Land Price Fluctuations, Commercial-Residential Segregation, and Gentrification

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Abstract

By examining the impact of a real estate bubble on residential distribution in Tokyo and Osaka, we show that land price fluctuations influence the residential location choice within a metropolitan area. During a period of rising land prices, land developers favor commercial development over residential use in the central city, thereby increasing the daytime population while decreasing the residential population there. Thus, commercial-residential segregation is intensified. In a downturn period, however, with the shrinking demand for commercial space, homes are favored by land developers. Hence, gentrification occurs as an unintended consequence of this endogenous conversion of the land-use pattern.

Keywords: gentrification; real estate bubble; land-use pattern; housing policy
JEL codes: R23; R31; H44

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1 Introduction

The share of the central city population in the major metropolitan areas (MAs) of the United States fell significantly in the second half of the 20th century. This situation has been attributed to factors, such as the increases in car-use and highway construction (LeRoy and Sonstelie, 1983; Baum-Snow, 2007; Garcia-López, 2010), housing capital depreciation and filtering down (Glaeser and Gyourko, 2005; Rosenthal, 2008; Brueckner and Rosenthal, 2009), racial residential segregation (Boustan and Margo, 2013), and issues in coordinating redevelopment (Rosenthal and Ross, 2015; Brooks and Lutz, 2016; Owens III et al., 2019).

After 2000, however, the residential distribution reversed in some urban areas. Population, as well as the relative income and the proportion of college graduates, were found to grow again in the central neighborhoods of US MAs and select European cities like London and Barcelona, thus forming an increasingly polarized urban spatial structure. The observed gentrification is argued to be associated with a new round of neighborhood housing cycles or neighborhood externalities (Brueckner and Rosenthal, 2009; Guerrieri et al., 2013), an increasing desire to save commuting time and enjoy the non-tradable amenities in the central city (Hamnett, 2003; McKinnish et al., 2010; Couture and Handbury, 2017; Lee and Lin, 2018; Su, 2019), changing labor market opportunities across locations (Baum-Snow and Hartley, 2020), and policies on urban renewal and environmental justice (Gamper-Rabindran and Timmins, 2011; González-Pampillón et al., 2019).[1]

Despite the above studies, research on this issue is far from conclusive. By exploiting a real estate bubble that occurred in the major MAs of Japan as a source of variation, we present the first evidence of a mechanism where price fluctuations in the real estate market act as a determinant of gentrification within an MA through land-use conversion. This real estate bubble, beginning from the early 1980s and collapsing in the early 1990s, was among the most aggressive in the history of Japan's urban development. Violent property price fluctuations mainly occurred in a relatively short period (one decade), thereby ensuring that the demographic pattern and infrastructure construction that may affect intra-MA population dynamics remained practically unchanged. This situation allows us to clearly identify the causal effects of land price fluctuations on the dynamics of residential location.

The key idea behind our study is that central cities are likely to be dominated by buildings for commercial use when the economy is in an upswing. Meanwhile, during the economic downturn, land development will relatively shift from commercial toward residential construction. There are theory-based reasons for the two aspects. First, housing rent is more inelastic than office and commercial rent in the central cities. That is, the price elasticity of demand is more elastic for residential lands than commercial lands. Second, land price elasticity of a building's height is smaller for residential than for commercial buildings because the elasticity of substitution between

[1] In addition, Boustan et al. (2019) investigate whether a massive housing investment in the form of high-rise condominium towers has contributed to the gentrification of a city. They find that the condominium development has no causal impact on the resident income, although they are positively correlated.

land and capital is smaller. That is, in the central cities with increasing land prices, developers tend to raise building heights to exploit the value of space in the sky fully. Commercial buildings are, in turn, preferred over residential buildings and housing supply is condensed in central cities when there is a real estate bubble, thus intensifying commercial-residential segregation. In contrast, housing supply is increased in the case of declining land prices, thereby encouraging residential recentralization.

We examine whether this conversion of land development strategy will affect housing supply and, in turn, residential location choice by comparing the central city population growth performance to that of the surrounding areas before, during, and after the bubble period. The non-central surrounding areas are taken as the comparison group because their land price changes during the bubble period were much less significant. Therefore, the land-use pattern was less responsive to this event. Our analyses are based on nearly 300 urban municipalities in the Tokyo and Osaka MAs (the two largest MAs of the country, covering nearly half of the country's population) in the 1980–2017 period. The city of Tokyo (Osaka) is the central city of the Tokyo (Osaka) MA.

Prior to the empirical analysis, we first illustrate our ideas with prominent stylized facts. We find that commercial land prices in the central cities did rose (fell) much faster than those of residential lands during the period of the bubble economy (bubble burst). Thus, central city housing construction was limited (expanded). Consistently, the residential population of central cities declined in the price-surging period but grew significantly after the bubble burst. In contrast, daytime population, which reflects the density of commercial activities, first grew and then shrank in the central cities.[2] [Unless otherwise specified, the population mentioned in the paper refers to the residential (or nighttime) population.]

Our empirical analyses proceed as follows. First, using a cross-section regression, we demonstrate that municipalities with land use that is more dominated by commercial activities during the bubble period (proxied by a lower nighttime population relative to the daytime population in 1990) show more significant residential growth in the subsequent two decades. This result remains after controlling for the initial population density and distance from the central business district (CBD) of the MA. The pattern suggests that the faster population growth in these areas might have been associated with a more intensive land-use conversion toward housing development after the bubble burst. Second, we examine the robustness of the initial result using a within municipality estimator and a larger sample. Third, our results are further confirmed by using an alternative measure of the explanatory variable, controlling a set of time-varying confounding factors (which are potentially associated with population growth but not captured by the standard two-way fixed effects) and regressing for a sub-sample (which is more likely to be involved in the residential location choice behavior within the central city commuter zone).

