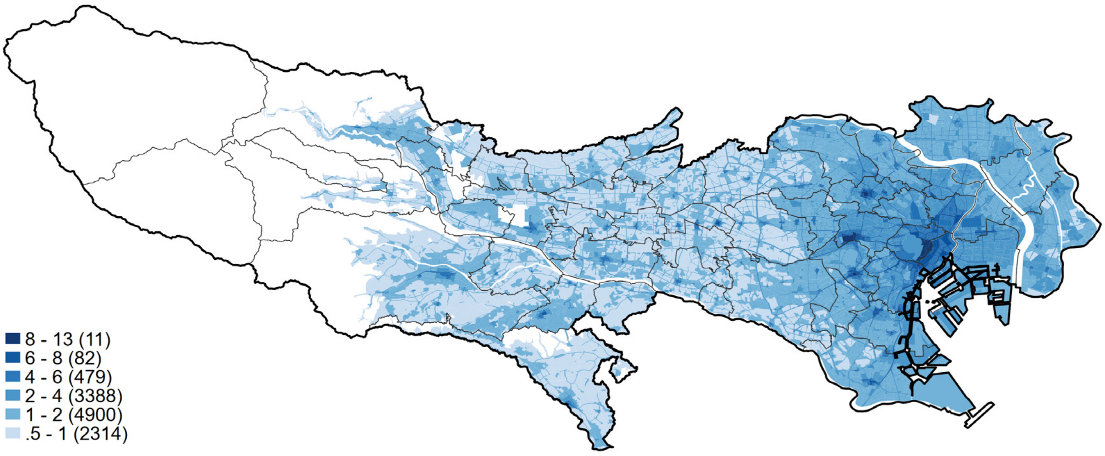
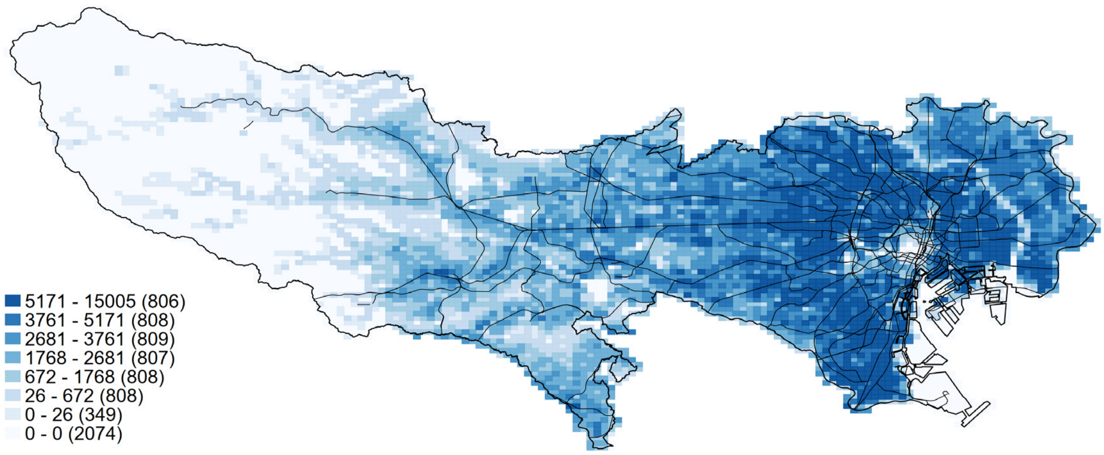
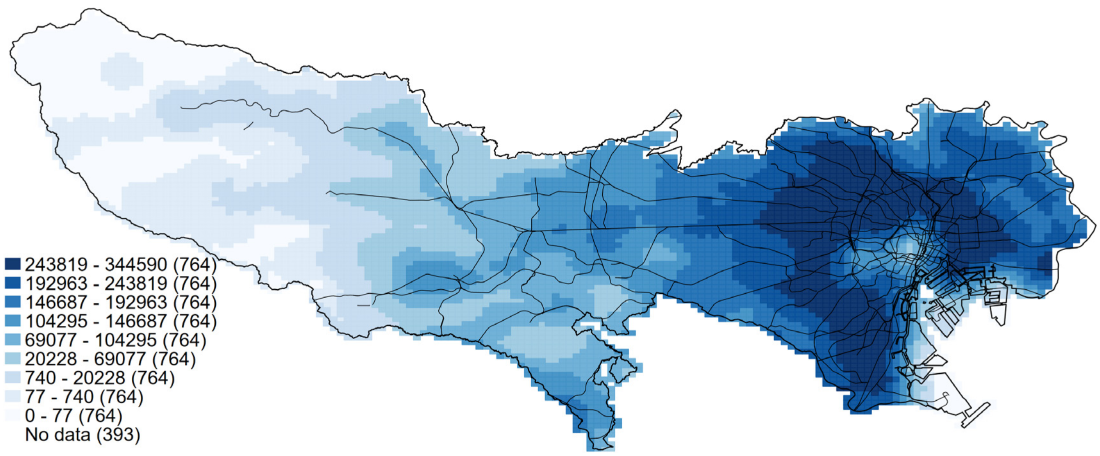


Figure 9. Floor Area Ratio by Use District

Note: Authors' creation using the use district Shapefiles (Ministry of Land, Infrastructure, Transport and Tourism, 2026).



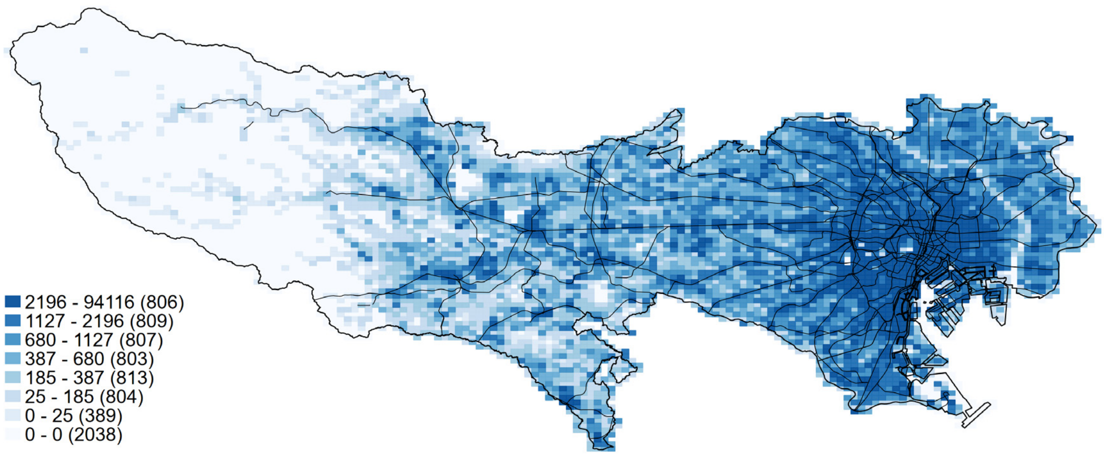
(a) Population



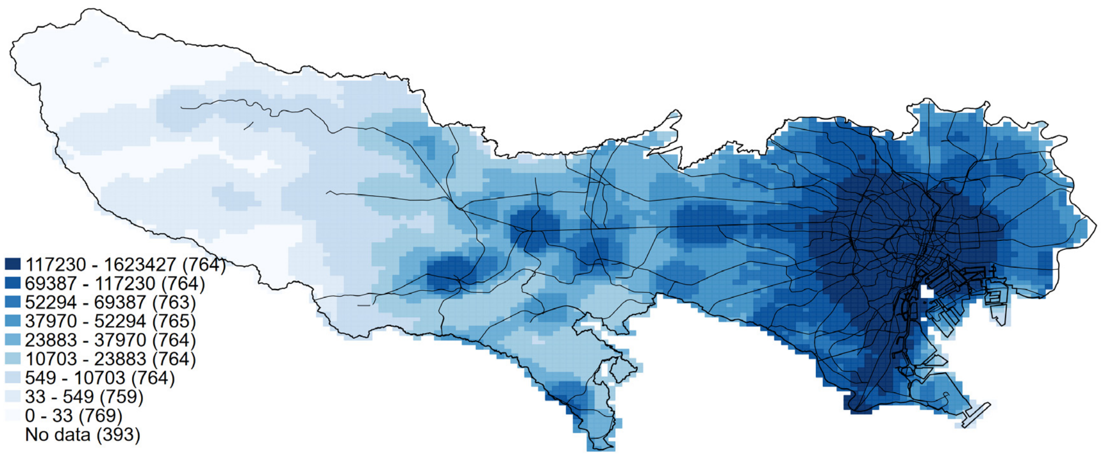
(b) Population within a circle of 2km radius

Figure 10. Population Distribution in Tokyo Prefecture (500m Grid)

Note: Authors' creation using the Mesh Statistics of 2020 Population Census (Ministry of Internal Affairs and Communications, 2026)



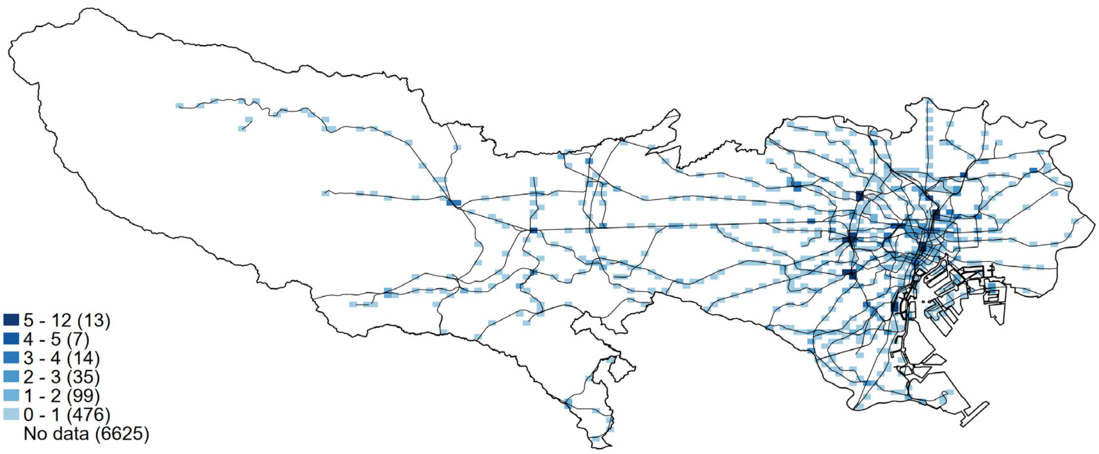
(a) Employees



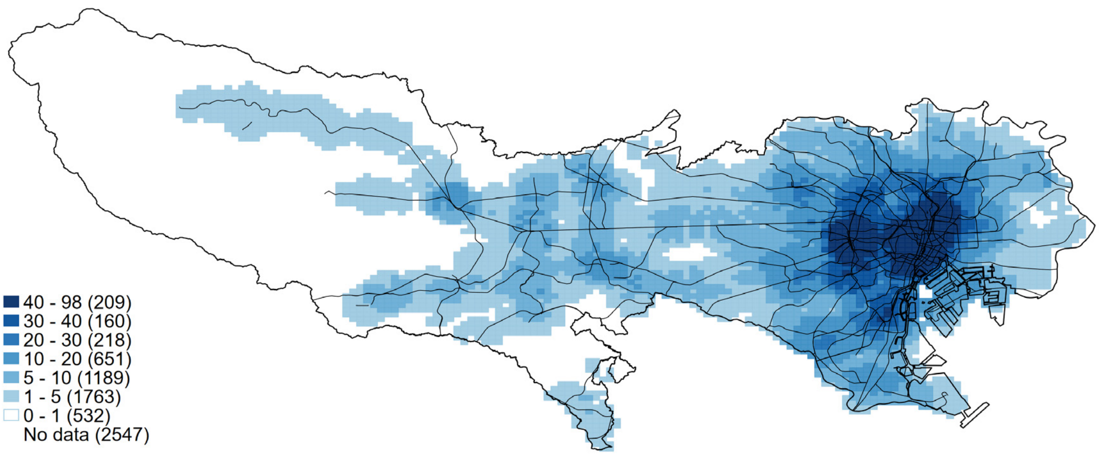
(b) Employees within a circle of 2km radius

Figure 11. Employee Distribution in Tokyo Prefecture (500m Grid)

Note: Authors' creation using the Mesh Statistics of 2021 Economic Census for Business Activity (Ministry of Internal Affairs and Communications and Ministry of Economy, Trade and Industry, 2026)



(a) Number of Railway Lines



(b) Number of Railway Lines within a circle of 2km radius

Figure 12. Accessibility of the Railway Network in Tokyo Prefecture (500m Grid)

Note: Authors' creation using National Land Numerical Information (Ministry of Land, Infrastructure, Transport and Tourism, 2026)

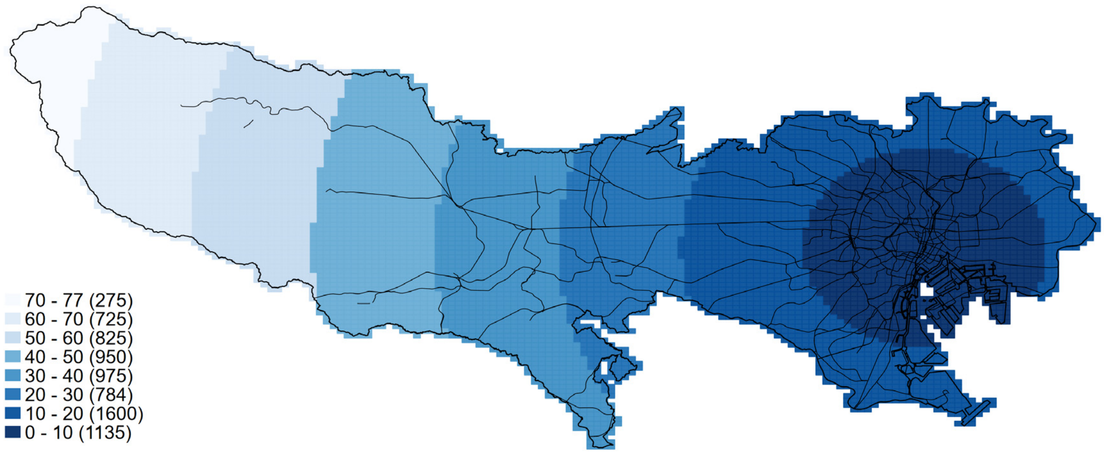
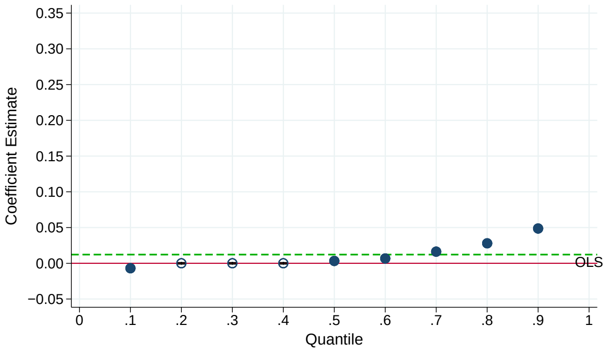
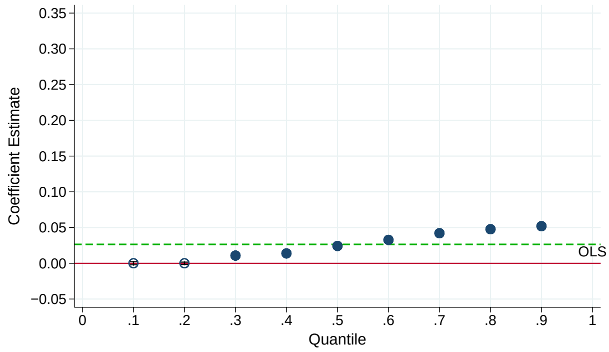


Figure 13. Distance from Tokyo Station (500m Grid)

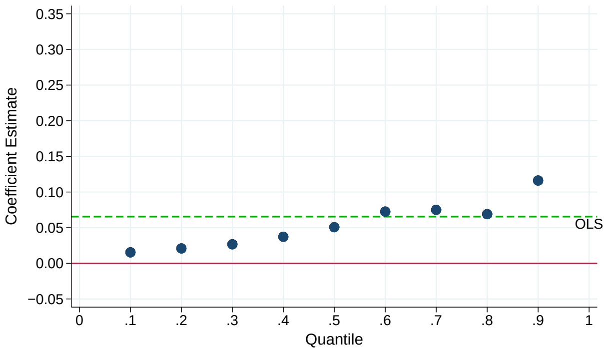
Note: Authors' creation.



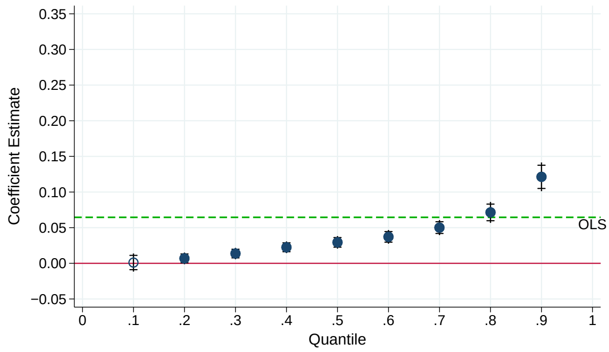
(a) Category 1 and 2 low-rise exclusive residential districts



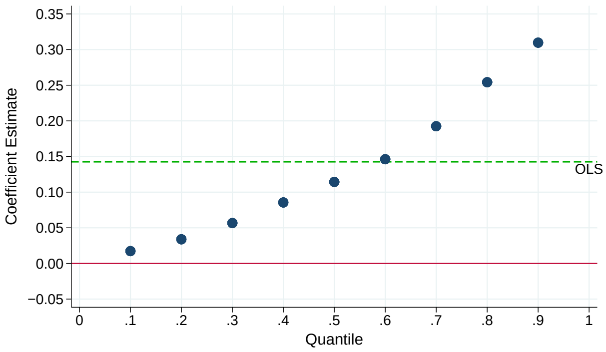
(b) Category 1 and 2 medium-to-high-rise exclusive residential districts



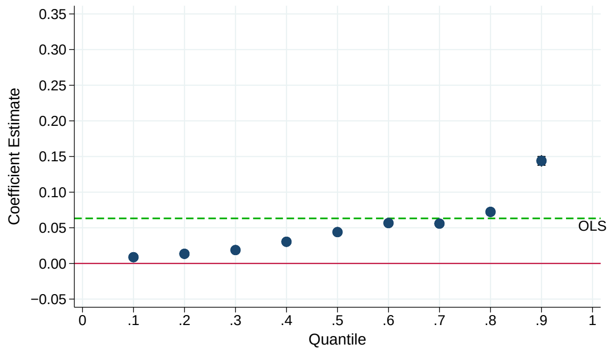
(c) Category 1 and 2 residential districts



(d) Quasi-residential district



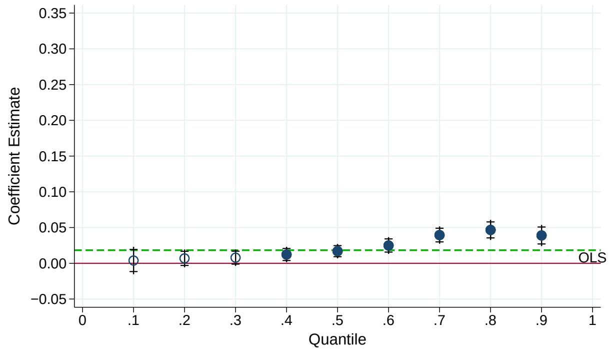
(e) Neighborhood commercial and commercial districts



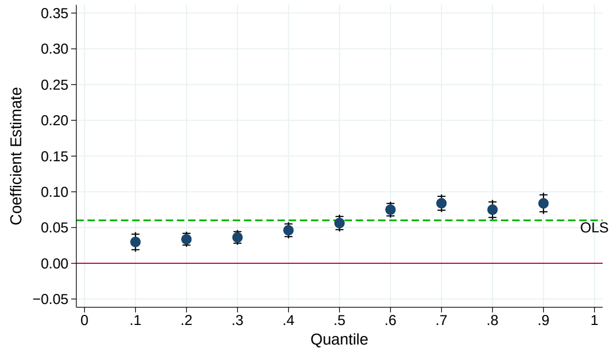
(f) Quasi-industrial district

Figure 14. Coefficient Plot for Floor Area Ratio of Residential Buildings

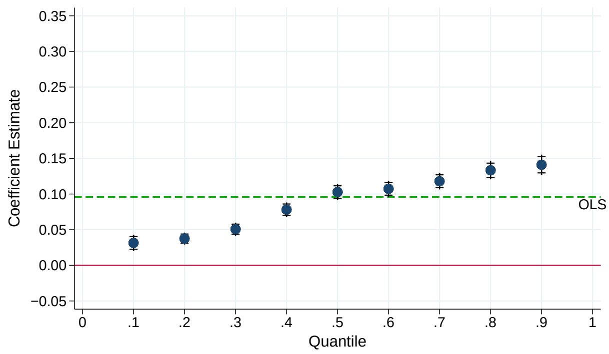
Note: Authors' creation.