We are also concerned about the issue of reverse causality. Land-use conversion and housing construction boom in the central cities, which were induced by the bubble burst, likely impact population growth. Meanwhile, the reverse is also possible. To address

[2] Daytime population is calculated as follows: nighttime population + the influx of commuters and students from other areas − the outflow of commuters and students to other areas.

this issue, we consider the impacts of the housing construction boom by examining the population growth with a time lag. We find that the population growth of a municipality in year t is positively related to its scale of housing starts in t–3, t–2, and t–1. However, the population growth in the past three years does not significantly predict the current intensity of housing starts. Therefore, gentrification in the central cities might have been triggered by the observed post-bubble housing boom, not the reverse. Finally, advances in transportation technology and policies associated with land-use regulation could, in principle, impact residential location choice. To rule out these possibilities, we check the related information and find they are largely unchanged during the study period.

We next provide extended results regarding the changes in the housing structure. High-rise condominiums dominate the new housing supply during the central city housing boom. Meanwhile, the proportion of commercial buildings in the central cities regarding the completion of new high-rise buildings has declined significantly. Moreover, new housing in the central cities was increasingly concentrated in large-sized "built-to-sell" dwelling units (70–100 m^2 in floor area), while most housing starts in the bubble period were for small "built-to-rent" homes (40–60 m^2). This situation is in line with the growing relative income of residents in the central cities accompanied by gentrification.

Given these results, we conclude that land price fluctuations impacted land-use patterns (for residential or commercial development), which is associated with the housing supply in related areas. The latter, in turn, affected population growth. This conclusion explains the recent gentrification in the central cities of the Tokyo and Osaka MAs. This study contributes to the literature in two aspects. First, we are evidently the first to explain the origin of gentrification from the perspective of land price fluctuations and endogenous land-use conversion. This supply-side explanation differs from the existing literature, which employs a demand-side perspective, such as the changes in the locations of employment opportunities and residents' preference, or posits that gentrification is the consequence of an exogenous community revitalization policy. Second, our study extends the research on gentrification by focusing on two typical Asian mega-cities; existing studies mainly focus on relatively smaller cities in North America and Europe. As stated by Brueckner et al. (1999) and Tabuchi (2019), residential locations in the major US MAs, Paris, and Tokyo are systematically different: the rich and poor colocate in the central areas of Tokyo, whereas the poor (rich) are concentrated in the central locations of US MAs (Paris). This situation implies that the mechanism of gentrification might also be different across city forms.

The remainder of this paper is organized as follows. Section 2 presents the background information. Section 3 introduces the hypothesis and stylized facts. Sections 4 and 5 detail the empirical results and additional discussion, respectively. Section 6 concludes with policy implications.

2 Background information

2.1 Demographic pattern of the Tokyo and Osaka MAs

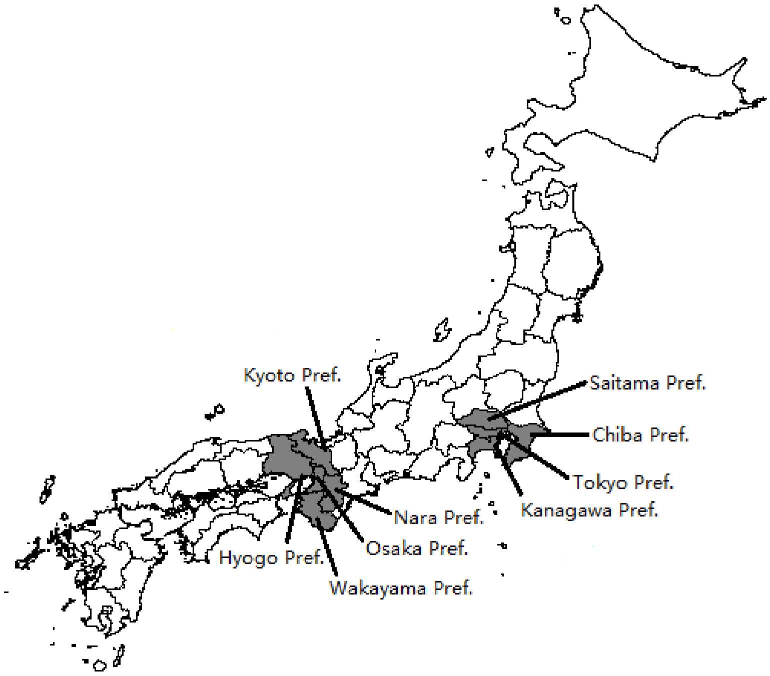


Figure 1: The locations of the Tokyo and Osaka MAs.

Major MAs tend to experience more significant land price fluctuations than small city areas during a bubble period, and land supply tends to be tighter and more sensitive to land price changes. We, therefore, focus our analysis on the two largest Japanese MAs (Tokyo and Osaka), which include nine out of the 47 prefectures of the country (see Figure 1).[3] They include 44.6% of Japan's population (as of 2015), although the land area is only 8.9% of the total. The economic agglomeration in the cities of Tokyo and Osaka is even more extensive; they account for only 0.6% of the country's total land while accommodating 9.4% of the residential population and absorbing 11.0% of the daytime population in 2015. Therefore, by studying these two MAs, we can systematically evaluate the gentrification process, if any, in Japan's densely populated urban areas.[4]

The Tokyo and Osaka MAs are both highly polarized; the densest municipalities are located closer to central Tokyo or Osaka (Figure 2). To measure the inter-MA population

[3] The Tokyo MA includes four prefectures: Tokyo, Kanagawa, Chiba, and Saitama. The Tokyo prefecture comprises the city of Tokyo and the surrounding municipality-level cities, towns, and villages that are economically and socially integrated with it. The city of Tokyo consists of 23 municipality-level wards. The Osaka MA includes five prefectures: Osaka, Kyoto, Hyogo, Nara, and Wakayama. The Osaka prefecture comprises the city of Osaka and dozens of municipality-level administrative units. The city of Osaka consists of 24 municipality-level wards.

[4] In 1990, there were 55 municipality-level wards and cities with a population density greater than 10,000 persons per km^2 in Japan, within which 29 are in the Tokyo MA, and the remaining 26 are in the Osaka MA.

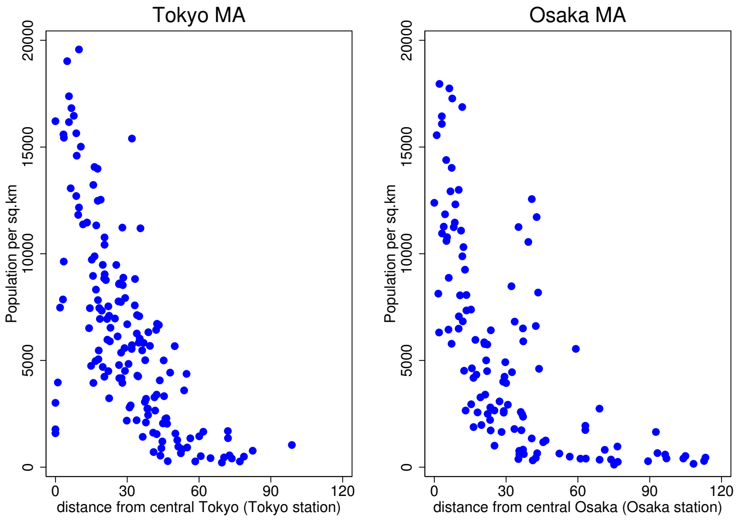


Figure 2: Population density relative to the distance from the central city.

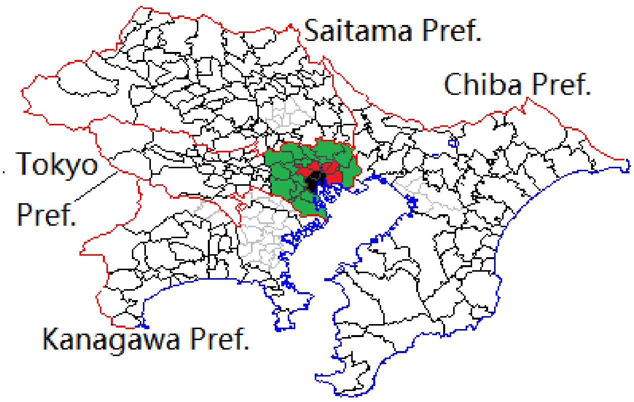
Notes: See data sources in Table A1.

dynamics, we further define a hierarchical structure with multiple levels of centrality. Regarding the Tokyo MA, the first level is the entire MA (34.0 million residents in 2005), the second is the city of Tokyo (8.3 million), and the third (fourth) is the eight (three) central municipality-level wards of Tokyo city, with a residential population of 1.6 (0.3) million (see their locations in Figure 3a). The eight central wards are generally regarded as the CBDs of Tokyo, among which the three central wards (Chiyoda, Chuo, and Minato) have the highest density of commercial activities. The hierarchical structure of the Osaka MA is analogous. The first level is the entire MA (19.3 million residents in 2005), the second is the city of Osaka (2.5 million), and the third is the three central wards of Osaka city (200,000 residents; Kita, Chuo, and Nishi) (Figure 3b). Note that Osaka city is much smaller in both land area and population size than Tokyo city; its CBD is, therefore, relatively smaller.

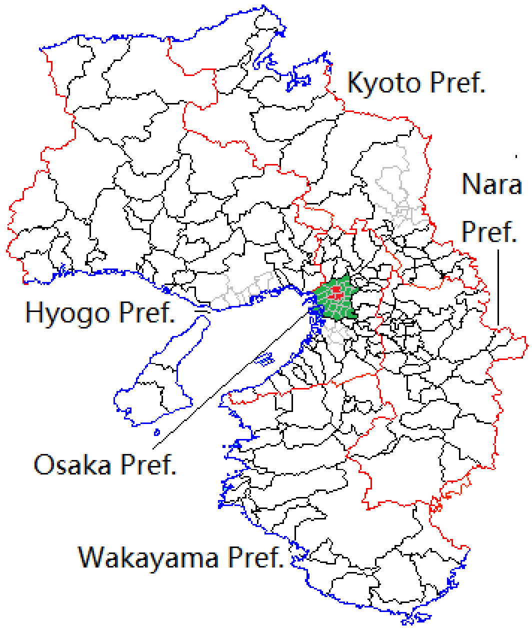
2.2 The real estate market of Japan, 1980–2017

Japan witnessed a bubble in the real estate market (which also involved other sectors) in the 1980s. Regardless of the approach used to calculate the price index, average land prices in Japan doubled in the period of 1980 to 1990; the main property appreciation occurred in its major MAs. Subsequently, the real estate bubble collapsed. By 2017, the land prices in Japan had not yet recovered to its early-1990s peak when the bubble burst. The causes of the bubble and its burst have been carefully studied in various streams of literature and have been attributed to the over-relaxed macroeconomic policy and external economic shocks (e.g., the Yen appreciation following the 1985 Plaza Accord); for more details, see, for example, Kanemoto (1997) and Nakamura and Saita (2007).

The left panel of Figure 4 shows the land prices by commercial and residential use for the six largest cities in the 1980–2017 period, and the right panel shows the city of



(a) The Tokyo MA



(b) The Osaka MA

Figure 3: The hierarchical structure of the Tokyo and Osaka MAs.

Notes: (a): The zoomed view of the Tokyo MA. The black area indicates the three central wards of Tokyo city, the area marked red (plus the three central wards) indicates the eight central wards, and the area marked green (plus the eight central wards) indicates the city of Tokyo (622 km^2). (b): The zoomed map of the Osaka MA. The area marked red indicates the three central wards of Osaka city, and the green area (plus the three central wards) indicates the city of Osaka (223 km^2). The red lines are prefectural boundaries, the blue lines are coastal lines, and the black (gray) lines are municipality-level city/town/village (ward) boundaries.

Tokyo.[5] In each group of samples, land prices increased dramatically in the 1980s. For instance, commercial land prices in the city of Tokyo increased seven-fold between 1980 and 1990.