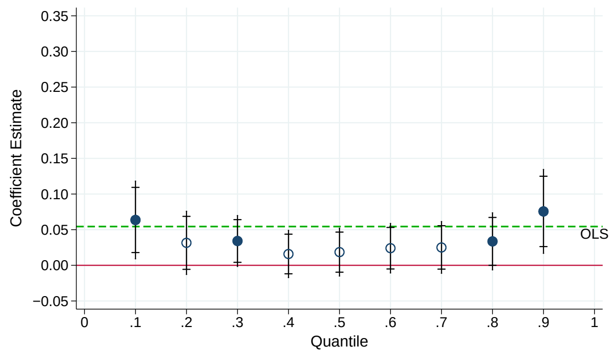
(a) Category 1 and 2 low-rise exclusive residential districts



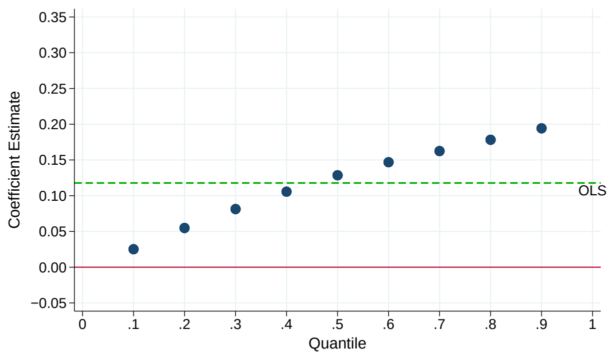
(b) Category 1 and 2 medium-to-high-rise exclusive residential districts



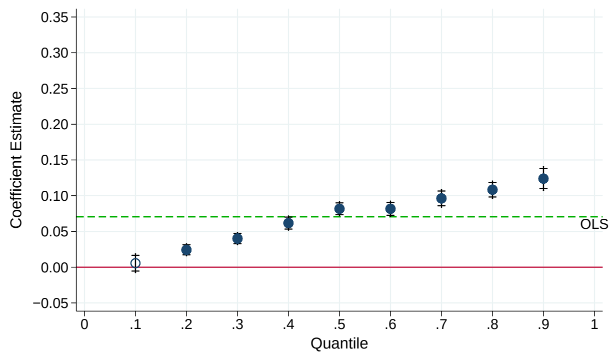
(c) Category 1 and 2 residential districts



(d) Quasi-residential district



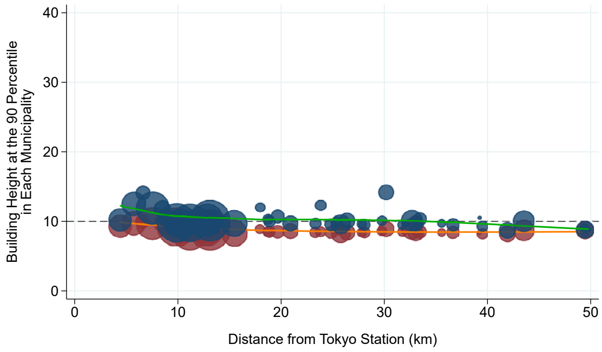
(e) Neighborhood commercial and commercial districts



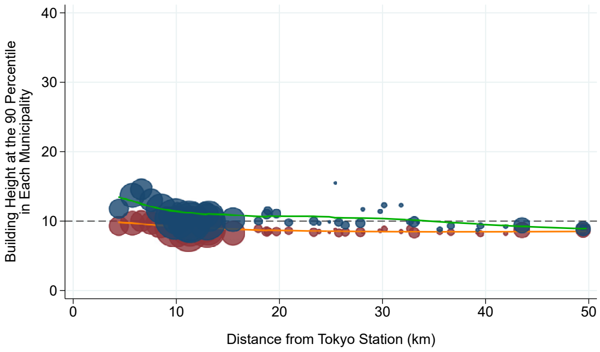
(f) Quasi-industrial district

Figure 15. Coefficient Plot for Floor Area Ratio of Commercial Buildings

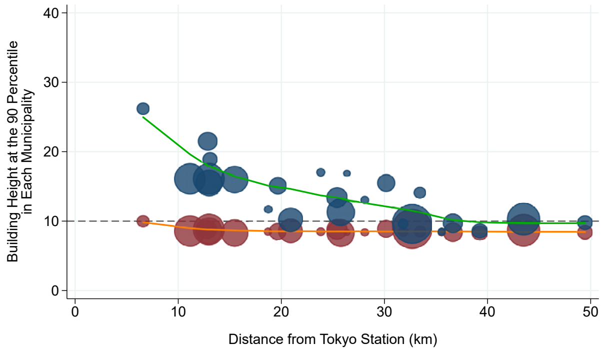
Note: Authors' creation.



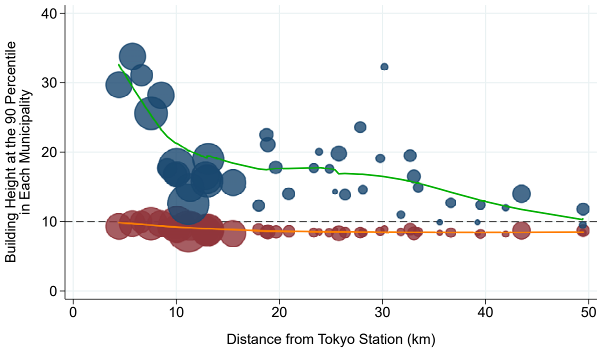
(a) Category 1 & 2 medium-to-high-rise exclusive residential districts



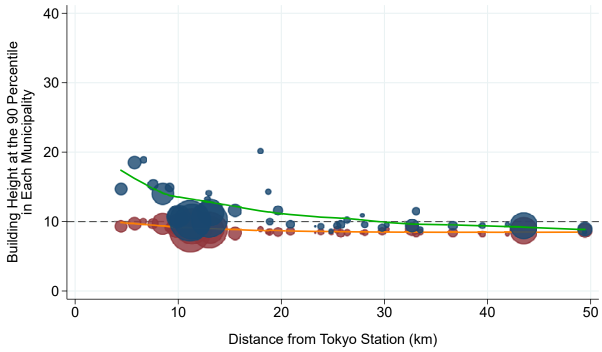
(b) Category 1 & 2 residential districts



(c) Quasi-residential districts



(d) Neighborhood commercial and commercial districts



(e) Quasi-industrial districts

Figure 16. Variation in 90th-Percentile Residential Building Height with Distance from Tokyo Station

Note: Authors' creation.

Online Appendix for

Urban Planning and Vertical Urbanization

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Appendix A Relationships between 90th-Percentile Residential Building Height and Area Characteristics

To visualize the relationship between residential building height and spatial variables, we apply locally weighted regression (LOWESS), a nonparametric smoothing technique that estimates conditional means locally rather than globally. This is done separately for each zoning category.

Figure A.1−A.5 visualize the statistical relationship of regional mesh statistics aggregated at the 500m mesh grid. The red line depicted in each scatterplot is based on the LOWESS regression.

Figure A.1 illustrates the scatterplot between 90th-percentile residential building heights and the floor area ratio designated at the location. Building height is strongly and monotonically increasing in the floor area ratio.

Figure A.2 illustrates the scatterplot between 90th-percentile residential building heights and the population within a circle of 2km radius.

Figure A.3 illustrates the scatterplot between 90th-percentile residential building heights and the employees within a circle of 2km radius. Building height is strongly and monotonically increasing in the number of employees in most use districts. This finding supports the interpretation that vertical development is driven by urban business centrality.

Figure A.4 illustrates the scatterplot between 90th-percentile residential building heights and the number of railway lines/stations within a circle of 2km radius.

Figure A.5 illustrates the scatterplot between 90th-percentile residential building heights and the distance from the Tokyo Station at the 500m mesh grid.

Overall, in Category 1 and 2 low-rise exclusive residential zones, the relationship between residential building height and area characteristics becomes relatively weak and flat. This pattern is consistent with the regulatory logic of these zones, which are designed to preserve low-rise residential environments. As a result, increases in local density or accessibility are more likely to be accommodated through horizontal intensification rather than vertical stacking.

[Figures A.1−A.5]

Appendix B Relationships between 90th-Percentile Commercial Building Height and Area Characteristics

To visualize the relationship between commercial building height and spatial variables, we apply locally weighted regression (LOWESS), a nonparametric smoothing technique that estimates conditional means locally rather than globally. This is done separately for each zoning category.

Figure B.1–B.5 visualize the statistical relationship of regional mesh statistics aggregated at the 500m mesh grid. The red line depicted in each scatterplot is based on the LOWESS regression.

Figure B.1 illustrates the scatterplot between 90th-percentile commercial building heights and the floor area ratio designated at the location.

Figure B.2 illustrates the scatterplot between 90th-percentile commercial building heights and the population within a circle of 2km radius.

Figure B.3 illustrates the scatterplot between 90th-percentile commercial building heights and the employees within a circle of 2km radius.

Figure B.4 illustrates the scatterplot between 90th-percentile commercial building heights and the number of railway lines/stations within a circle of 2km radius.

Figure B.5 illustrates the scatterplot between 90th-percentile commercial building heights and the distance from the Tokyo Station at the 500m mesh grid.

Overall, in Category 1 and 2 low-rise exclusive residential zones, similar to the residential building height, the relationship between residential building height and area characteristics becomes relatively weak and flat. This pattern is consistent with the regulatory logic of these zones, which are designed to preserve low-rise residential environments. As a result, increases in local density or accessibility are more likely to be accommodated through horizontal intensification rather than vertical stacking.

[Figures B.1−B.5]

Appendix C Residential Building Height by Use District within Municipalities

Figure C.1 illustrates the median and 90th-percentile residential building heights by use district within municipalities. The blue and red bars represent the median and 90th-percentile residential building heights at the 500m mesh grid. This comparison highlights municipal-level heterogeneity in residential vertical development and shows how the upper tail of residential building height differs across use districts.

[Figure C.1]

Appendix D Commercial Building Height by Use District within Municipalities

Figure D.1 illustrates the median and 90th-percentile commercial building heights by use district within municipalities. The blue and red bars represent the median and 90th-percentile commercial building heights at the 500m mesh grid. This comparison highlights municipal-level heterogeneity in vertical development of commercial buildings and shows how the upper tail of commercial building height differs across use districts.

[Figure D.1]

Appendix E Quantile Regression Estimation Results of Residential Buildings

Tables E.1−E.6 present the quantile regression estimation results of residential buildings by use district. These tables correspond to Tables 5 and 6 in the main text.

Table E.1 reports quantile regression estimates for residential buildings in Category 1 and 2 low-rise exclusive residential districts.

Table E.2 presents quantile regression results for residential buildings in Category 1 and 2 medium-to-high-rise exclusive residential districts.

Table E.3 reports quantile regression estimates for residential buildings in Category 1 and 2 residential districts.

Table E.4 presents quantile regression results for residential buildings in quasi-residential districts.

Table E.5 reports quantile regression estimates for residential buildings in neighborhood commercial and commercial districts.

Table E.6 presents quantile regression results for residential buildings in quasi-industrial districts.

[Tables E.1−E.6]

Appendix F Quantile Regression Estimation Results of Commercial Buildings

Tables F.1–F.6 present the quantile regression estimation results of commercial buildings by use district. These tables correspond to Tables 8 and 9 in the main text.

Table F.1 reports quantile regression estimates for commercial buildings in Category 1 and 2 low-rise exclusive residential districts.

Table F.2 presents quantile regression results for commercial buildings in Category 1 and 2 medium-to-high-rise exclusive residential districts.

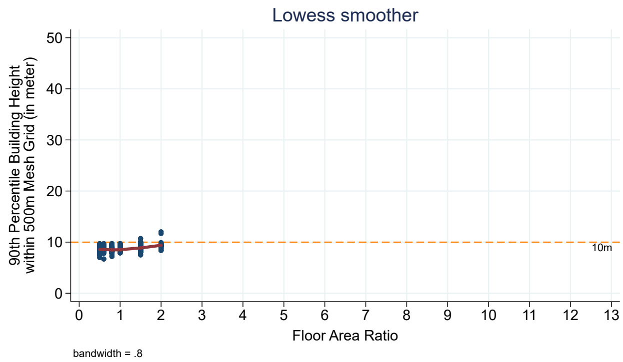
Table F.3 reports quantile regression estimates for commercial buildings in Category 1 and 2 residential districts.

Table F.4 presents quantile regression results for commercial buildings in quasi-residential districts.

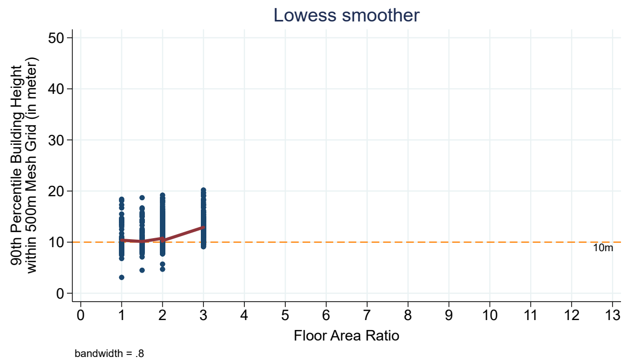
Table F.5 reports quantile regression estimates for commercial buildings in neighborhood commercial and commercial districts.

Table F.6 presents quantile regression results for commercial buildings in quasi-industrial districts.

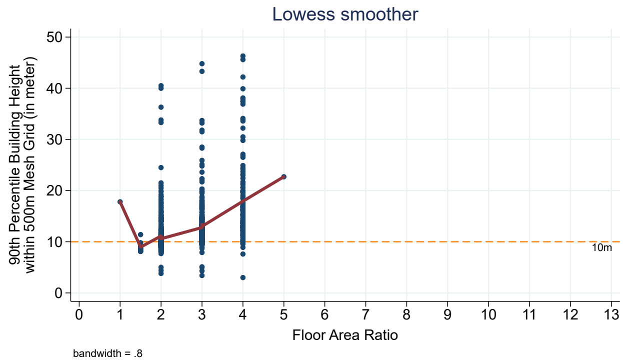
[Tables F.1−F.6]



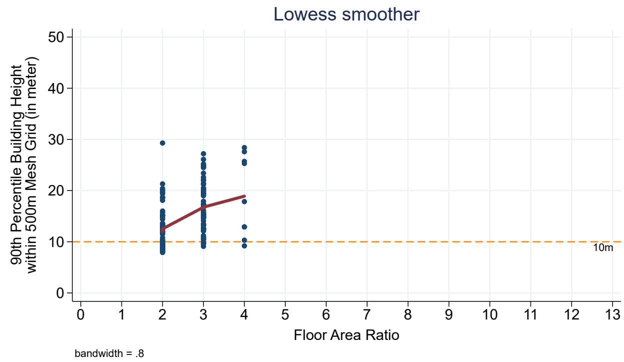
(a) Category 1 & 2 low-rise exclusive residential districts



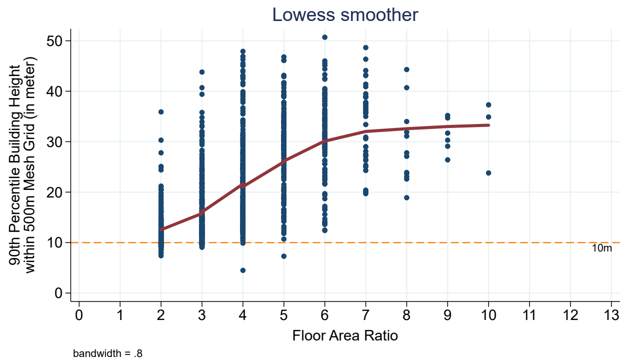
(b) Category 1 & 2 medium-to-high-rise exclusive residential districts



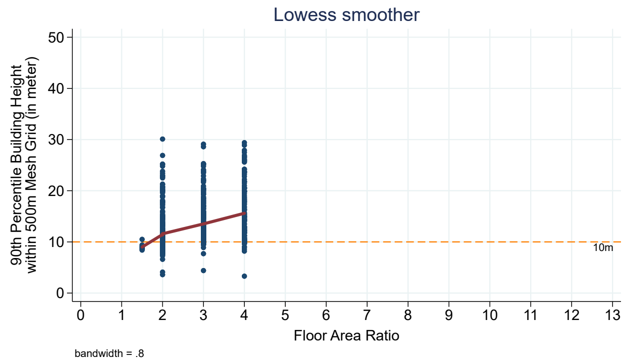
(c) Category 1 & 2 residential districts



(d) Quasi-residential district



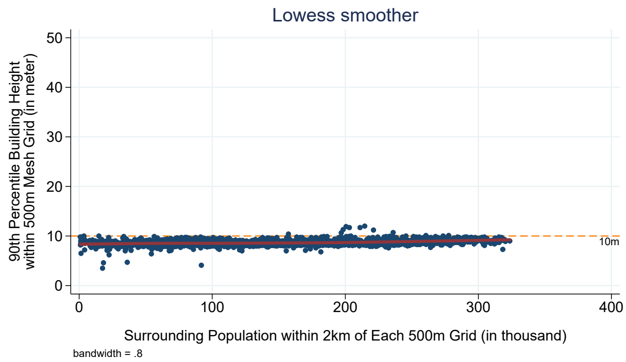
(e) Neighborhood commercial and commercial districts



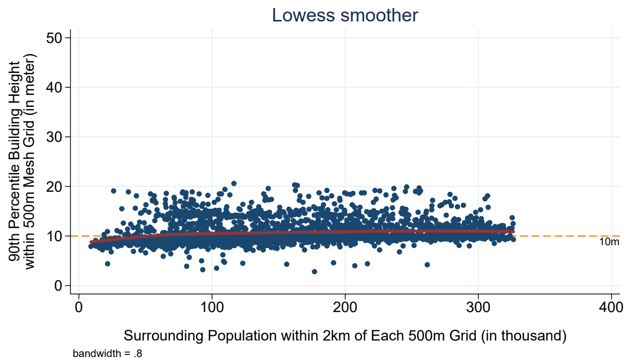
(f) Quasi-industrial district

Figure A.1. Scatterplot of 90th-Percentile Residential Building Height versus Floor Area Ratio

Note: Authors' compilation. Building height data are obtained from the 3D City Model PLATEAU, provided by the Ministry of Land, Infrastructure, Transport and Tourism (2026b). Floor area ratio data are derived from 2011 use district data in the National Land Numerical Information, provided by the Ministry of Land, Infrastructure, Transport and Tourism (2026a). All data are aggregated to the 500-m grid-cell level.