Dramatic fluctuations in land prices have affected the frequency of land transactions. As presented in Figure 5, the number of land transactions decreased nationwide (as well as in Tokyo; historical data for Osaka are not available) in the 1980s. This event was partially because the landlords expected that their assets in hand would appreciate further (Nakamura and Saita, 2007). The number of house tenure also decreased in this period; the pattern was further magnified in major cities. According to Hirayama (2005, 2006), which summarized the number of first-time homebuyers in Japan from 1979 through 1998, 2,050,000 households moved from rental to owned homes nationwide (185, 000 for the city of Tokyo) during the 1979–1983 period. The subsequent jump in housing prices reduced this number to 1,736,000 and 1,659,000 during the 1984–1988 and 1989–1993 periods, respectively (147,000 and 107,000 for the city of Tokyo).

[5] "*Land price index for the six largest cities*" is a widely used indicator reflecting the trend of Japanese real estate prices. The six largest cities are Tokyo, Osaka, Yokohama, Kobe, Kyoto, and Nagoya, of which five are included in the Tokyo and Osaka MAs (except for Nagoya). Historical data for city-level land price index are not readily available; we show the related data for the city of Tokyo only, which are estimated by Shimizu and Nishimura (2007) using land transaction data.

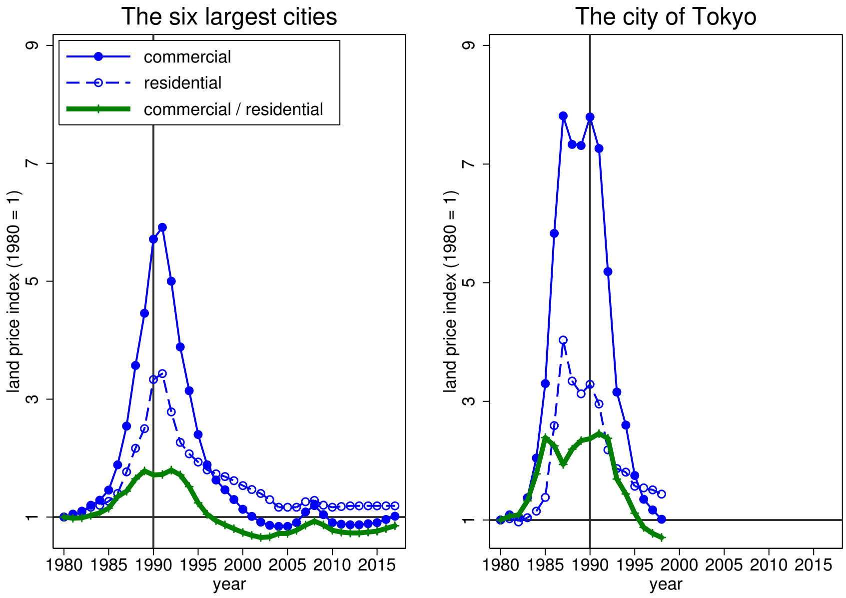


Figure 4: Land price fluctuations in the major urban areas of Japan.

Notes: Data for the six largest cities are obtained from the CEIC DATA, which report the average land prices in these cities in July of each year (updated to 2002), and the Japanese Real Estate Statistics 2019, released by the Mitsui Fudosan Co.,Ltd. (Planning and Research Department) (data of the 2003–2017 period). Data for the city of Tokyo are obtained from Shimizu and Nishimura (2007), which are only available for the 1980–1998 period. The residential land price index is estimated based on the land transactions in the Setagaya ward of Tokyo city, and the commercial land price index is estimated based on its three central wards.

Nevertheless, after the downturn of property prices, the number of land transactions in Tokyo city and the Tokyo MA increased, although it continued to decrease nationwide (Figure 5). The number of house tenures also rebounded to 2,124,000 for the entire country during the 1994–1998 period (198,000 for the city of Tokyo) (Hirayama, 2005). Thus, Tokyo witnessed a housing construction boom after the bubble burst, which will be formally discussed later.

The commercial and residential land markets have notably exhibited different price fluctuations during and after the bubble. In both plots of Figure 4, the appreciation of the commercial land is much more significant than that of residential land during the bubble period. That is, the capital gain is disproportionately larger for the former. Consistently, as described in Shimizu et al. (2010), office buildings and commercial facilities were intensively constructed in Japanese central cities during the bubble period, and small houses and land were intensively bundled for office building development under strong expectations of surging office rents (by contrast, housing rent is subject to strict rent control). According to Oizumi (1994), in the city of Tokyo, the share of office in the total floor area of buildings for all uses increased from 11% in 1972 to 16% in 1990; in its three central wards, this figure increased from 44% to 56%.

However, after the bubble burst, commercial land has experienced more significant capital losses; the price in the six largest cities (the city of Tokyo) fell to the 1980 level

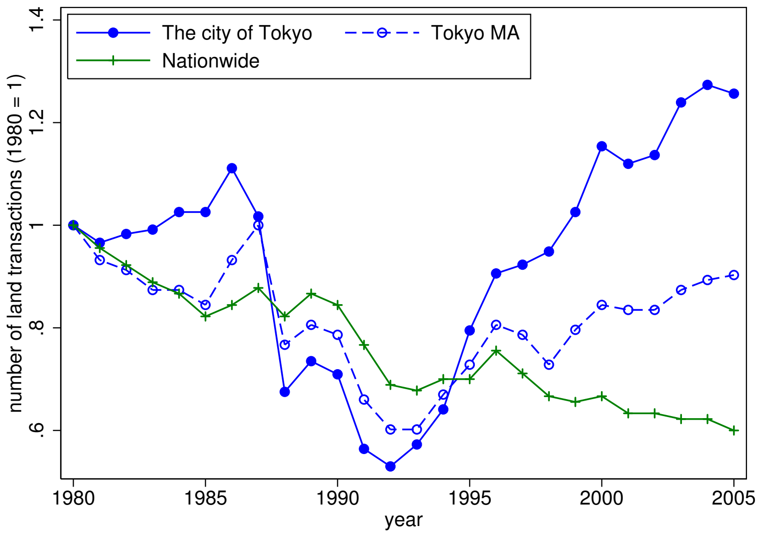


Figure 5: Number of land transactions.

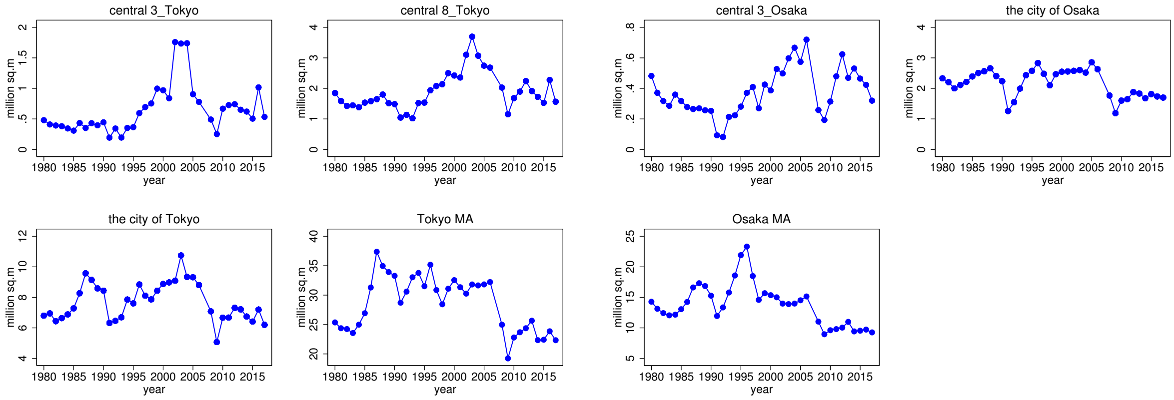
Notes: Data on the number of land transactions are obtained from Nakamura and Saita (2007), which is calculated based on the raw data reported by the Annual Report on Civil Affairs, Litigations, and Human Rights, the Ministry of Justice.

in 2001 (1998) (Figure 4), whereas residential land maintained a capital return of 47% (44%) (taking the 1980 price as a benchmark). That is, the demand for commercial buildings, as well as prices, fell more than those for homes after the bubble burst (see the green lines of Figure 4), which implies higher comparative returns from residential development.

The scale of housing construction in the Tokyo and Osaka MAs responded to the land price fluctuations.[6] Figure 6 shows the number of housing starts in our sample areas. The MA-level scales of housing starts before and after the bubble burst are comparable. Although the number of housing starts exhibited a sharp drop in the period of 1990 to 1992, it quickly recovered. Nevertheless, once we focus on the central cities, especially on the CBDs, we find that there was a housing construction boom after the bubble burst (relative to the bubble period).

The yearly housing starts stabilized below 500,000 m^2 in the three central wards of Tokyo during the 1980–1994 period, however, this figure soared rapidly to 1.7 million in the 1994–2002 period (Figure 6). The proportion of housing starts (in m^2) of the three (eight) central wards of Tokyo in the total housing starts of the entire city was below 5% (20%) in the bubble period (left panel of Figure 7). However, it quickly jumped to approximately 19% (34%) in the early 2000s. Similarly, the proportion of housing starts in the city of Tokyo regarding the entire Tokyo MA increased. The right panel of Figure 7 displays the patterns for Osaka, which are analogous. The proportion of Tokyo (Osaka) city's residential buildings in the total floor area of building starts has been rising (i.e., the share of commercial and office buildings declined) since the collapse of

[6]New homes dominate the housing market of Japan because existing homes are discriminated against in the mortgage market, and homebuyers prefer them less; for more details, see Kobayashi (2016).



(a) The Tokyo MA (b) The Osaka MA

Figure 6: Number of housing starts.

Notes: See data sources in Table A1. Data for 2007 are missing.

the real estate bubble (Hirayama, 2005; see for more details in Section 5).

3 Hypothesis and stylized facts

Based on the background information, we propose a theory-based testable hypothesis regarding the impacts of land price fluctuations on residential location choice to guide our empirical analysis.

During the bubble economy, the density of business activity increased rapidly in Tokyo and Osaka due to the large inflows of capital and employment. This situation may have led to a strong tendency for business activities to be concentrated in their CBDs, which can be explained by two mechanisms. First is the well-known agglomeration economies in production, as illustrated in the classic urban economics literature, such as Fujita and Ogawa (1982) and Lucas and Rossi-Hansberg (2002). Second is a supply-side factor that was recently introduced by Ahlfeldt and McMillen (2018); they find that land price elasticity of building height is smaller for residential than for commercial buildings because the elasticity of substitution between land and capital is smaller.[7] Thus, in the case that land price increases and land developers make the buildings

[7]Since unit construction costs increase with building height, there exists a correspondence between land price and building height. As land price increases, land developers tend to make the buildings higher. Using historical building height and land price data on Chicago, Ahlfeldt and McMillen (2018) find that it is more difficult to compensate residents than office users for the limited access to private and communal exterior space, thereby making high-rise buildings more preferable for office uses than for residents. Moreover, the building height elasticity of construction cost is larger for residential buildings. The cost of height is higher for residential than for commercial buildings due to notable differences in the design of buildings. That is, the losses of usable floor space as building height increases are different; for more details, see Ahlfeldt and McMillen (2018). Moreover, Koster et al. (2013) suggest that office rents are higher for high-rise buildings because of within-building agglomeration economies, landmarks, and view effects. Liu et al. (2018) further find that high-productivity companies are located higher up in high-rise office buildings; less productive offices are further down.