(a) Category 1 & 2 low-rise exclusive residential districts



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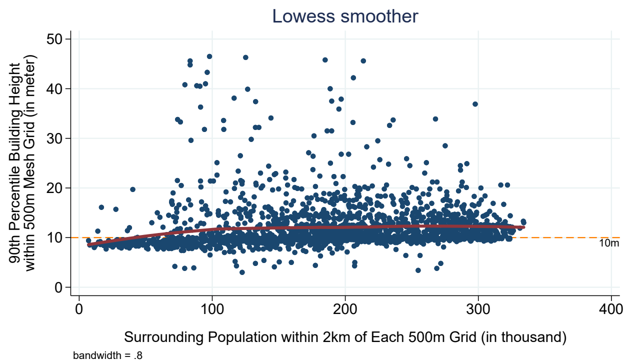
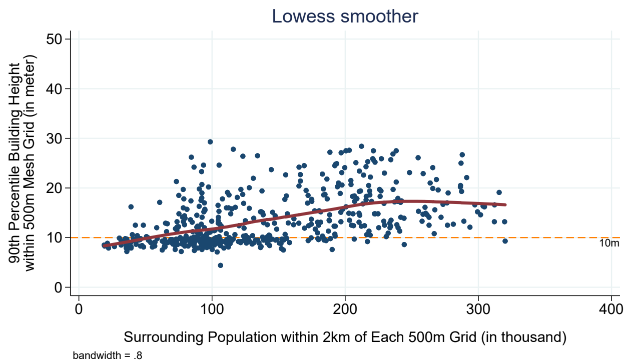
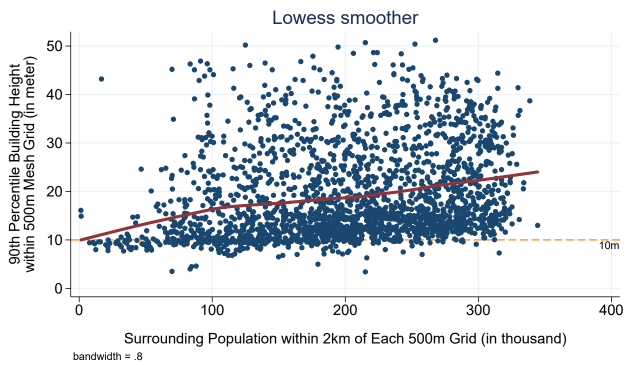


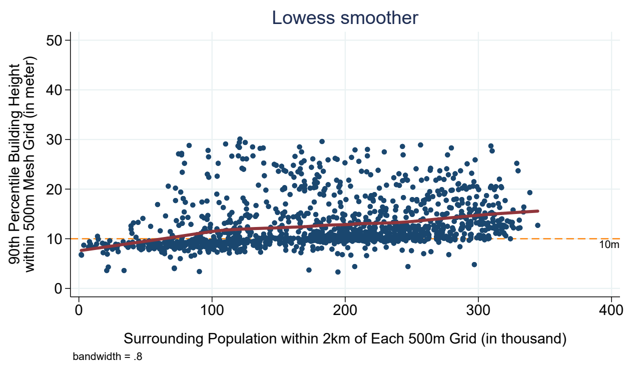
(c) Category 1 & 2 residential districts



(d) Quasi-residential district



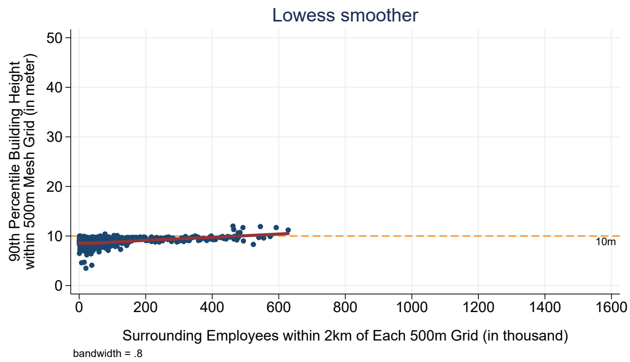
(e) Neighborhood commercial and commercial districts



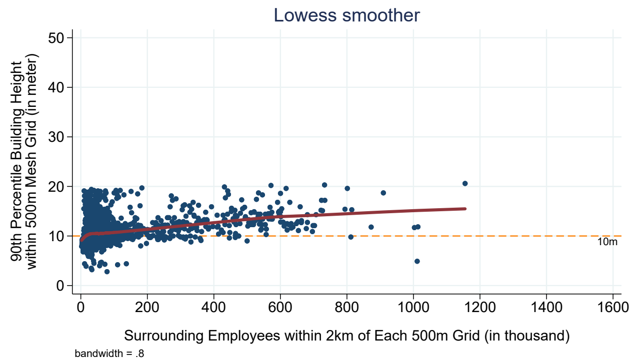
(f) Quasi-industrial district

Figure A.2. Scatterplot of 90th-Percentile Residential Building Height versus Population

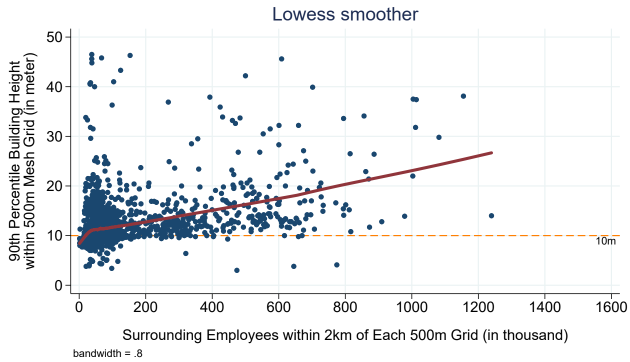
Note: Authors' compilation. Building height data are obtained from the 3D City Model PLATEAU, provided by the Ministry of Land, Infrastructure, Transport and Tourism (2026b). Population data are derived from the Mesh Statistics of the 2020 Population Census, provided by the Ministry of Internal Affairs and Communications (2026). All data are aggregated to the 500-m grid-cell level.



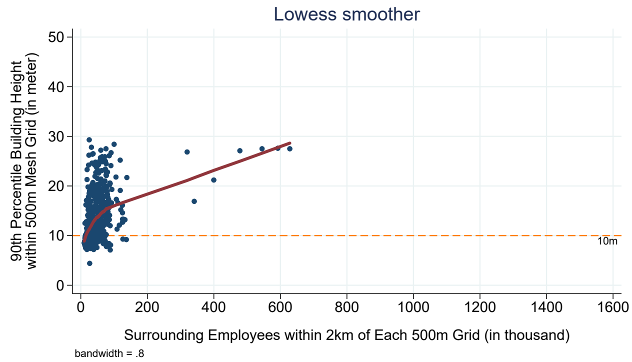
(a) Category 1 & 2 low-rise exclusive residential districts



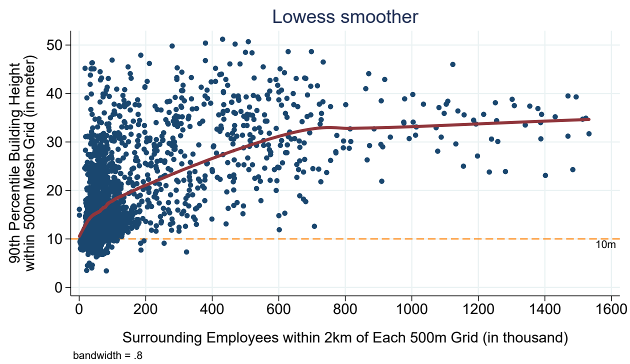
(b) Category 1 & 2 medium-to-high-rise exclusive residential districts



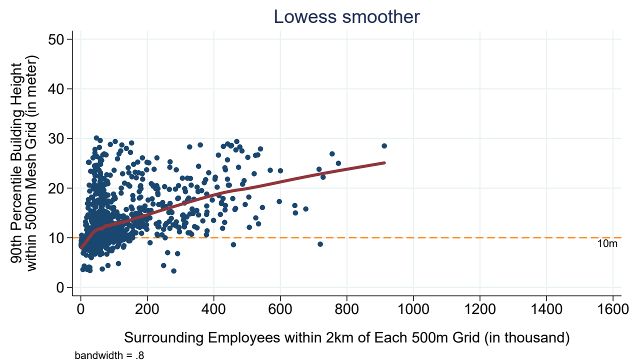
(c) Category 1 & 2 residential districts



(d) Quasi-residential district



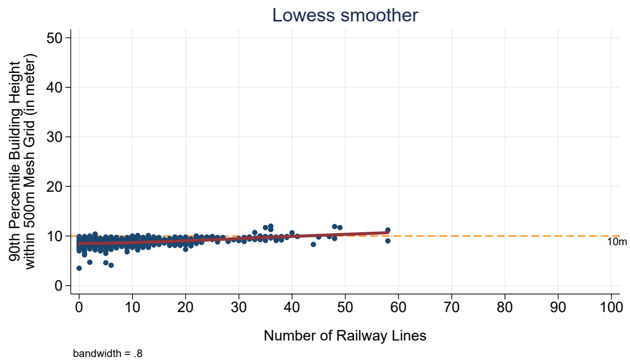
(e) Neighborhood commercial and commercial districts



(f) Quasi-industrial district

Figure A.3. Scatterplot of 90th-Percentile Residential Building Height versus Employees

Note: Authors' compilation. Building height data are obtained from the 3D City Model PLATEAU, provided by the Ministry of Land, Infrastructure, Transport and Tourism (2026b). Population data are derived from the Mesh Statistics of the 2021 Economic Census for Business Activity, provided by the Ministry of Internal Affairs and Communications (2026). All data are aggregated to the 500-m grid-cell.



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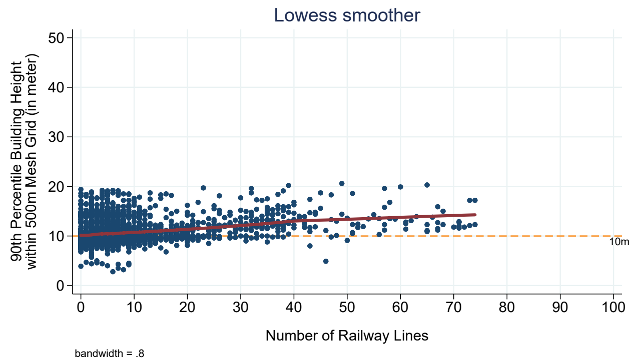
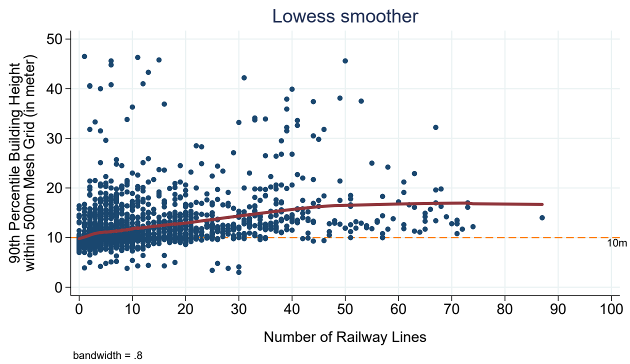
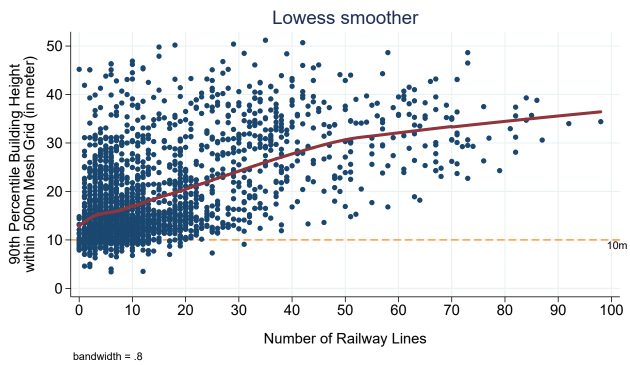


(b) Category 1 & 2 medium-to-high-rise exclusive residential districts



(c) Category 1 & 2 residential districts

(d) Quasi-residential district



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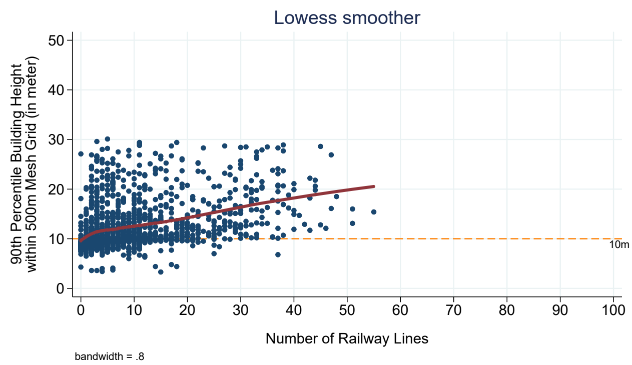
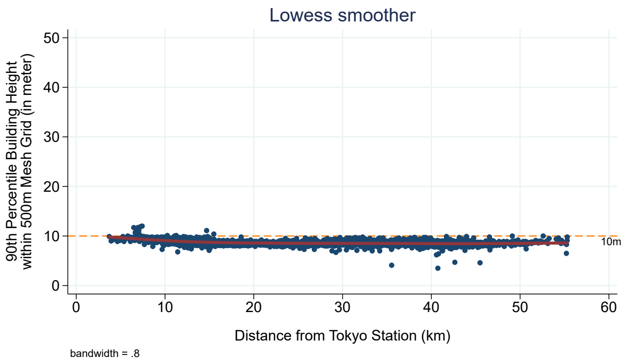


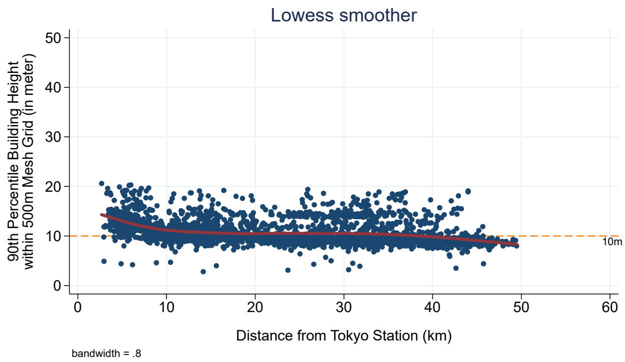
(f) Quasi-industrial district

Figure A.4. Scatterplot of 90th-Percentile Residential Building Height versus the Number of Railway Lines

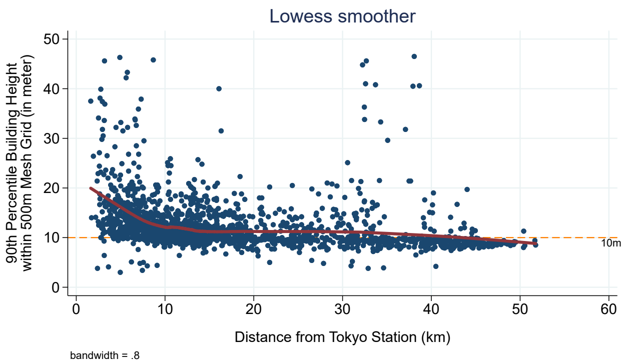
Note: Authors' compilation. Building height data are obtained from the 3D City Model PLATEAU, provided by the Ministry of Land, Infrastructure, Transport and Tourism (2026b). Railway data are derived from the National Land Numerical Information, provided by the Ministry of Internal Affairs and Communications (2026). All data are aggregated to the 500-m grid-cell level.