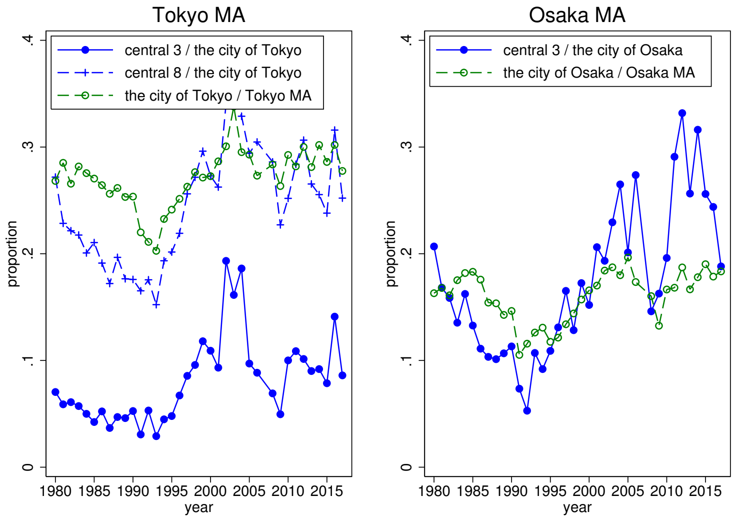


Figure 7: Housing construction intensity in the central locations.

Notes: See data sources in Table A1. Data for 2007 are missing.

taller, construction for office uses are preferable to for residential use.

The facts justify these two mechanisms, as discussed previously. That is, there was a stronger price appreciation in commercial land than in residential land in the central cities during the bubble period, and housing development was restrained. By contrast, commercial land experienced a disproportionate capital loss (relative to residential land) in the period of market decline, and housing development was expanded (as in Figures 4–6).[8] Moreover, the changes in office and housing rent also coincide with the above mechanisms. Office rents are generally higher than housing rents in Japanese urban centers (Shimizu et al., 2010). Based on a privately collected database covering more than 10,000 rent contracts in the city of Tokyo from 1991 to 2004, Shimizu et al. (2010) find that, in only a tiny number of locations in Tokyo (most are in the periphery), office rents are lower than housing rents (in an equivalent location) in 1991. However, along with the burst of the bubble economy, an increasing number of locations, even in the CBDs, exhibit lower rents for office space than for housing.

Based on the differential changes in land prices and land-use patterns, we expect that the real estate bubble and the burst might have influenced the residential distribution within an MA.[9] Our hypothesis is presented as follows: 1) *Commercial-residential segregation in the central cities would be strengthened during the period of the real estate bubble. Thus, daytime population increased in the central cities and residential decentralization occurred.* 2) *Along with the declining land prices and shrinking demand for commercial and*

[8]Aside from the proposed explanation, macroeconomic policies, such as low interest rate and tax reduction for purchasing homes, accelerated home purchases. They also contributed to the rebounding of housing development in the central cities (Hirayama, 2005).

[9]Liu et al. (2016) also estimate the within-city heterogeneity in response to a real estate bubble; they find relative prices between small and large houses were stable during the bubble period but diverged after the bubble burst (small home price index fell more). Our study differs from their work by focusing on the relative prices between residential land and commercial land.

office space after the bubble burst, there was an incentive for land developers to shift from commercial to residential land use, thus resulting in an expansion of housing supply and residential recentralization (or, gentrification).

Note that, although Japanese urban planning constraints, to some extent, prevent housing lands from being used for other purposes, no legal regulations exist that prohibit the conversion of commercial land into housing.[10] Therefore, land-use conversion is legally feasible in central city areas. The findings of Shimizu et al. (2010) can further justify this situation. They find that vacancy rates soared in many office buildings of Tokyo due to the collapse of the bubble economy; the recession prompted landlords to switch from commercial land to housing development. Furthermore, as described in Hideo (2014), after the bubble burst, many companies affected by the debt crisis had to sell their land assets that were previously used as parking lots or offices. These assets were mainly converted into high-rise condominiums.

To empirically test our hypothesis, we examine the population dynamics in central cities before and after the bubble economy. Note that the land proportion by land-use nature (e.g., residential, industrial, and commercial) is technically the most direct way to justify our hypothesis on commercial-residential segregation. However, it is practically not feasible because commercial land can easily be used for residential purposes. Therefore, we use the daytime population as a proxy for the intensity of land use for commercial activities in an area and nighttime (residential) population as a proxy for the degree of residential land use in that area. If land use in central cities is segregated (increasingly dominated by commercial use) during the bubble period, we expect the nighttime (daytime) population to shrink (increase); that is, the nighttime-to-daytime population ratio (hereafter, NDPR) declines.

Before we introduce our empirical strategy, Figure 8 displays the nighttime population growth of each hierarchy of the Tokyo and Osaka MAs from 1980 to 2017. This graph reveals many striking patterns. Although the two MAs, as a whole, exhibit solid population growth, their central locations declined significantly during the bubble period. The population size of central cities rebounded after 1995. Evidently, the population increase in central city areas has been much faster than the larger metropolitan region. Moreover, consistent with the changes in income composition that are found in existing studies on gentrification, central locations have increasingly become attractive for wealthy residents over time.[11] This situation suggests that gentrification (not a simple displacement of residents) occurred in central cities.

Figure 9 (left panel), which displays the daytime population in central cities, further demonstrates our hypothesis. The growth of the daytime population was inversely proportional to that of the nighttime population. It expanded in central locations during the 1980–1990 period but decreased after the bubble burst. Moreover, more central

[10] In some cases, a change from residential to commercial regarding land use is possible. Moreover, some housing buildings were informally used for commercial and office purposes during the bubble period because office rents were higher than housing rents (Shimizu et al., 2010).

[11] The taxable income of the residents of the three central wards of Tokyo was 1.37 times that of the city average during the 1990–1995 period. This figure increased to 1.61 in 2005 and to 1.69 in 2015. Regarding the eight central wards, it increased from 1.11 during the 1990–1995 period to 1.21 in 2015 (Data sources: The Residential Population Survey of Japan, various years).