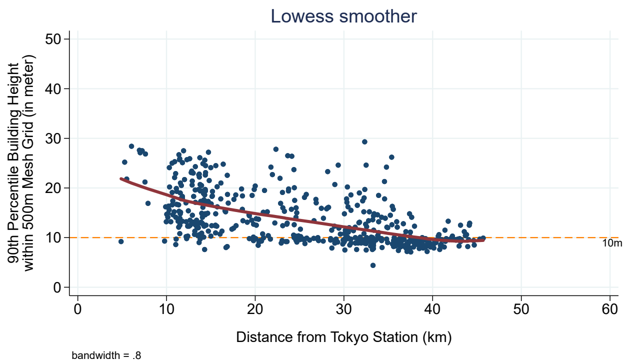
(a) Category 1 & 2 low-rise exclusive residential districts



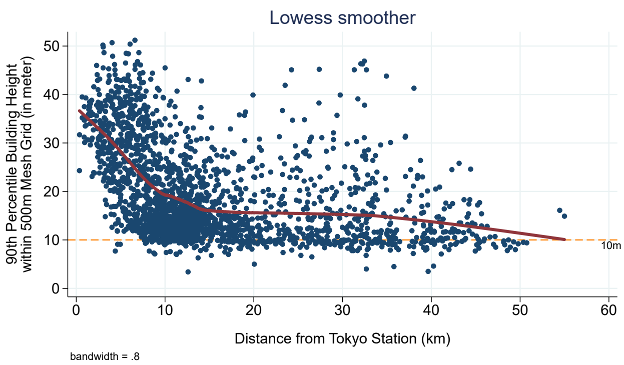
(b) Category 1 & 2 medium-to-high-rise exclusive residential districts



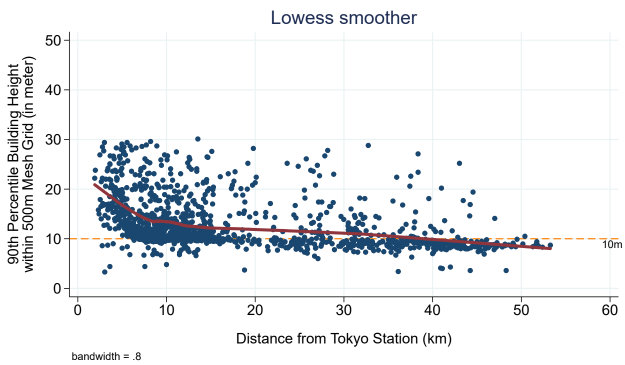
(c) Category 1 & 2 residential districts



(d) Quasi-residential district



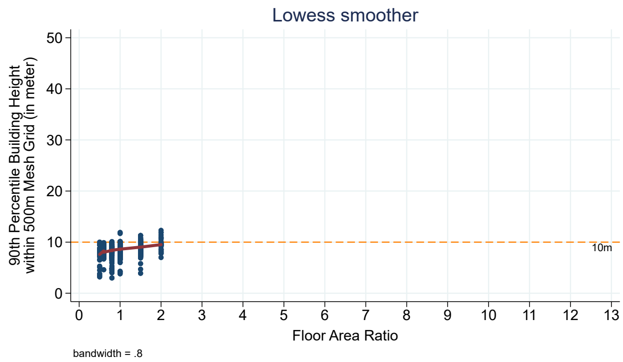
(e) Neighborhood commercial and commercial districts



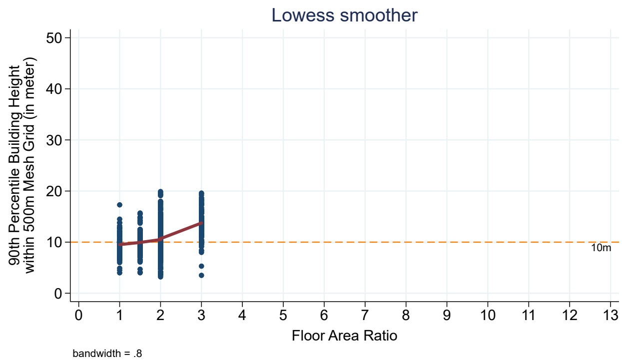
(f) Quasi-industrial district

Figure A.5. Scatterplot of 90th-Percentile Residential Building Height versus Distance from Tokyo Station

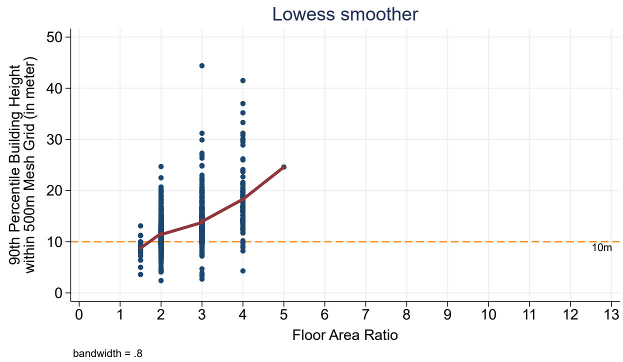
Note: Authors' compilation. Building height data are obtained from the 3D City Model PLATEAU, provided by the Ministry of Land, Infrastructure, Transport and Tourism (2026b). Station data are derived from the National Land Numerical Information, provided by the Ministry of Internal Affairs and Communications (2026). All data are aggregated to the 500-m grid-cell level.



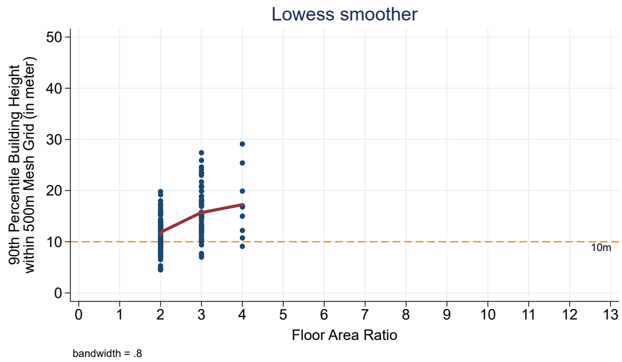
(a) Category 1 & 2 low-rise exclusive residential districts



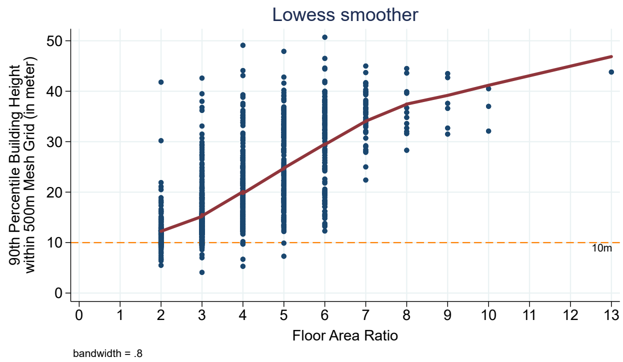
(b) Category 1 & 2 medium-to-high-rise exclusive residential districts



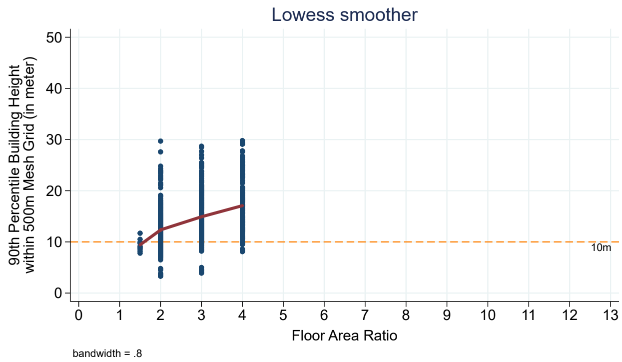
(c) Category 1 & 2 residential districts



(d) Quasi-residential district



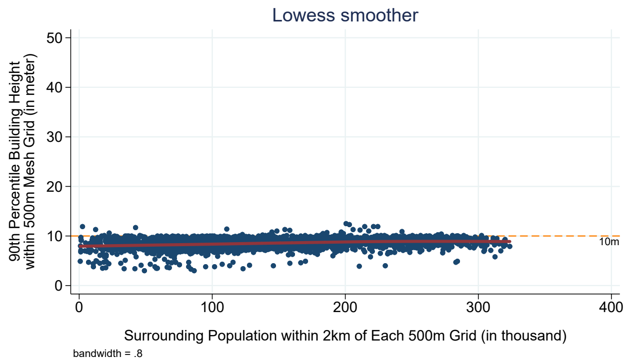
(e) Neighborhood commercial and commercial districts



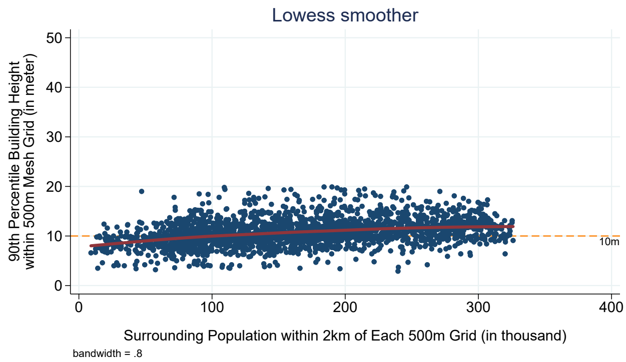
(f) Quasi-industrial district

Figure B.1. Scatterplot of 90th-Percentile Commercial Building Height versus Floor Area Ratio

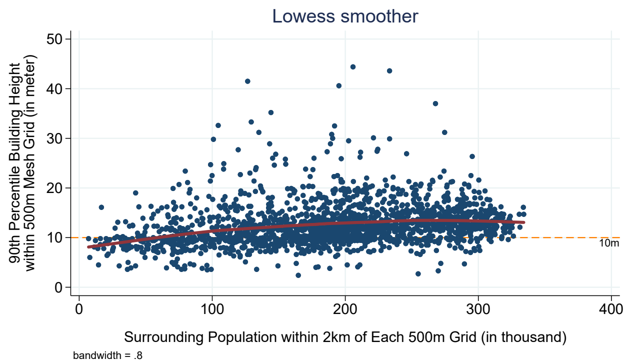
Note: Authors' compilation. Building height data are obtained from the 3D City Model PLATEAU, provided by the Ministry of Land, Infrastructure, Transport and Tourism (2026b). Floor area ratio data are derived from 2011 use district data in the National Land Numerical Information, provided by the Ministry of Land, Infrastructure, Transport and Tourism (2026a). All data are aggregated to the 500-m grid-cell level.



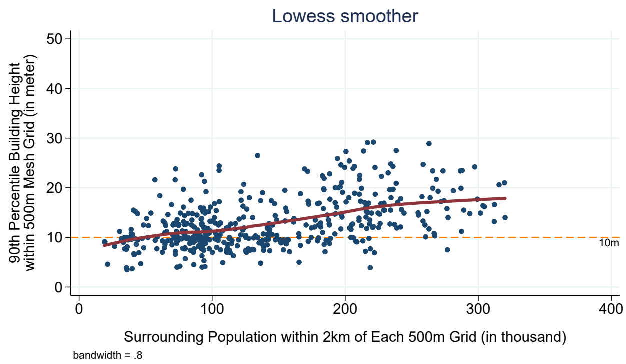
(a) Category 1 & 2 low-rise exclusive residential districts



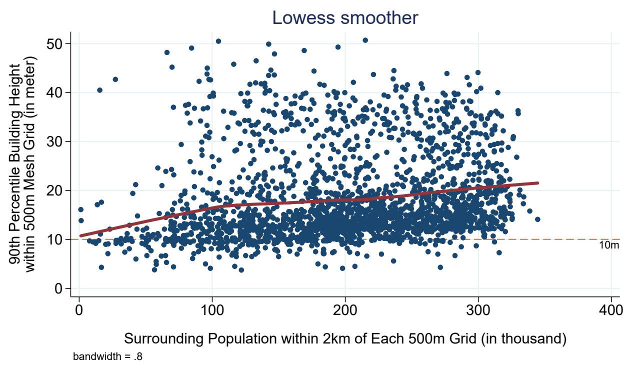
(b) Category 1 & 2 medium-to-high-rise exclusive residential districts



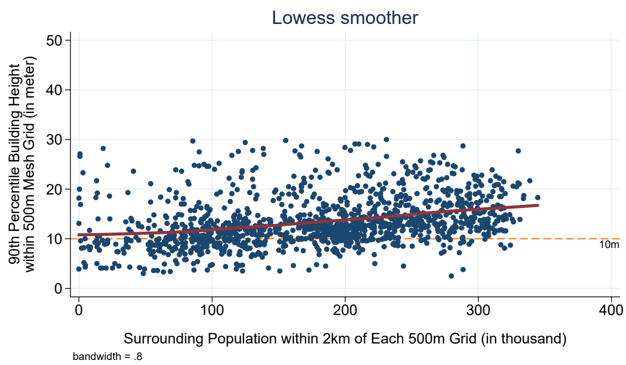
(c) Category 1 & 2 residential districts



(d) Quasi-residential district



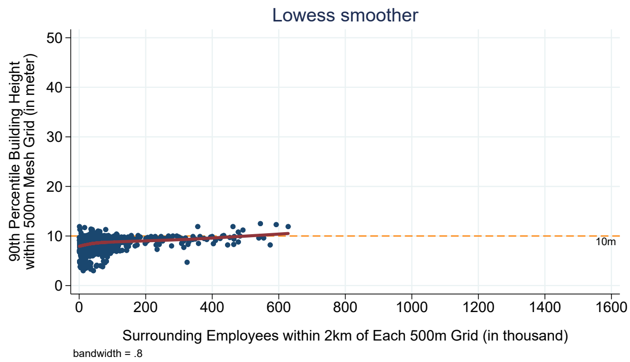
(e) Neighborhood commercial and commercial districts



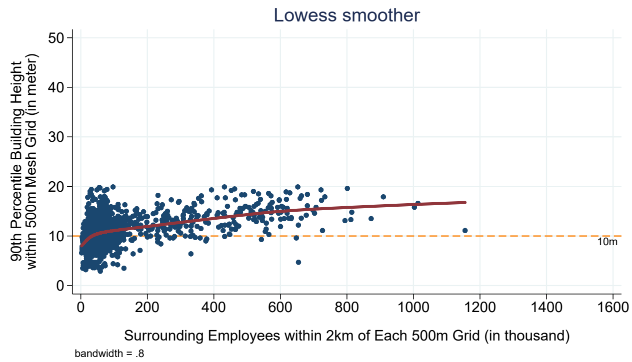
(f) Quasi-industrial district

Figure B.2. Scatterplot of 90th-Percentile Commercial Building Height versus Population

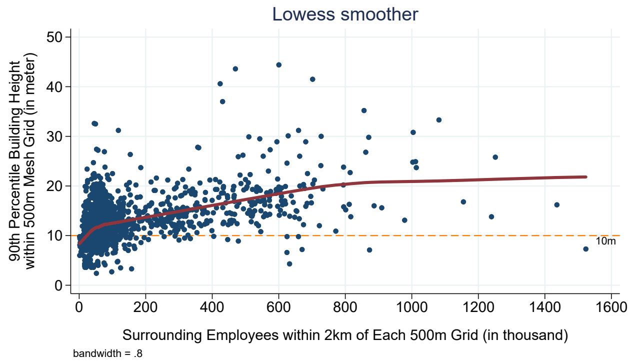
Note: Authors' compilation. Building height data are obtained from the 3D City Model PLATEAU, provided by the Ministry of Land, Infrastructure, Transport and Tourism (2026b). Population data are derived from the Mesh Statistics of the 2020 Population Census, provided by the Ministry of Internal Affairs and Communications (2026). All data are aggregated to the 500-m grid-cell level.



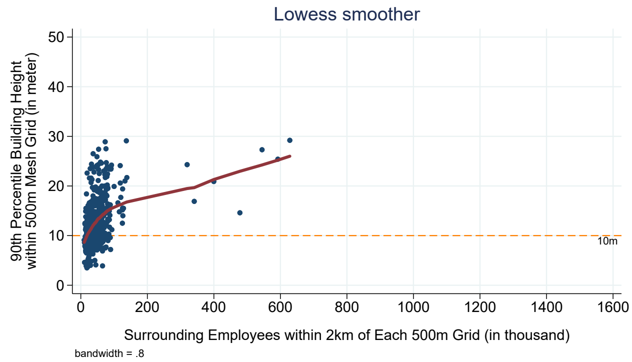
(a) Category 1 & 2 low-rise exclusive residential districts



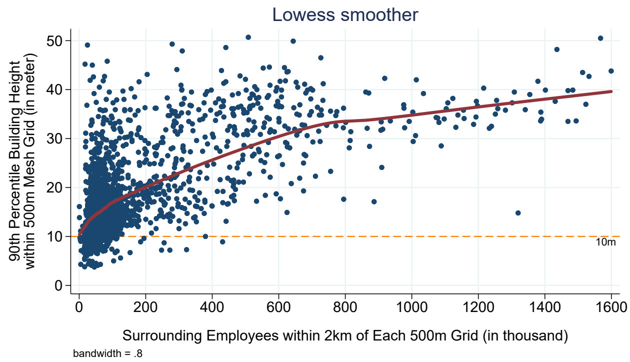
(b) Category 1 & 2 medium-to-high-rise exclusive residential districts



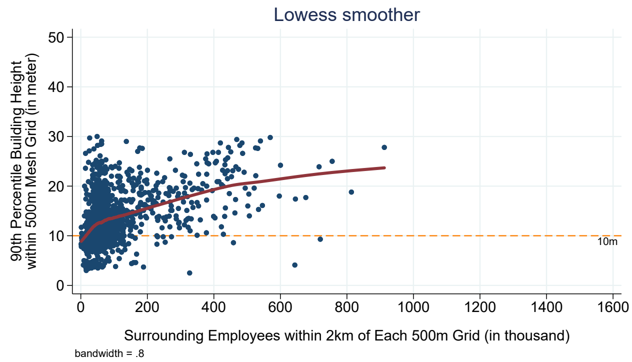
(c) Category 1 & 2 residential districts



(d) Quasi-residential district



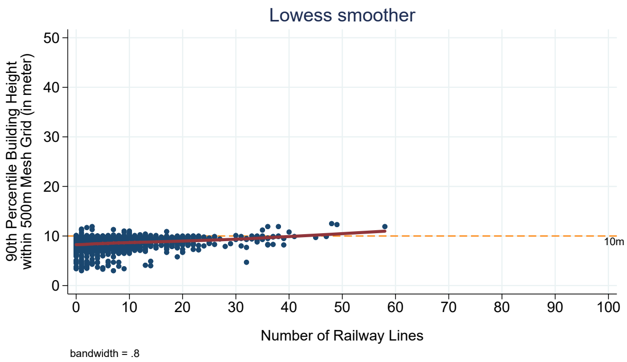
(e) Neighborhood commercial and commercial districts



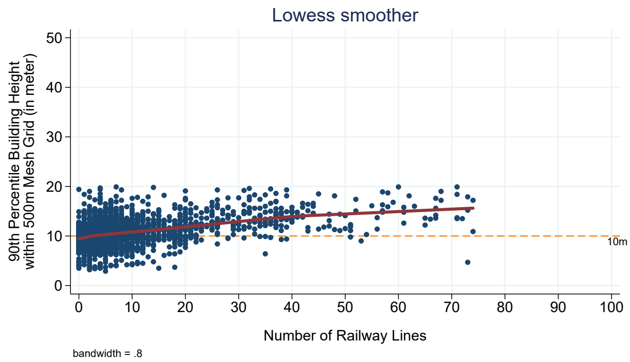
(f) Quasi-industrial district

Figure B.3. Scatterplot of 90th-Percentile Commercial Building Height versus Employees

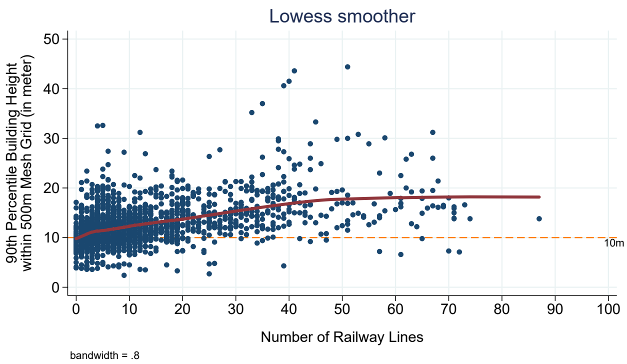
Note: Authors' compilation. Building height data are obtained from the 3D City Model PLATEAU, provided by the Ministry of Land, Infrastructure, Transport and Tourism (2026b). Population data are derived from the Mesh Statistics of the 2021 Economic Census for Business Activity, provided by the Ministry of Internal Affairs and Communications (2026). All data are aggregated to the 500-m grid-cell.