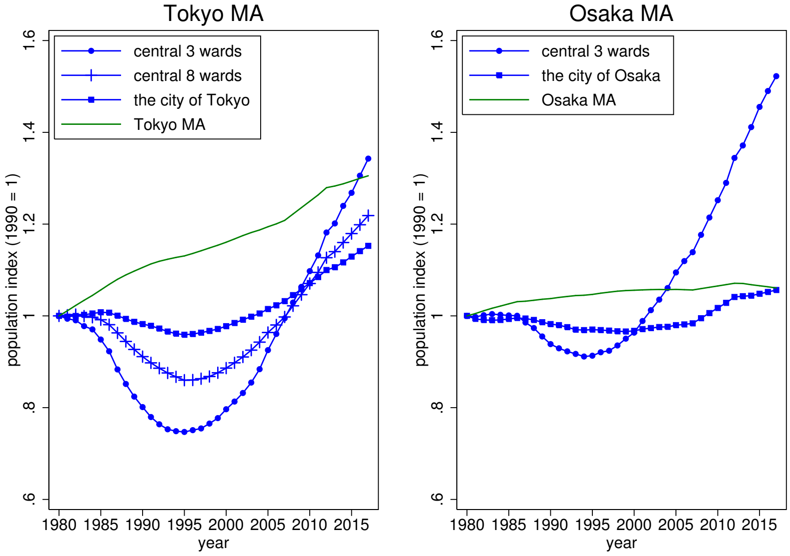


Figure 8: Residential population growth in the Tokyo and Osaka MAs.

Notes: See data sources in Table A1.

locations tend to show stronger growth during the bubble period. For example, the three central wards of Tokyo (Osaka) reached an extremely high daytime population density (63,000 (51,000) persons per km^2) in 1990 and then lost 14% (16%) of their daytime population in the subsequent two decades. Thus, NDPR first declined during the 1980–1990 period and then rebounded after 1995 (Figure 9, right panel), implying that the commercial-residential segregation in the central cities first exacerbated and then weakened.

4 Econometric specification and results

According to the stylized facts described above, we can infer that the burst of the real estate bubble was a promoter of gentrification in Tokyo and Osaka, if we are able to confirm that a causal relationship exists after controlling for the confounding factors. Note that the macroeconomic factors that triggered the bursting of the economic bubble were not affected by the gentrification process of Japanese cities. The economic bubble and the following burst also affected other sectors, such as the stock market. Therefore, the exogeneity assumption is satisfied in analyzing the impacts of the bubble burst on gentrification.

4.1 Cross-section estimates

We first examine the relationship between NDPR and post-1990 population growth using cross-sectional data at the municipality level. Land development in municipalities with a lower NDPR in 1990 tended to be more dominated by commercial use during the bubble period. These municipalities are, in turn, expected to have experienced a more

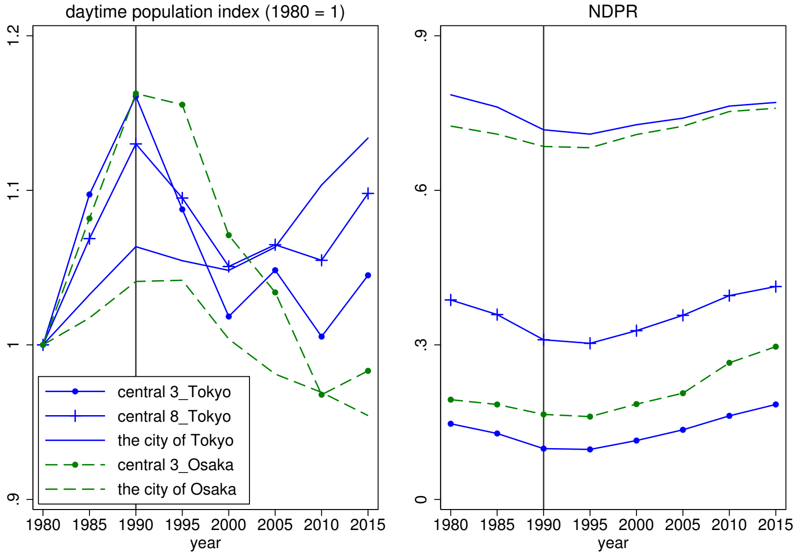


Figure 9: Daytime population growth in the Tokyo and Osaka MAs.

Notes: See data sources in Table A1. Daytime population data are available in a five-year frequency.

pronounced decline in land prices after 1990.[12] Therefore, they may have triggered relatively more land-use conversion from commercial to residential construction and increased more of the residential population, as we hypothesized.

Municipality-level daytime population data are only available for the Tokyo and Osaka prefectures. Regarding the other prefectures that are not the core of a large MA, the daytime population and nighttime population are less disparate and not reported in the relevant prefectural statistical yearbook. Therefore, our estimations cover 49 (56) urban municipalities of the Tokyo (Osaka) prefecture, 23 (24) of which constitute the city of Tokyo (Osaka).

Our first regression models the link between the annualized rate of residential population growth during the 1990–2015 period in municipality i (the left-hand-side (LHS) variable), which is expressed as a percentage, and its NDPR in 1990 (the right-hand-side (RHS) variable):

$$\frac{\ln(Pop_i^{2015}) - \ln(Pop_i^{1990})}{25} \times 100 = \alpha + \beta NDPR_{i,1990} + \epsilon_i. \quad (1)$$

The estimated β, as presented in column 1 of the Table 1 (panel A for the Tokyo prefecture and panel B for the Osaka prefecture), demonstrates our hypothesis, which is negative and statistically significant. The summary statistics of the variables used in the regressions are shown in panel A of Table A1. We can interpret the result for Tokyo as follow. A one standard deviation decrease in NDPR in 1990 (0.354) implies

[12]In municipalities where the existence of factories mainly dominate lands, the residential population would also be much smaller than the daytime population (people at their workplace). Hence, a lower NDPR is not related to a higher dominance of commercial land use, thereby causing a measurement problem. However, within our sample, all municipalities with a low NDPR are in the central locations of the Tokyo and Osaka MAs, where the number of factories is minimal.

an increase in annualized population growth for the next 25 years equal to nearly half of mean growth rate (0.6%). To relieve the limitations arising from a small number of observations, the significance of using bootstrapped standard errors (500 bootstrap repetitions) is also reported (in bracket). The results are largely consistent.