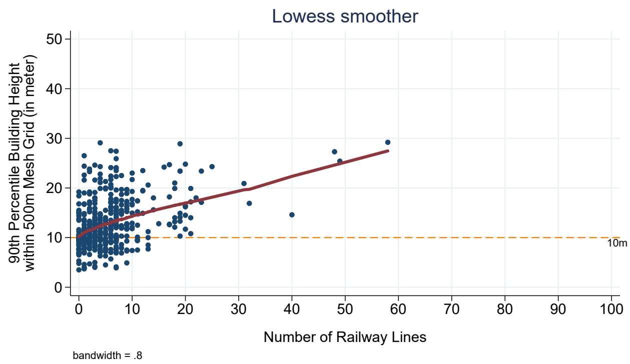
(a) Category 1 & 2 low-rise exclusive residential districts



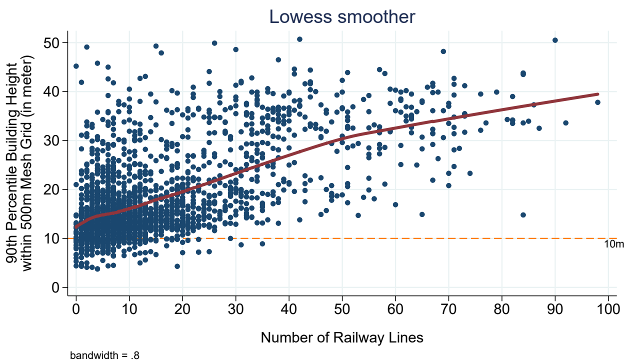
(b) Category 1 & 2 medium-to-high-rise exclusive residential districts



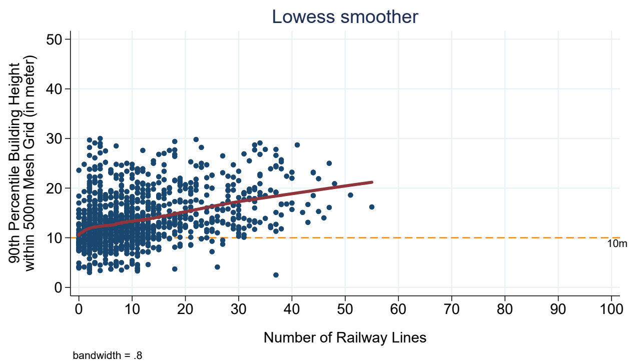
(c) Category 1 & 2 residential districts



(d) Quasi-residential district



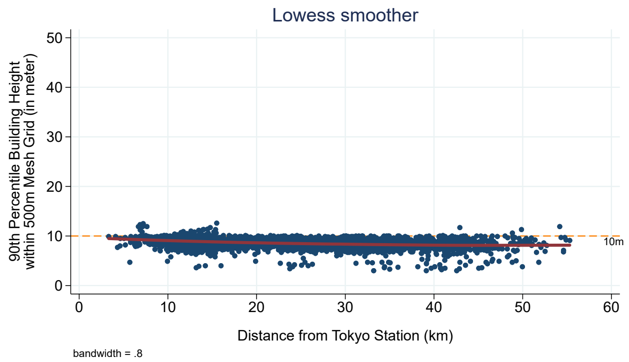
(e) Neighborhood commercial and commercial districts



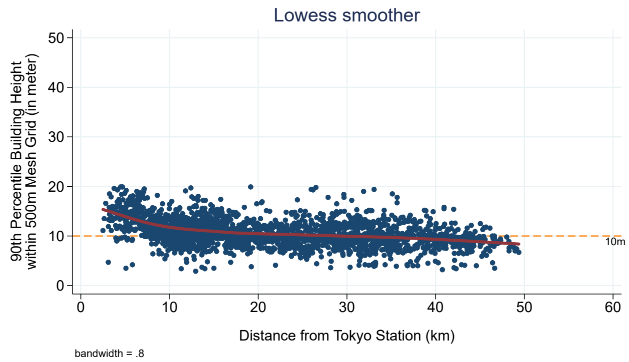
(f) Quasi-industrial district

Figure B.4. Scatterplot of 90th-Percentile Commercial Building Height versus the Number of Railway Lines

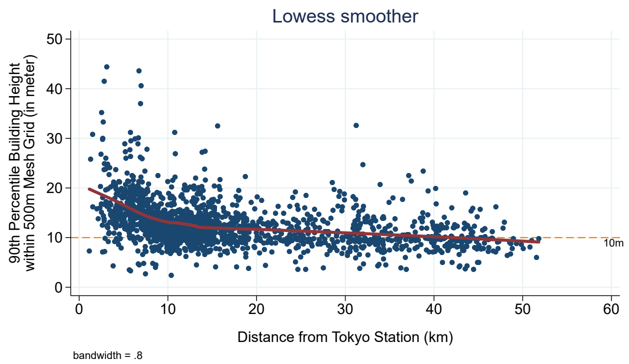
Note: Authors' compilation. Building height data are obtained from the 3D City Model PLATEAU, provided by the Ministry of Land, Infrastructure, Transport and Tourism (2026b). Railway data are derived from the National Land Numerical Information, provided by the Ministry of Internal Affairs and Communications (2026). All data are aggregated to the 500-m grid-cell level.



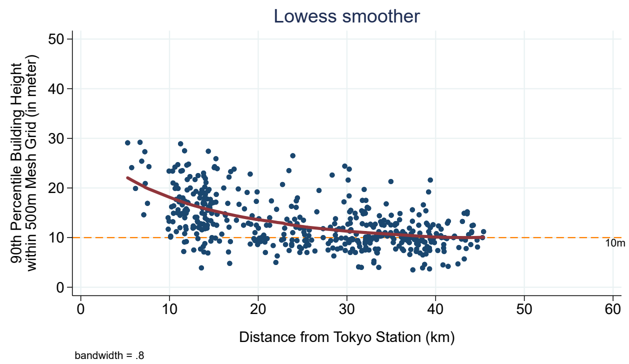
(a) Category 1 & 2 low-rise exclusive residential districts



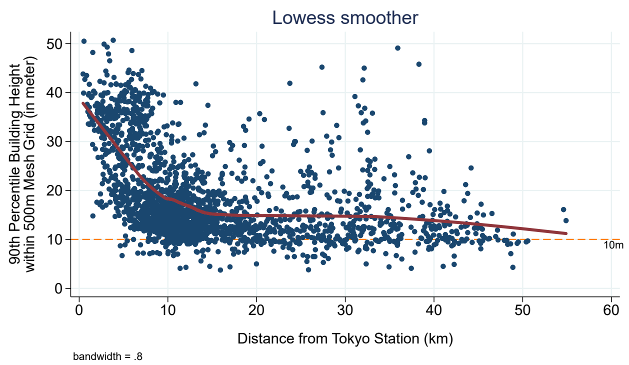
(b) Category 1 & 2 medium-to-high-rise exclusive residential districts



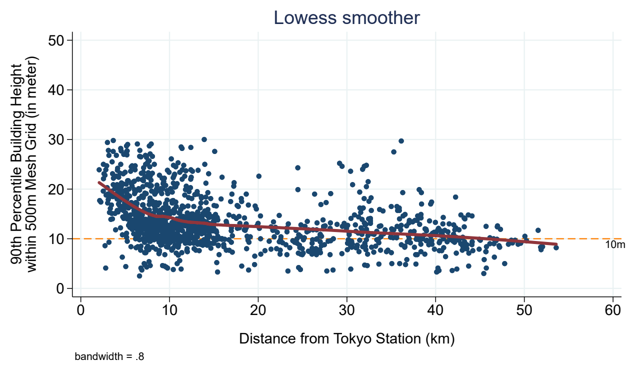
(c) Category 1 & 2 residential districts



(d) Quasi-residential district



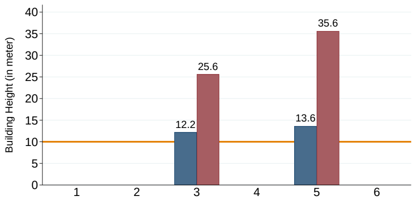
(e) Neighborhood commercial and commercial districts



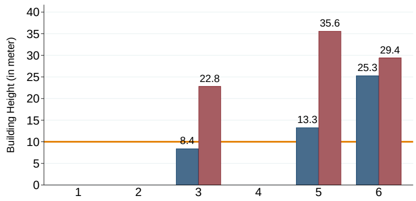
(f) Quasi-industrial district

Figure B.5. Scatterplot of 90th-Percentile Commercial Building Height versus Distance from Tokyo Station

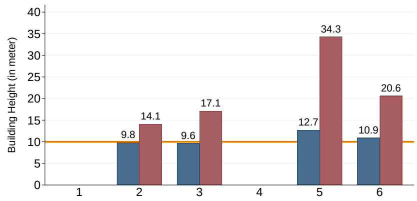
Note: Authors' compilation. Building height data are obtained from the 3D City Model PLATEAU, provided by the Ministry of Land, Infrastructure, Transport and Tourism (2026b). Station data are derived from the National Land Numerical Information, provided by the Ministry of Internal Affairs and Communications (2026). All data are aggregated to the 500-m grid-cell level.



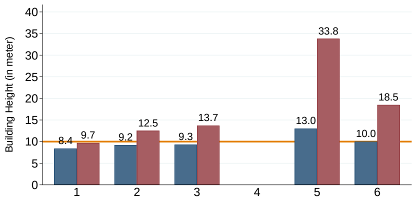
(a) 13101 Chiyoda-ku



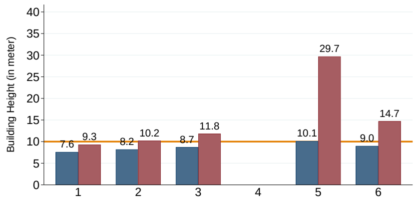
(b) 13102 Chuo-ku



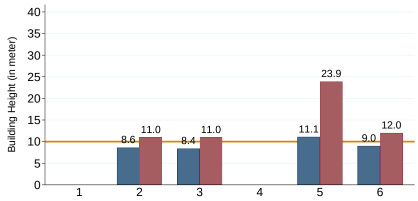
(c) 13103 Minato-ku



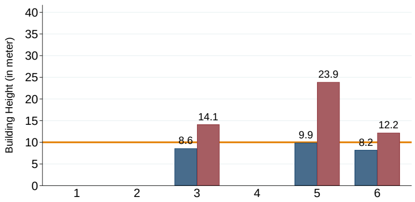
(d) 13104 Shinjuku-ku



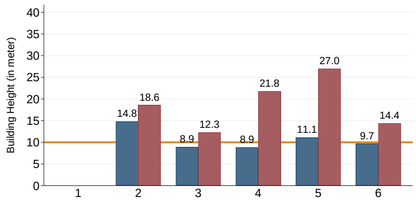
(e) 13105 Bunkyo-ku



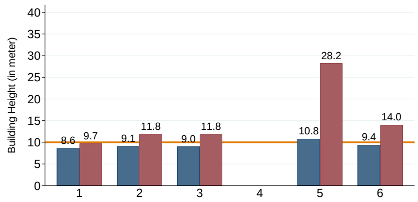
(f) 13106 Taito-ku



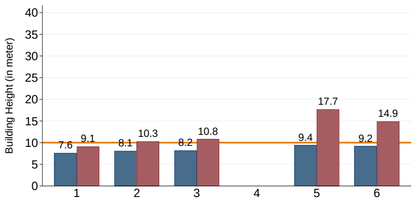
(g) 13107 Sumida-ku



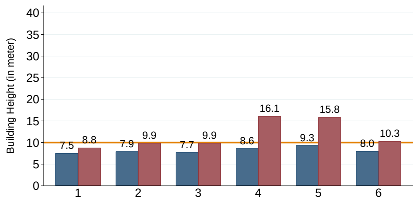
(h) 13108 Koto-ku



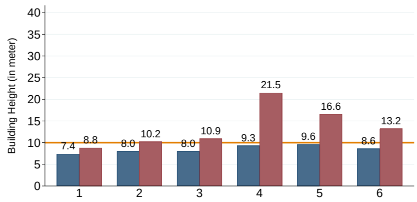
(i) 13109 Shinagawa-ku



(j) 13110 Meguro-ku



(k) 13111 Ota-ku



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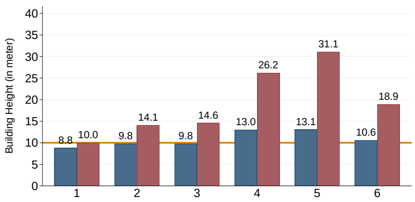

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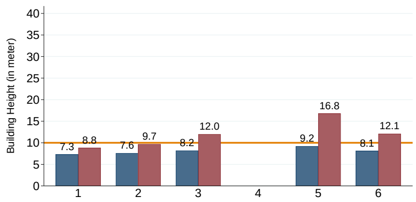
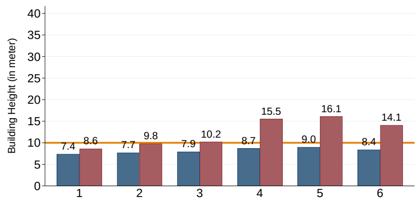
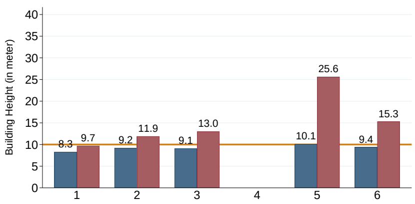


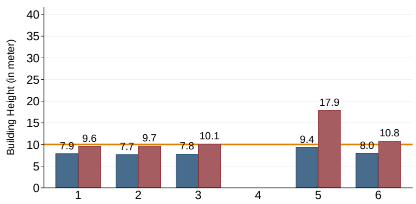
(n) 13114 Nakano-ku



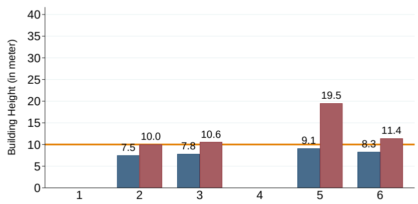
(o) 13115 Suginami-ku



(p) 13116 Toshima-ku



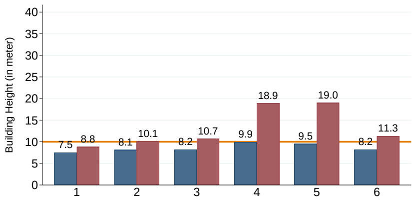
(q) 13117 Kita-ku



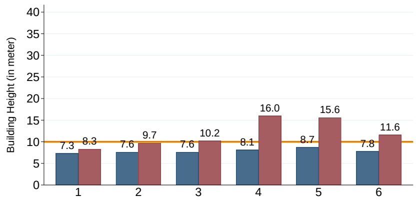
(r) 13118 Arakawa-ku

Figure C.1. Median and 90th-Percentile Residential Building Height by Use District within Municipalities

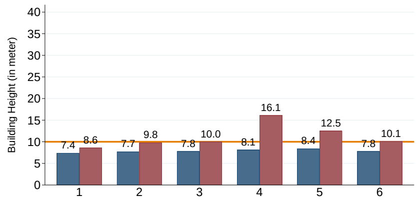
Note: Authors' compilation. Building height data are obtained from the 3D City Model PLATEAU, provided by the Ministry of Land, Infrastructure, Transport and Tourism (2026b). All data are aggregated to the municipality–use district level.



(s) 13119 Itabashi-ku



(t) 13120 Nerima-ku



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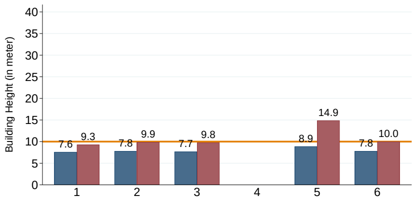
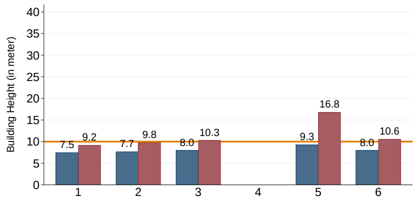
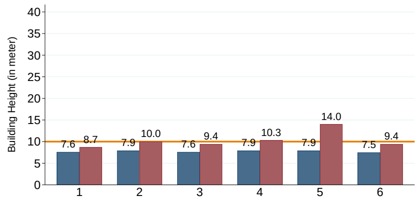


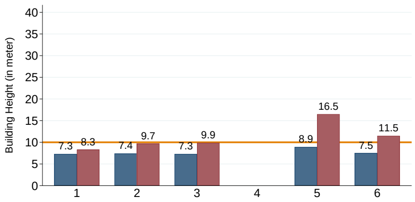
(v) 13122 Katsushika-ku



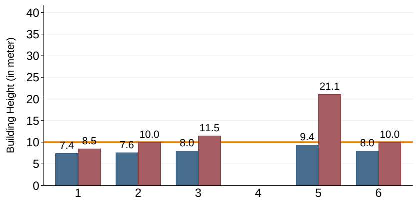
(w) 13123 Edogawa-ku



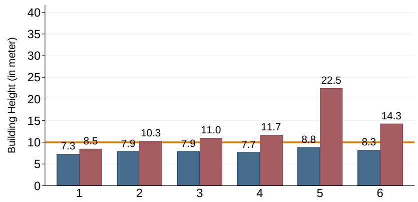
(x) 13201 Hachioji-shi



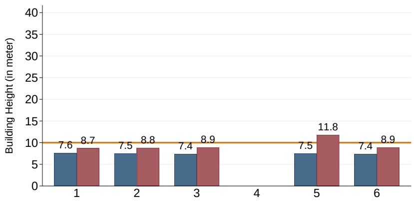
(y) 13202 Tachikawa-shi



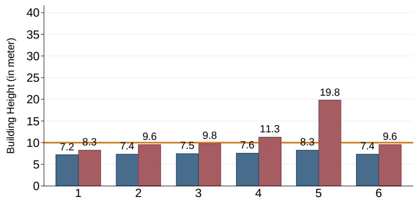
(z) 13203 Musashino-shi



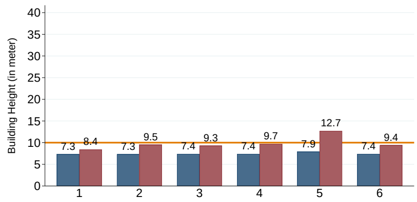
(aa) 13204 Mitaka-shi



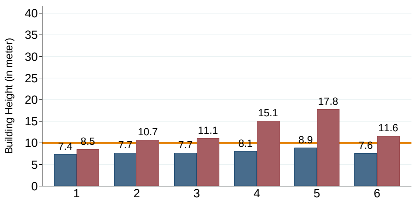
(ab) 13205 Ome-shi



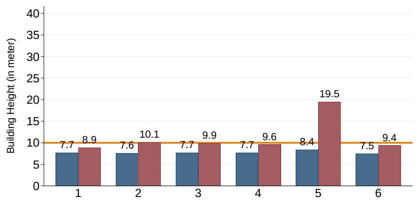
(ac) 13206 Fuchu-shi



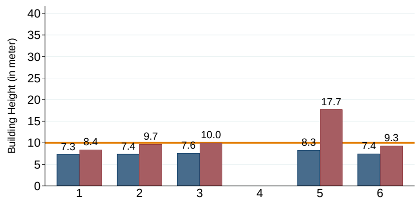
(ad) 13207 Akishima-shi



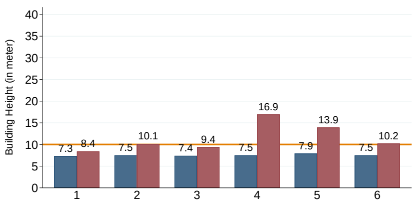
(ae) 13208 Chofu-shi



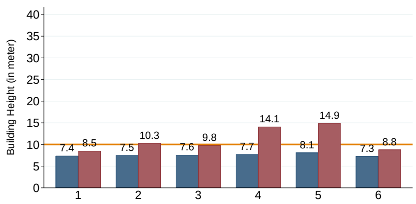
(af) 13209 Machida-shi



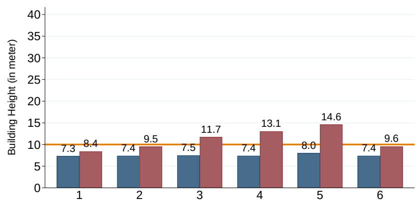
(ag) 13210 Koganei-shi



(ah) 13211 Kodaira-shi

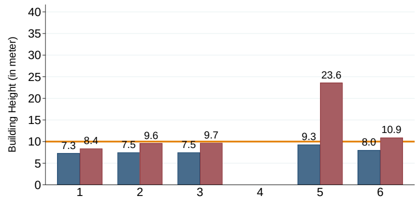


(ai) 13212 Hino-shi

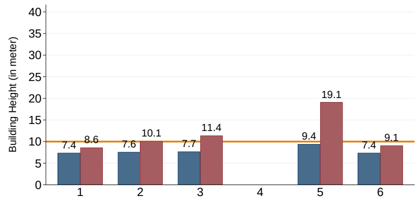


(aj) 13213 Higashimurayama-shi

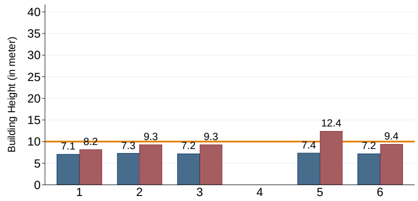
Figure C.1. Median and 90th-Percentile Residential Building Height by Use District within Municipalities (*Continued*)



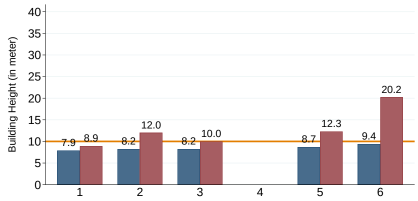
(ak) 13214 Kokubunji-shi



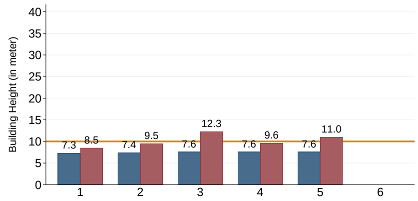
(al) 13215 Kunitachi-shi



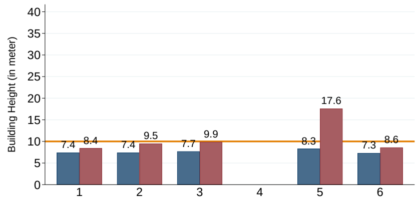
(am) 13218 Fussa-shi



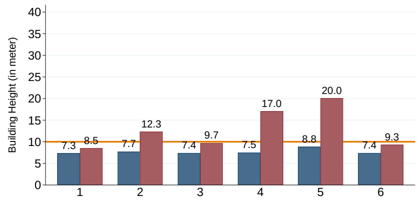
(an) 13219 Komae-shi



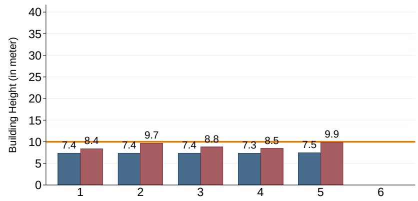
(ao) 13220 Higashiyamato-shi



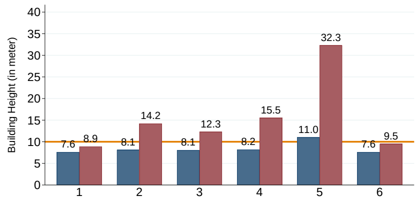
(ap) 13221 Kiyose-shi



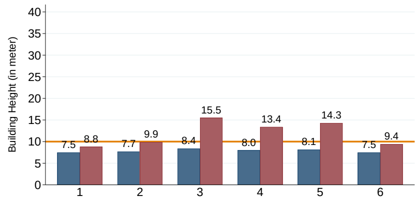
(aq) 13222 Higashikurume-shi



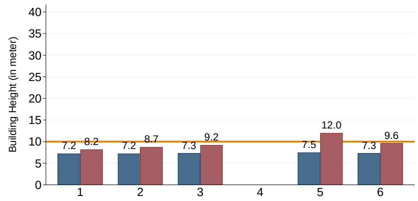
(ar) 13223 Musashimurayama-shi



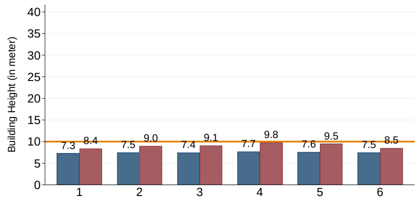
(as) 13224 Tama-shi



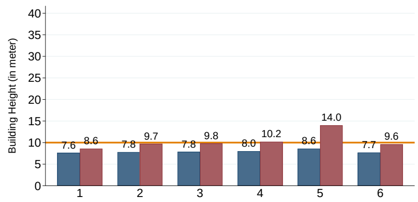
(at) 13225 Inagi-shi



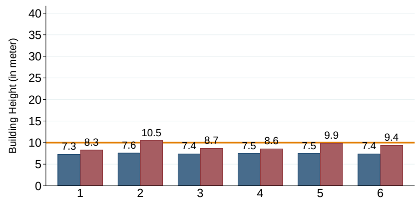
(au) 13227 Hamura-shi



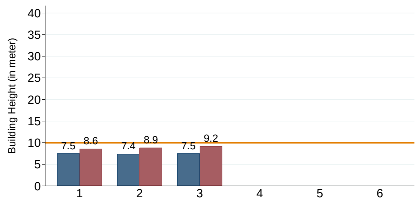
(av) 13228 Akiruno-shi



(aw) 13229 Nishitokyo-shi

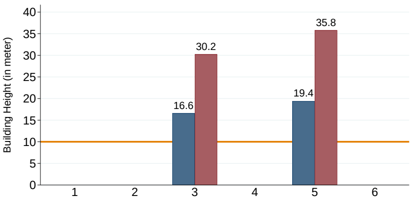


(ax) 13303 Mizuho-machi

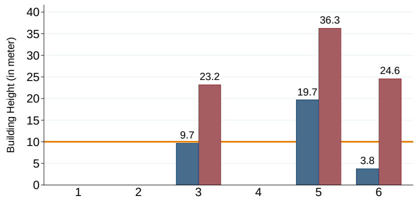


(ay) 13305 Hinode-machi

Figure C.1. Median and 90th-Percentile Residential Building Height by Use District within Municipalities (*Continued*)



(a) 13101 Chiyoda-ku



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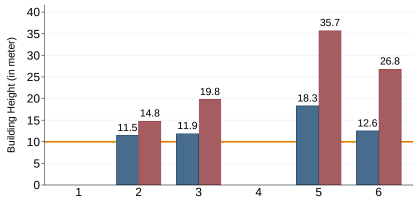

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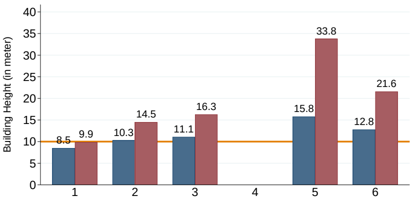

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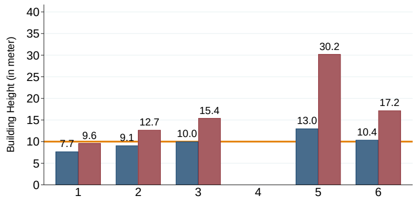

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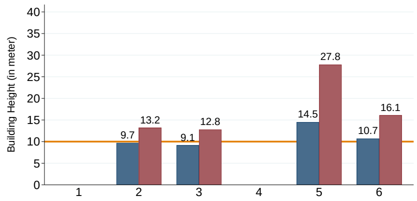

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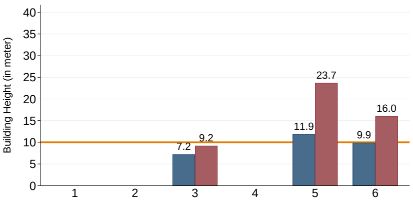
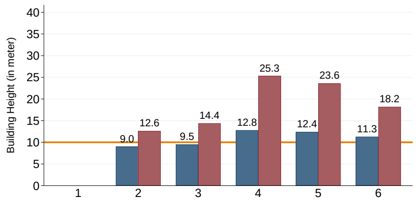


(g) 13107 Sumida-ku



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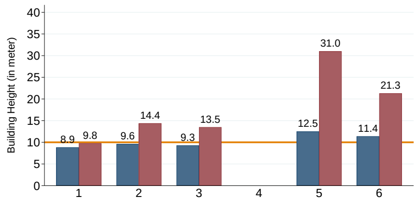
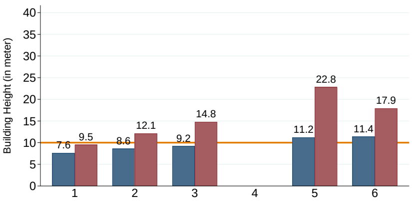
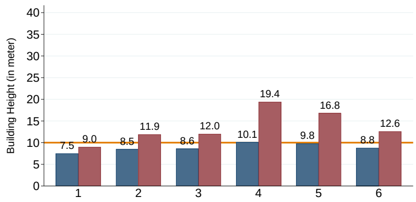


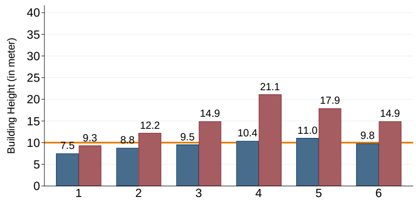
(i) 13109 Shinagawa-ku



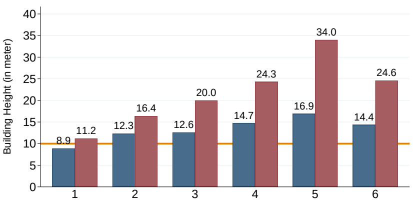
(j) 13110 Meguro-ku



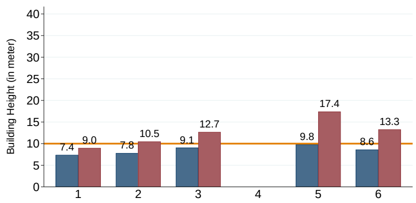
(k) 13111 Ota-ku



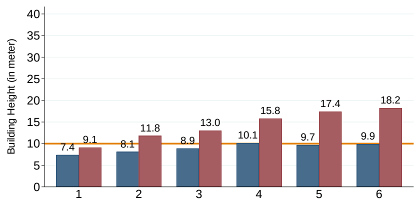
(l) 13112 Setagaya-ku



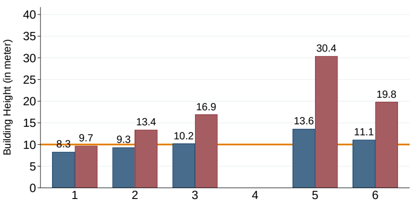
(m) 13113 Shibuya-ku



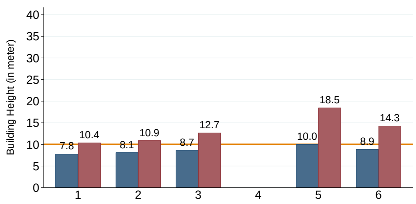
(n) 13114 Nakano-ku



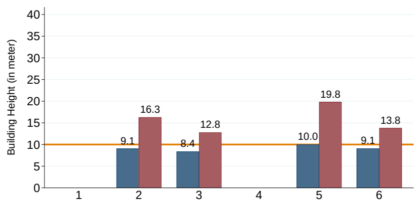
(o) 13115 Suginami-ku



(p) 13116 Toshima-ku



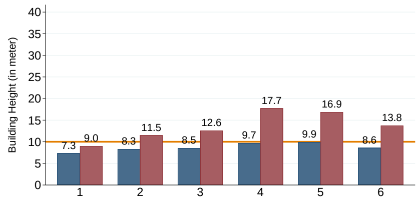
(q) 13117 Kita-ku



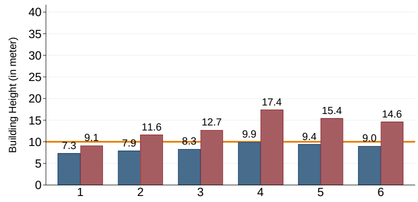
(r) 13118 Arakawa-ku

Figure D.1. Median and 90th-Percentile Commercial Building Height by Use District within Municipalities)

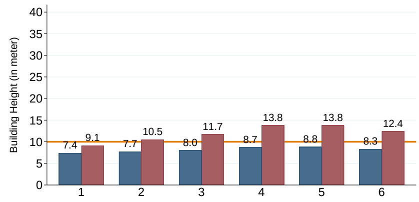
Note: Authors' compilation. Building height data are obtained from the 3D City Model PLATEAU, provided by the Ministry of Land, Infrastructure, Transport and Tourism (2026b). All data are aggregated to the municipality–use district level.



(s) 13119 Itabashi-ku



(t) 13120 Nerima-ku



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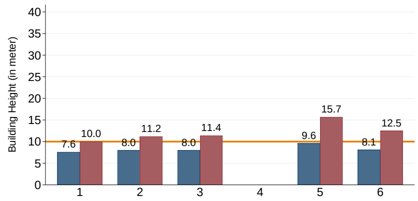

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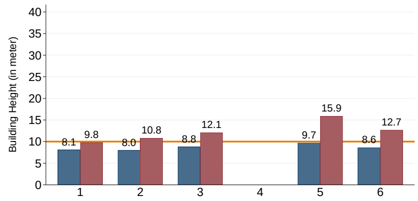
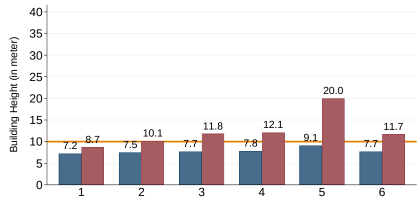
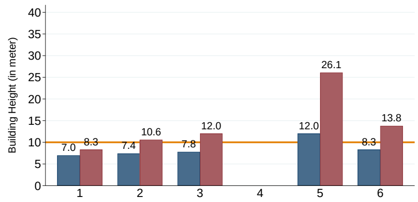


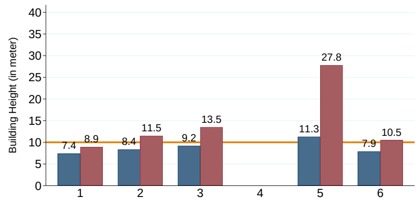
(w) 13123 Edogawa-ku



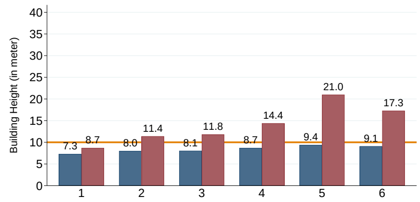
(x) 13201 Hachioji-shi



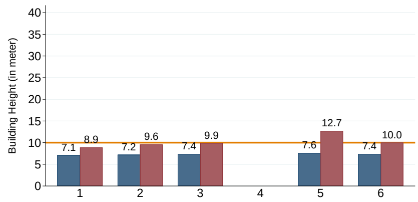
(y) 13202 Tachikawa-shi



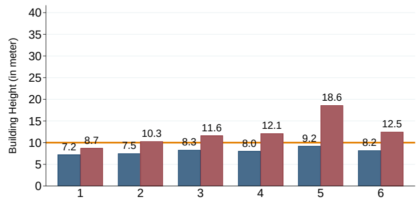
(z) 13203 Musashino-shi



(aa) 13204 Mitaka-shi



(ab) 13205 Ome-shi



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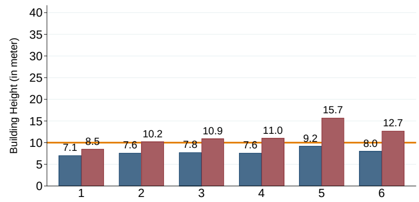

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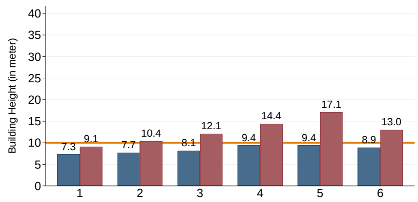
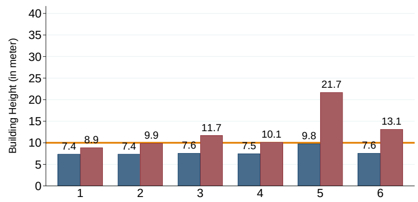
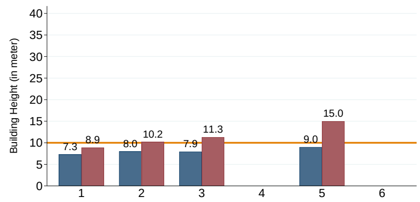


(ae) 13208 Chofu-shi



(af) 13209 Machida-shi



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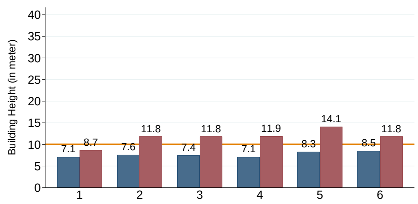

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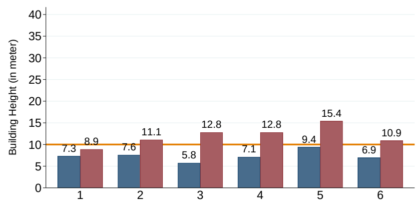

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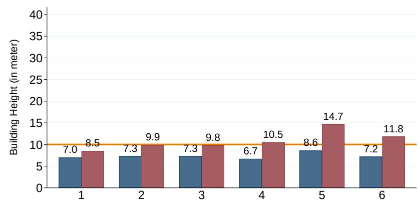
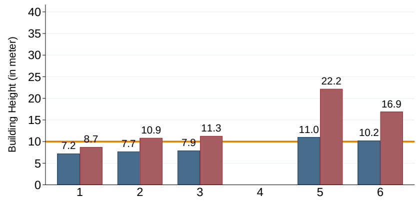


(aj) 13213 Higashimurayama-shi

Figure D.1. Median and 90th-Percentile Commercial Building Height by Use District within Municipalities (*Continued*)



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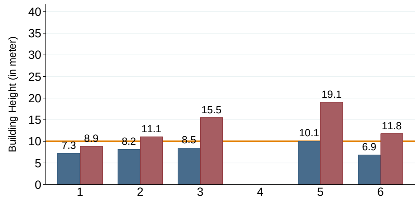
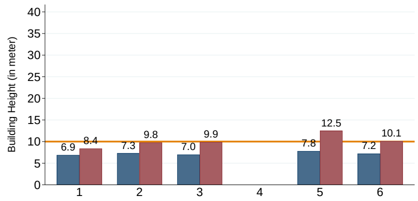
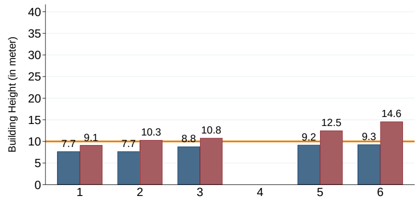


(al) 13215 Kunitachi-shi



(am) 13218 Fussa-shi



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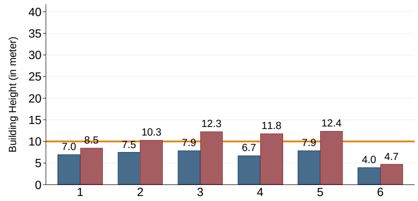

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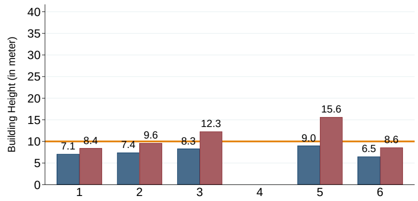

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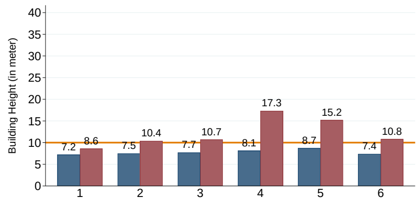

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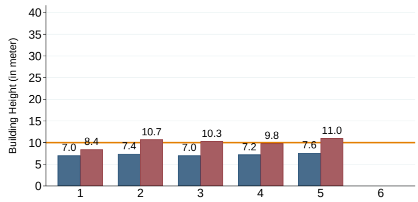

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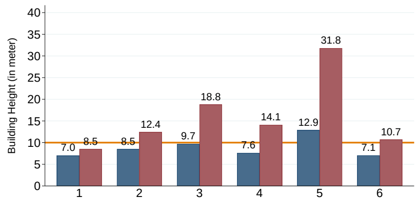

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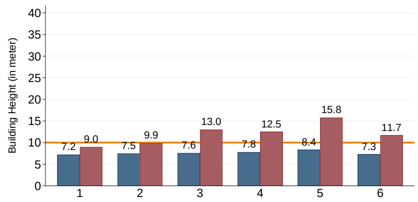

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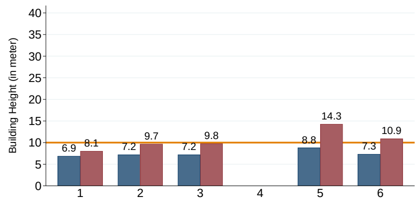

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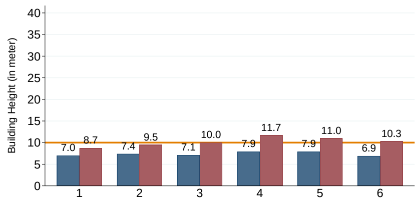

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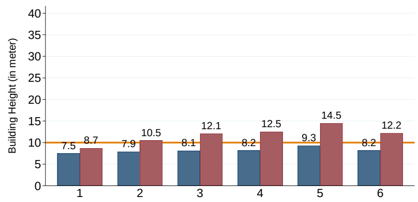

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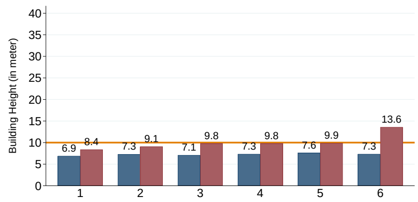
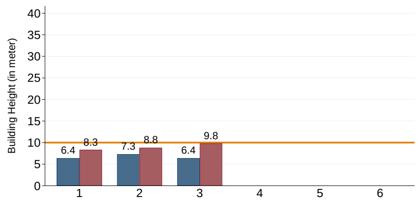


(ax) 13303 Mizuho-machi



(ay) 13305 Hinode-machi

Figure D.1. Median and 90th-Percentile Commercial Building Height by Use District within Municipalities (*Continued*)

Table E.1. Quantile Regression Estimation Results of Residential Buildings for Category 1 & 2 Low-rise Exclusive Residential Districts

	Dependent Variable: log(Building Height)								
Variables	$\tau = 0.1$ (1)	$\tau = 0.2$ (2)	$\tau = 0.3$ (3)	$\tau = 0.4$ (4)	$\tau = 0.5$ (5)	$\tau = 0.6$ (6)	$\tau = 0.7$ (7)	$\tau = 0.8$ (8)	$\tau = 0.9$ (9)
Floor Area Ratio in Location	−0.0069***	−0.0000	−0.0000	0.0000	0.0033***	0.0068***	0.0163***	0.0280***	0.0487***
	(0.0014)	(0.0006)	(0.0006)	(0.0006)	(0.0006)	(0.0007)	(0.0009)	(0.0011)	(0.0014)
log(Population within a 2km-radius Circle)	0.0500***	0.0000	−0.0000	0.0000	0.0044***	0.0015	0.0017*	0.0019	0.0084***
	(0.0027)	(0.0009)	(0.0007)	(0.0008)	(0.0009)	(0.0009)	(0.0010)	(0.0012)	(0.0013)
log(Employees within a 2km-radius Circle)	−0.0193***	−0.0000	0.0000	0.0000	−0.0122***	−0.0109***	−0.0106***	−0.0103***	−0.0138***
	(0.0014)	(0.0006)	(0.0005)	(0.0005)	(0.0006)	(0.0006)	(0.0006)	(0.0007)	(0.0009)
Station Dummy within a 500m Grid	−0.0042***	−0.0000	0.0000	0.0000	0.0012**	0.0019***	0.0025***	0.0040***	0.0066***
	(0.0010)	(0.0005)	(0.0005)	(0.0005)	(0.0005)	(0.0006)	(0.0006)	(0.0008)	(0.0009)
Number of Railways within a 2km-radius Circle	0.0001	−0.0000	0.0000	−0.0000	0.0004***	0.0005***	0.0006***	0.0008***	0.0009***
	(0.0001)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0001)	(0.0001)
log(Distance from Tokyo Station)	0.0309***	−0.0000	0.0000	−0.0000	−0.0168***	−0.0224***	−0.0274***	−0.0449***	−0.0592***
	(0.0032)	(0.0015)	(0.0014)	(0.0014)	(0.0016)	(0.0017)	(0.0019)	(0.0023)	(0.0028)
Municipality Fixed Effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Number of Observations	932,416	932,416	932,416	932,416	932,416	932,416	932,416	932,416	932,416
Pseudo R^2	0.0313	0.0132	0.0184	0.0222	0.0252	0.0293	0.0342	0.0395	0.0471

Notes: Heteroskedasticity-consistent standard errors are in parentheses. * denotes statistical significance at the 10 % level, ** at the 5 % level, and *** at the 1 % level. The parameter τ represents the τth quantile of the quantile regression.

Table E.2. Quantile Regression Estimation Results of Residential Buildings for Category 1 and 2 Medium-to-high-rise Exclusive Residential Districts

	Dependent Variable: log(Building Height)								
Variables	$\tau = 0.1$ (1)	$\tau = 0.2$ (2)	$\tau = 0.3$ (3)	$\tau = 0.4$ (4)	$\tau = 0.5$ (5)	$\tau = 0.6$ (6)	$\tau = 0.7$ (7)	$\tau = 0.8$ (8)	$\tau = 0.9$ (9)
Floor Area Ratio in Location	−0.0000	−0.0000	0.0108***	0.0138***	0.0243***	0.0328***	0.0421***	0.0477***	0.0520***
	(0.0013)	(0.0010)	(0.0009)	(0.0009)	(0.0010)	(0.0011)	(0.0012)	(0.0013)	(0.0018)
log(Population within a 2km-radius Circle)	0.0000	0.0000	−0.0033*	−0.0045**	−0.0073***	−0.0055**	−0.0022	−0.0129***	−0.0216***
	(0.0031)	(0.0023)	(0.0020)	(0.0020)	(0.0022)	(0.0026)	(0.0029)	(0.0033)	(0.0044)
log(Employees within a 2km-radius Circle)	0.0000	0.0000	−0.0026**	−0.0036***	−0.0029**	−0.0083***	−0.0100***	−0.0037**	−0.0093***
	(0.0018)	(0.0014)	(0.0012)	(0.0013)	(0.0014)	(0.0016)	(0.0016)	(0.0017)	(0.0024)
Station Dummy within a 500m Grid	−0.0000	−0.0000	−0.0004	−0.0003	−0.0002	−0.0000	0.0009	0.0029**	0.0018
	(0.0012)	(0.0010)	(0.0009)	(0.0010)	(0.0011)	(0.0012)	(0.0012)	(0.0011)	(0.0016)
Number of Railways within a 2km-radius Circle	0.0000	−0.0000	0.0001	0.0002**	0.0003***	0.0004***	0.0005***	0.0003***	0.0004***
	(0.0001)	(0.0001)	(0.0001)	(0.0001)	(0.0001)	(0.0001)	(0.0001)	(0.0001)	(0.0001)
log(Distance from Tokyo Station)	0.0000	−0.0000	−0.0020	−0.0031	−0.0089***	−0.0246***	−0.0309***	−0.0296***	−0.0265***
	(0.0037)	(0.0031)	(0.0030)	(0.0030)	(0.0033)	(0.0035)	(0.0038)	(0.0043)	(0.0053)
Municipality Fixed Effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Number of Observations	417,888	417,888	417,888	417,888	417,888	417,888	417,888	417,888	417,888
Pseudo R^2	0.0203	0.0227	0.0323	0.0439	0.0557	0.0638	0.0615	0.0581	0.0851

Notes: Heteroskedasticity-consistent standard errors are in parentheses. * denotes statistical significance at the 10 % level, ** at the 5 % level, and *** at the 1 % level. The parameter τ represents the τth quantile of the quantile regression.

Table E.3. Quantile Regression Estimation Results of Residential Buildings for Category 1 & 2 Residential Districts

	Dependent Variable: log(Building Height)								
	$\tau = 0.1$	$\tau = 0.2$	$\tau = 0.3$	$\tau = 0.4$	$\tau = 0.5$	$\tau = 0.6$	$\tau = 0.7$	$\tau = 0.8$	$\tau = 0.9$
Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Floor Area Ratio in Location	0.0154***	0.0209***	0.0267***	0.0373***	0.0507***	0.0725***	0.0750***	0.0690***	0.1162***
	(0.0010)	(0.0008)	(0.0009)	(0.0010)	(0.0012)	(0.0013)	(0.0012)	(0.0012)	(0.0024)
log(Population within a 2km-radius Circle)	0.0087***	0.0090***	0.0068***	0.0026	0.0005	0.0000	−0.0011	−0.0182***	−0.0459***
	(0.0032)	(0.0025)	(0.0024)	(0.0025)	(0.0027)	(0.0030)	(0.0030)	(0.0031)	(0.0050)
log(Employees within a 2km-radius Circle)	−0.0005	−0.0038**	−0.0052***	−0.0057***	−0.0006	0.0000	−0.0033*	0.0011	0.0096***
	(0.0023)	(0.0018)	(0.0019)	(0.0019)	(0.0021)	(0.0021)	(0.0019)	(0.0022)	(0.0036)
Station Dummy within a 500m Grid	−0.0004	−0.0008	−0.0005	0.0001	0.0000	0.0000	0.0003	0.0016	0.0083***
	(0.0012)	(0.0010)	(0.0010)	(0.0011)	(0.0012)	(0.0013)	(0.0012)	(0.0012)	(0.0019)
Number of Railways within a 2km-radius Circle	−0.0002**	−0.0001	−0.0001	0.0000	−0.0000	0.0000	0.0000	−0.0001	−0.0005***
	(0.0001)	(0.0001)	(0.0001)	(0.0001)	(0.0001)	(0.0001)	(0.0001)	(0.0001)	(0.0002)
log(Distance from Tokyo Station)	0.0027	0.0088***	0.0158***	0.0079**	0.0005	0.0000	−0.0007	0.0018	0.0052
	(0.0040)	(0.0032)	(0.0033)	(0.0036)	(0.0041)	(0.0045)	(0.0041)	(0.0041)	(0.0067)
Municipality Fixed Effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Number of Observations	323,691	323,691	323,691	323,691	323,691	323,691	323,691	323,691	323,691
Pseudo R^2	0.0225	0.0182	0.0264	0.0393	0.0531	0.0589	0.0565	0.0671	0.1105

Notes: Heteroskedasticity-consistent standard errors are in parentheses. * denotes statistical significance at the 10 % level, ** at the 5 % level, and *** at the 1 % level. The parameter τ represents the τth quantile of the quantile regression.

Table E.4. Quantile Regression Estimation Results of Residential Buildings for Quasi-residential Districts

	Dependent Variable: log(Building Height)								
Variables	$\tau = 0.1$ (1)	$\tau = 0.2$ (2)	$\tau = 0.3$ (3)	$\tau = 0.4$ (4)	$\tau = 0.5$ (5)	$\tau = 0.6$ (6)	$\tau = 0.7$ (7)	$\tau = 0.8$ (8)	$\tau = 0.9$ (9)
Floor Area Ratio in Location	0.0011	0.0069*	0.0137***	0.0225***	0.0294***	0.0371***	0.0501***	0.0714***	0.1213***
	(0.0061)	(0.0038)	(0.0037)	(0.0038)	(0.0041)	(0.0045)	(0.0050)	(0.0071)	(0.0099)
log(Population within a 2km-radius Circle)	0.1362***	0.0126	−0.0055	−0.0063	−0.0167	−0.0306**	−0.0507***	−0.0225	−0.0092
	(0.0377)	(0.0180)	(0.0132)	(0.0129)	(0.0136)	(0.0154)	(0.0185)	(0.0210)	(0.0321)
log(Employees within a 2km-radius Circle)	−0.0573***	0.0014	0.0055	0.0061	0.0140*	0.0178**	0.0255**	0.0204	0.0136
	(0.0175)	(0.0085)	(0.0076)	(0.0078)	(0.0083)	(0.0090)	(0.0117)	(0.0135)	(0.0233)
Station Dummy within a 500m Grid	0.0066	0.0160*	0.0169*	0.0324***	0.0342***	0.0387***	0.0403***	0.0489**	0.0364
	(0.0114)	(0.0086)	(0.0099)	(0.0104)	(0.0106)	(0.0113)	(0.0139)	(0.0199)	(0.0300)
Number of Railways within a 2km-radius Circle	−0.0018*	−0.0012*	−0.0006	−0.0003	0.0001	0.0003	−0.0002	−0.0002	0.0014
	(0.0010)	(0.0007)	(0.0007)	(0.0008)	(0.0009)	(0.0011)	(0.0013)	(0.0020)	(0.0021)
log(Distance from Tokyo Station)	0.0023	−0.0507**	−0.0707***	−0.1020***	−0.1516***	−0.1631***	−0.2190***	−0.2558***	−0.3974***
	(0.0400)	(0.0253)	(0.0240)	(0.0262)	(0.0274)	(0.0299)	(0.0408)	(0.0484)	(0.0734)
Municipality Fixed Effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Number of Observations	14,783	14,783	14,783	14,783	14,783	14,783	14,783	14,783	14,783
Pseudo R^2	0.0234	0.0155	0.0194	0.0276	0.0408	0.0569	0.0678	0.0929	0.1460

Notes: Heteroskedasticity-consistent standard errors are in parentheses. * denotes statistical significance at the 10 % level, ** at the 5 % level, and *** at the 1 % level. The parameter τ represents the τth quantile of the quantile regression.

Table E.5. Quantile Regression Estimation Results of Residential Buildings for Neighborhood Commercial and Commercial Districts

	Dependent Variable: log(Building Height)								
Variables	$\tau = 0.1$ (1)	$\tau = 0.2$ (2)	$\tau = 0.3$ (3)	$\tau = 0.4$ (4)	$\tau = 0.5$ (5)	$\tau = 0.6$ (6)	$\tau = 0.7$ (7)	$\tau = 0.8$ (8)	$\tau = 0.9$ (9)
Floor Area Ratio in Location	0.0290***	0.0048	0.0134***	0.0109***	0.0119***	0.0156***	0.0191***	0.0463***	0.0603***
	(0.0030)	(0.0030)	(0.0033)	(0.0039)	(0.0037)	(0.0039)	(0.0044)	(0.0054)	(0.0063)
log(Population within a 2km-radius Circle)	0.0003	0.0104***	0.0189***	0.0239***	0.0297***	0.0359***	0.0395***	0.0229***	0.0327***
	(0.0015)	(0.0016)	(0.0019)	(0.0022)	(0.0022)	(0.0021)	(0.0026)	(0.0028)	(0.0042)
log(Employees within a 2km-radius Circle)	−0.0018**	−0.0014*	−0.0020*	0.0023*	0.0044***	0.0031**	−0.0012	−0.0079***	−0.0096***
	(0.0008)	(0.0009)	(0.0010)	(0.0012)	(0.0013)	(0.0012)	(0.0014)	(0.0016)	(0.0023)
Station Dummy within a 500m Grid	0.0006***	0.0011***	0.0012***	0.0013***	0.0014***	0.0013***	0.0010***	0.0009***	−0.0001
	(0.0001)	(0.0001)	(0.0001)	(0.0001)	(0.0001)	(0.0001)	(0.0001)	(0.0001)	(0.0002)
Number of Railways within a 2km-radius Circle	−0.0181***	−0.0073**	−0.0047	−0.0152***	−0.0216***	−0.0093*	0.0029	−0.0100	0.0100
	(0.0032)	(0.0033)	(0.0041)	(0.0047)	(0.0050)	(0.0050)	(0.0058)	(0.0063)	(0.0083)
log(Distance from Tokyo Station)	0.0170***	0.0345***	0.0573***	0.0869***	0.1155***	0.1507***	0.2026***	0.2743***	0.3363***
	(0.0005)	(0.0005)	(0.0007)	(0.0008)	(0.0008)	(0.0009)	(0.0011)	(0.0012)	(0.0011)
Municipality Fixed Effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Number of Observations	694,978	694,978	694,978	694,978	694,978	694,978	694,978	694,978	694,978
Pseudo R^2	0.0183	0.0290	0.0453	0.0604	0.0781	0.1143	0.1450	0.1917	0.2483

Notes: Heteroskedasticity-consistent standard errors are in parentheses. * denotes statistical significance at the 10 % level, ** at the 5 % level, and *** at the 1 % level. The parameter τ represents the τth quantile of the quantile regression.

Table E.6. Quantile Regression Estimation Results of Residential Buildings for Quasi-industrial Districts

	Dependent Variable: log(Building Height)								
	$\tau = 0.1$	$\tau = 0.2$	$\tau = 0.3$	$\tau = 0.4$	$\tau = 0.5$	$\tau = 0.6$	$\tau = 0.7$	$\tau = 0.8$	$\tau = 0.9$
Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Floor Area Ratio in Location	0.0173***	0.0339***	0.0567***	0.0856***	0.1144***	0.1462***	0.1925***	0.2542***	0.3097***
	(0.0007)	(0.0008)	(0.0010)	(0.0012)	(0.0013)	(0.0014)	(0.0016)	(0.0017)	(0.0016)
log(Population within a 2km-radius Circle)	0.0313***	0.0060	0.0182***	0.0189***	0.0222***	0.0249***	0.0337***	0.0471***	0.0495***
	(0.0049)	(0.0046)	(0.0051)	(0.0059)	(0.0057)	(0.0060)	(0.0067)	(0.0083)	(0.0105)
log(Employees within a 2km-radius Circle)	−0.0049*	0.0063**	0.0116***	0.0160***	0.0216***	0.0276***	0.0257***	0.0234***	0.0358***
	(0.0026)	(0.0027)	(0.0032)	(0.0037)	(0.0036)	(0.0036)	(0.0042)	(0.0049)	(0.0072)
Station Dummy within a 500m Grid	−0.0021	−0.0015	−0.0011	0.0036*	0.0059***	0.0039*	0.0019	−0.0038	−0.0021
	(0.0014)	(0.0014)	(0.0017)	(0.0020)	(0.0020)	(0.0020)	(0.0022)	(0.0026)	(0.0036)
Number of Railways within a 2km-radius Circle	0.0007***	0.0012***	0.0013***	0.0014***	0.0012***	0.0011***	0.0009***	0.0007***	−0.0006**
	(0.0001)	(0.0001)	(0.0002)	(0.0002)	(0.0002)	(0.0002)	(0.0002)	(0.0002)	(0.0003)
log(Distance from Tokyo Station)	−0.0147***	0.0027	0.0098	0.0060	−0.0031	0.0090	0.0184*	0.0146	0.0214
	(0.0055)	(0.0055)	(0.0068)	(0.0076)	(0.0081)	(0.0083)	(0.0094)	(0.0106)	(0.0136)
Municipality Fixed Effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Number of Observations	273,822	273,822	273,822	273,822	273,822	273,822	273,822	273,822	273,822
Pseudo R^2	0.0179	0.0291	0.0468	0.0639	0.0834	0.1207	0.1518	0.1960	0.2462

Notes: Heteroskedasticity-consistent standard errors are in parentheses. * denotes statistical significance at the 10 % level, ** at the 5 % level, and *** at the 1 % level. The parameter τ represents the τth quantile of the quantile regression.

Table F.1. Quantile Regression Estimation Results of Commercial Buildings for Category 1 & 2 Low-rise Exclusive Residential Districts

	Dependent Variable: log(Building Height)								
	$\tau = 0.1$	$\tau = 0.2$	$\tau = 0.3$	$\tau = 0.4$	$\tau = 0.5$	$\tau = 0.6$	$\tau = 0.7$	$\tau = 0.8$	$\tau = 0.9$
Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Floor Area Ratio in Location	0.0039	0.0069	0.0079	0.0123**	0.0170***	0.0249***	0.0395***	0.0467***	0.0389***
	(0.0094)	(0.0060)	(0.0055)	(0.0051)	(0.0047)	(0.0056)	(0.0058)	(0.0068)	(0.0072)
log(Population within a 2km-radius Circle)	0.0538***	0.0775***	0.0808***	0.0436***	0.0284***	0.0208***	0.0172**	0.0190**	0.0105
	(0.0200)	(0.0146)	(0.0107)	(0.0094)	(0.0073)	(0.0076)	(0.0081)	(0.0085)	(0.0106)
log(Employees within a 2km-radius Circle)	−0.0007	−0.0107	−0.0154**	−0.0183***	−0.0195***	−0.0178***	−0.0189***	−0.0255***	−0.0161**
	(0.0125)	(0.0081)	(0.0066)	(0.0054)	(0.0050)	(0.0050)	(0.0056)	(0.0060)	(0.0065)
Station Dummy within a 500m Grid	0.0201**	0.0062	0.0010	0.0024	0.0073	0.0112**	0.0121**	0.0131**	0.0158***
	(0.0080)	(0.0052)	(0.0046)	(0.0046)	(0.0045)	(0.0046)	(0.0048)	(0.0053)	(0.0056)
Number of Railways within a 2km-radius Circle	0.0024***	0.0013***	0.0008*	0.0010**	0.0011***	0.0015***	0.0019***	0.0023***	0.0015***
	(0.0008)	(0.0005)	(0.0004)	(0.0004)	(0.0004)	(0.0004)	(0.0004)	(0.0005)	(0.0004)
log(Distance from Tokyo Station)	0.0253	0.0524**	0.0274	−0.0118	−0.0443***	−0.0585***	−0.0622***	−0.0718***	−0.0319*
	(0.0345)	(0.0218)	(0.0170)	(0.0151)	(0.0140)	(0.0144)	(0.0162)	(0.0191)	(0.0194)
Municipality Fixed Effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Number of Observations	24,687	24,687	24,687	24,687	24,687	24,687	24,687	24,687	24,687
Pseudo R^2	0.1431	0.0690	0.0281	0.0206	0.0218	0.0257	0.0315	0.0411	0.0478

Notes: Heteroskedasticity-consistent standard errors are in parentheses. * denotes statistical significance at the 10 % level, ** at the 5 % level, and *** at the 1 % level. The parameter τ represents the τth quantile of the quantile regression.

Table F.2. Quantile Regression Estimation Results of Commercial Buildings for Category 1 and 2 Medium-to-high-rise Exclusive Residential Districts

	Dependent Variable: log(Building Height)								
Variables	$\tau = 0.1$ (1)	$\tau = 0.2$ (2)	$\tau = 0.3$ (3)	$\tau = 0.4$ (4)	$\tau = 0.5$ (5)	$\tau = 0.6$ (6)	$\tau = 0.7$ (7)	$\tau = 0.8$ (8)	$\tau = 0.9$ (9)
Floor Area Ratio in Location	0.0299***	0.0337***	0.0362***	0.0462***	0.0563***	0.0750***	0.0840***	0.0750***	0.0839***
	(0.0066)	(0.0050)	(0.0049)	(0.0054)	(0.0056)	(0.0053)	(0.0059)	(0.0066)	(0.0072)
log(Population within a 2km-radius Circle)	0.1070***	0.0734***	0.0402***	0.0317***	0.0331***	0.0352***	0.0289**	0.0135	0.0179
	(0.0187)	(0.0150)	(0.0109)	(0.0104)	(0.0111)	(0.0120)	(0.0119)	(0.0116)	(0.0137)
log(Employees within a 2km-radius Circle)	−0.0104	0.0088	−0.0049	−0.0046	−0.0060	−0.0007	0.0053	0.0094	0.0134
	(0.0110)	(0.0082)	(0.0069)	(0.0071)	(0.0074)	(0.0081)	(0.0077)	(0.0074)	(0.0105)
Station Dummy within a 500m Grid	0.0105	0.0131***	0.0097**	0.0126**	0.0216***	0.0226***	0.0155***	0.0168***	0.0188***
	(0.0065)	(0.0046)	(0.0046)	(0.0051)	(0.0057)	(0.0056)	(0.0050)	(0.0053)	(0.0070)
Number of Railways within a 2km-radius Circle	0.0021***	0.0009**	0.0013***	0.0014***	0.0017***	0.0014***	0.0008**	0.0006	0.0004
	(0.0005)	(0.0004)	(0.0004)	(0.0004)	(0.0004)	(0.0004)	(0.0004)	(0.0004)	(0.0005)
log(Distance from Tokyo Station)	0.0335	0.0546***	0.0225	0.0209	0.0167	0.0111	0.0023	−0.0095	0.0147
	(0.0233)	(0.0178)	(0.0155)	(0.0160)	(0.0188)	(0.0189)	(0.0177)	(0.0172)	(0.0218)
Municipality Fixed Effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Number of Observations	31,275	31,275	31,275	31,275	31,275	31,275	31,275	31,275	31,275
Pseudo R^2	0.1062	0.0589	0.0640	0.0773	0.0891	0.0916	0.0985	0.1261	0.1335

Notes: Heteroskedasticity-consistent standard errors are in parentheses. * denotes statistical significance at the 10 % level, ** at the 5 % level, and *** at the 1 % level. The parameter τ represents the τth quantile of the quantile regression.

Table F.3. Quantile Regression Estimation Results of Commercial Buildings for Category 1 & 2 Residential Districts

	Dependent Variable: log(Building Height)								
	$\tau = 0.1$	$\tau = 0.2$	$\tau = 0.3$	$\tau = 0.4$	$\tau = 0.5$	$\tau = 0.6$	$\tau = 0.7$	$\tau = 0.8$	$\tau = 0.9$
Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Floor Area Ratio in Location	0.0314***	0.0375***	0.0507***	0.0781***	0.1028***	0.1073***	0.1179***	0.1333***	0.1410***
	(0.0054)	(0.0039)	(0.0043)	(0.0048)	(0.0053)	(0.0054)	(0.0055)	(0.0061)	(0.0069)
log(Population within a 2km-radius Circle)	0.0404**	−0.0118	−0.0289***	−0.0301***	−0.0099	−0.0028	−0.0162	−0.0248*	−0.0242
	(0.0167)	(0.0118)	(0.0110)	(0.0114)	(0.0122)	(0.0126)	(0.0126)	(0.0144)	(0.0197)
log(Employees within a 2km-radius Circle)	0.0253**	0.0278***	0.0254***	0.0156*	−0.0039	−0.0023	0.0131	0.0081	0.0023
	(0.0123)	(0.0091)	(0.0090)	(0.0089)	(0.0092)	(0.0094)	(0.0094)	(0.0107)	(0.0135)
Station Dummy within a 500m Grid	0.0111*	0.0112**	0.0144***	0.0172***	0.0165***	0.0112**	0.0022	0.0011	−0.0016
	(0.0060)	(0.0047)	(0.0049)	(0.0053)	(0.0056)	(0.0052)	(0.0054)	(0.0063)	(0.0072)
Number of Railways within a 2km-radius Circle	−0.0006	−0.0006	−0.0003	−0.0003	0.0001	0.0004	0.0003	0.0008	0.0017***
	(0.0005)	(0.0004)	(0.0004)	(0.0004)	(0.0004)	(0.0004)	(0.0004)	(0.0005)	(0.0006)
log(Distance from Tokyo Station)	−0.0423**	−0.0377**	−0.0429***	−0.0606***	−0.0633***	−0.0285	−0.0245	−0.0345*	−0.0291
	(0.0200)	(0.0158)	(0.0151)	(0.0169)	(0.0184)	(0.0175)	(0.0174)	(0.0201)	(0.0256)
Municipality Fixed Effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Number of Observations	32,763	32,763	32,763	32,763	32,763	32,763	32,763	32,763	32,763
Pseudo R^2	0.0691	0.0566	0.0724	0.0925	0.0999	0.1106	0.1396	0.1539	0.1831

Notes: Heteroskedasticity-consistent standard errors are in parentheses. * denotes statistical significance at the 10 % level, ** at the 5 % level, and *** at the 1 % level. The parameter τ represents the τth quantile of the quantile regression.

Table F.4. Quantile Regression Estimation Results of Commercial Buildings for Quasi-residential Districts

	Dependent Variable: log(Building Height)								
	$\tau = 0.1$	$\tau = 0.2$	$\tau = 0.3$	$\tau = 0.4$	$\tau = 0.5$	$\tau = 0.6$	$\tau = 0.7$	$\tau = 0.8$	$\tau = 0.9$
Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Floor Area Ratio in Location	0.0636**	0.0315	0.0341*	0.0159	0.0185	0.0240	0.0251	0.0336	0.0756**
	(0.0278)	(0.0226)	(0.0182)	(0.0169)	(0.0171)	(0.0177)	(0.0185)	(0.0204)	(0.0300)
log(Population within a 2km-radius Circle)	0.1043	0.2091**	0.0717	0.0479	0.0086	−0.0078	−0.0106	−0.0190	−0.1591*
	(0.0709)	(0.0944)	(0.0590)	(0.0510)	(0.0500)	(0.0501)	(0.0518)	(0.0562)	(0.0846)
log(Employees within a 2km-radius Circle)	−0.0009	−0.0114	−0.0006	−0.0005	0.0124	0.0398	0.0251	0.0324	0.0739
	(0.0535)	(0.0566)	(0.0350)	(0.0308)	(0.0303)	(0.0297)	(0.0293)	(0.0315)	(0.0501)
Station Dummy within a 500m Grid	0.0746*	0.0675*	0.0516	0.0463	0.0525*	0.0433	0.0210	0.0294	0.0311
	(0.0427)	(0.0392)	(0.0316)	(0.0313)	(0.0316)	(0.0312)	(0.0310)	(0.0376)	(0.0620)
Number of Railways within a 2km-radius Circle	0.0010	−0.0028	−0.0016	−0.0006	−0.0001	−0.0022	−0.0021	−0.0013	−0.0008
	(0.0036)	(0.0035)	(0.0026)	(0.0025)	(0.0027)	(0.0029)	(0.0033)	(0.0035)	(0.0043)
log(Distance from Tokyo Station)	−0.0035	−0.0179	−0.0846	−0.0459	−0.1081	−0.1639*	−0.1959**	−0.1856*	−0.2906*
	(0.1226)	(0.1437)	(0.0989)	(0.0903)	(0.0921)	(0.0968)	(0.0976)	(0.1029)	(0.1564)
Municipality Fixed Effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Number of Observations	3,793	3,793	3,793	3,793	3,793	3,793	3,793	3,793	3,793
Pseudo R^2	0.1253	0.0882	0.0689	0.0765	0.0865	0.0932	0.1121	0.1322	0.1414

Notes: Heteroskedasticity-consistent standard errors are in parentheses. * denotes statistical significance at the 10 % level, ** at the 5 % level, and *** at the 1 % level. The parameter τ represents the τth quantile of the quantile regression.

Table F.5. Quantile Regression Estimation Results of Commercial Buildings for Neighborhood Commercial and Commercial Districts

	Dependent Variable: log(Building Height)								
	$\tau = 0.1$	$\tau = 0.2$	$\tau = 0.3$	$\tau = 0.4$	$\tau = 0.5$	$\tau = 0.6$	$\tau = 0.7$	$\tau = 0.8$	$\tau = 0.9$
Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Floor Area Ratio in Location	0.0252***	0.0549***	0.0813***	0.1056***	0.1286***	0.1469***	0.1625***	0.1783***	0.1943***
	(0.0013)	(0.0014)	(0.0015)	(0.0015)	(0.0015)	(0.0014)	(0.0014)	(0.0016)	(0.0019)
log(Population within a 2km-radius Circle)	−0.0352***	−0.0762***	−0.0725***	−0.0574***	−0.0505***	−0.0307***	0.0069	0.0482***	0.0679***
	(0.0086)	(0.0085)	(0.0088)	(0.0087)	(0.0086)	(0.0079)	(0.0084)	(0.0084)	(0.0100)
log(Employees within a 2km-radius Circle)	0.0127***	0.0447***	0.0715***	0.0722***	0.0727***	0.0741***	0.0857***	0.0980***	0.1117***
	(0.0048)	(0.0053)	(0.0060)	(0.0064)	(0.0062)	(0.0057)	(0.0059)	(0.0066)	(0.0078)
Station Dummy within a 500m Grid	−0.0048*	−0.0004	0.0022	0.0040	0.0075**	0.0042	0.0081***	0.0136***	0.0174***
	(0.0025)	(0.0027)	(0.0030)	(0.0031)	(0.0031)	(0.0030)	(0.0030)	(0.0032)	(0.0037)
Number of Railways within a 2km-radius Circle	0.0020***	0.0024***	0.0013***	0.0008***	0.0002	0.0000	−0.0004	−0.0010***	−0.0022***
	(0.0002)	(0.0003)	(0.0003)	(0.0003)	(0.0003)	(0.0002)	(0.0002)	(0.0002)	(0.0002)
log(Distance from Tokyo Station)	−0.0003	0.0247**	0.0121	0.0050	−0.0094	−0.0021	0.0139	0.0247***	0.0235**
	(0.0096)	(0.0105)	(0.0110)	(0.0106)	(0.0105)	(0.0101)	(0.0091)	(0.0096)	(0.0114)
Municipality Fixed Effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Number of Observations	151,896	151,896	151,896	151,896	151,896	151,896	151,896	151,896	151,896
Pseudo R^2	0.0449	0.0873	0.1248	0.1608	0.1870	0.2208	0.2550	0.2833	0.2752

Notes: Heteroskedasticity-consistent standard errors are in parentheses. * denotes statistical significance at the 10 % level, ** at the 5 % level, and *** at the 1 % level. The parameter τ represents the τth quantile of the quantile regression.

Table F.6. Quantile Regression Estimation Results of Commercial Buildings for Quasi-industrial Districts

	Dependent Variable: log(Building Height)								
Variables	$\tau = 0.1$ (1)	$\tau = 0.2$ (2)	$\tau = 0.3$ (3)	$\tau = 0.4$ (4)	$\tau = 0.5$ (5)	$\tau = 0.6$ (6)	$\tau = 0.7$ (7)	$\tau = 0.8$ (8)	$\tau = 0.9$ (9)
Floor Area Ratio in Location	0.0056	0.0243***	0.0401***	0.0617***	0.0817***	0.0817***	0.0962***	0.1084***	0.1239***
	(0.0067)	(0.0043)	(0.0044)	(0.0051)	(0.0050)	(0.0055)	(0.0063)	(0.0062)	(0.0085)
log(Population within a 2km-radius Circle)	0.1488***	0.0743***	0.0315***	0.0221**	0.0112*	0.0201***	0.0050	−0.0438	−0.1157***
	(0.0164)	(0.0211)	(0.0118)	(0.0111)	(0.0063)	(0.0061)	(0.0079)	(0.0328)	(0.0411)
log(Employees within a 2km-radius Circle)	−0.0178	0.0364***	0.0255**	0.0286***	0.0284***	0.0295***	0.0328***	0.0501***	0.0928***
	(0.0167)	(0.0138)	(0.0113)	(0.0106)	(0.0103)	(0.0113)	(0.0109)	(0.0154)	(0.0198)
Station Dummy within a 500m Grid	0.0018	−0.0039	−0.0118**	−0.0144**	−0.0151**	−0.0182***	−0.0107	−0.0036	−0.0020
	(0.0068)	(0.0054)	(0.0055)	(0.0062)	(0.0069)	(0.0065)	(0.0069)	(0.0078)	(0.0096)
Number of Railways within a 2km-radius Circle	0.0016**	−0.0002	0.0007	0.0015**	0.0013**	0.0016***	0.0032***	0.0030***	0.0030***
	(0.0007)	(0.0006)	(0.0006)	(0.0006)	(0.0006)	(0.0006)	(0.0006)	(0.0006)	(0.0008)
log(Distance from Tokyo Station)	−0.1518***	−0.1246***	−0.1687***	−0.1771***	−0.1968***	−0.1763***	−0.1527***	−0.1512***	−0.1515***
	(0.0291)	(0.0240)	(0.0219)	(0.0226)	(0.0236)	(0.0237)	(0.0243)	(0.0270)	(0.0348)
Municipality Fixed Effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Number of Observations	28,141	28,141	28,141	28,141	28,141	28,141	28,141	28,141	28,141
Pseudo R^2	0.0831	0.0499	0.0626	0.0815	0.0905	0.1031	0.1234	0.1271	0.1464

Notes: Heteroskedasticity-consistent standard errors are in parentheses. * denotes statistical significance at the 10 % level, ** at the 5 % level, and *** at the 1 % level. The parameter τ represents the τth quantile of the quantile regression.