We then address the issues of omitted variables. Municipalities with a lower NDPR tend to be closer to the CBD and have a higher initial residential density. These inherent heterogeneities are likely to influence commercial-residential segregation and population growth simultaneously after the bubble burst. In columns 2 and 3 of Table 1, by replacing the independent variable with geographic distance from the Tokyo (Osaka) station (a proxy for the proximity to the CBD) and population density in 1990, respectively, we find that these two factors are significantly correlated with the post-1990 population growth in the Tokyo prefecture (the coefficients for Osaka are insignificant). However, the reported R-squared is much smaller in columns 2 and 3 than that in column 1 (0.056 and 0.081 vs. 0.325 for Tokyo; 0.018 and 0.005 vs. 0.421 for Osaka), which suggests that NDPR is more persuasive as a determinant of the post-1990 population growth, than the other two factors. Adding these two controls into Eq. 1, NDPR in 1990 is still significantly correlated with the population growth in the 1990–2015 period (column 4 of Table 1).

Our point of view is further validated by a subsample regression using only the municipality-level wards in the cities of Tokyo and Osaka. Using this sub-sample, we can deal with the issue that some peripheral municipalities in the prefecture are not in the commuting zone of the central city, and their NDPR and population growth are likely to be affected by unobservable factors that are not included in the regression. The results for this subsample, which are shown in column 5, are essentially unchanged. We also conduct a test using population growth from 1980 to 1990 as the LHS variable in column 6. In this regression, NDPR in 1980 is considered the independent variable. The estimated coefficient shows that they are positively correlated. The residential population in the municipalities with a low NDPR—commercial use dominated land development—shrank during the real estate bubble, which is consistent with the stylized facts we discussed earlier.

4.2 Within estimator

We then check the robustness of our results by employing a within (fixed effects) municipality estimator over time. The data we use here is slightly different from those used in the cross-section regression. First, we extend the sample in some specifications, which covers all urban municipalities of the Tokyo and Osaka MAs and avoids the latent selection bias that results from using only data of the Tokyo and Osaka prefectures. Second, our municipality sample covers 23 years (1980–2003); data after 2003 are excluded. This exclusion is because Japan underwent a nationwide municipality consolidation in the 2000s (mainly implemented in the 2003–2006 period), resulting in economic and demographic data in many municipalities that are incomparable before and after this event. This boundary adjustment did not affect the Tokyo and Osaka prefectures. Since the sharp fluctuations in land prices mainly occurred in the 1985-1995 period, we expect that the missing recent data (after 2003) will not affect the interpretation of our results.

As shown in Eq. 2, we set the LHS variable as population growth rate in municipality i in year t; $PopG_{i,t} = (\ln(Pop_{i,t}) - \ln(Pop_{i,t-1})) \times 100$. For the RHS, we include a set of interaction terms between a dummy variable indicating municipalities whose NDPR in 1990 are smaller than 0.8, and period dummy variables (P^a; $a = 1$ through 4) for the four periods (1985–1990, 1990–1995, 1995–2000, and 2000–2003; the 1980–1985 period is set as the benchmark):

$$PopG_{i,t} = \alpha + \sum_{a=1}^{4} \beta_a D[NDPR_{i,1990} < 0.8] \times P_t^a + \gamma_i + \sigma_t + \epsilon_{i,t}. \quad (2)$$

Our key coefficients of interest are β_a, which capture the treatment effect of the bubble and its burst on the relative population growth of the central locations (with a low NDPR) and the non-central area (the remaining municipalities in the Tokyo and Osaka prefectures); the latter is taken as the comparison group because its land prices and land-use patterns were relatively stable during the bubble economy. γ and σ capture municipality and year fixed effects, respectively. The former controls for all time-invariant differences between municipalities while the latter controls for time-variant changes that similarly affect all municipalities, such as a negative income shock due to the bubble burst. α is the constant term and ϵ stands for the error term.

The estimation results of Eq. 2 are presented in columns 1 and 2 of Table 2 for the Tokyo and Osaka prefectures, respectively; summary statistics are presented in panel B of Table A1. Taking the Tokyo prefecture as an example, the annual population growth rate during the bubble period (1985–1990) in the group with a low NDPR is 1.5 percentage points lower than that in the remaining sample areas. Meanwhile, shortly after the bubble burst, the estimated coefficients became significantly positive. These results coincide with the cross-section estimates, as shown in Table 1. The pattern of changes in the key coefficients for the Osaka prefecture is similar.

We next checked for the robustness of this association to alternatively measuring the extent of commercial-residential segregation based on a set of dummy variables. According to Figure 9 (right panel), the more central the location is, the lower the NDPR, that is, the more evident the commercial-residential segregation. The specific hierarchy of centrality a municipality belongs to is, therefore, used to proxy the degree of land-use segregation. Using this measurement approach, we can extend our analysis to all urban municipalities in the Tokyo and Osaka MAs. Considering the Tokyo MA as an example, our regression takes the following form:

$$PopG_{i,t} = \alpha + \sum_{a=1}^{4} \beta_a C3_i \times P_t^a + \sum_{a=1}^{4} \phi_a C8_i \times P_t^a + \sum_{a=1}^{4} \psi_a CC_i \times P_t^a + \gamma_i + \sigma_t + \epsilon_{i,t}, \quad (3)$$

where $C3$ is a dummy variable taking the value of one for the three central wards of Tokyo and zero otherwise; $C8$ is a dummy variable that is equal to one for the remaining five of the eight central wards of Tokyo (excluding the three central wards); and CC is a dummy variable denoting the remaining 15 wards of the city of Tokyo (excluding its eight central wards). The peripheral Tokyo MA municipalities that are outside the Tokyo city are set as the comparison. Other variables are the same as in Eq. 2.

Regarding the Osaka MA, $C3$ refers to the three central wards of Osaka city and CC denotes its remaining 21 wards; C8 does not apply in the case of Osaka.

The estimation results are presented in columns 3 and 4 of Table 2 for the Tokyo and Osaka MAs, respectively. In column 3, we find that the annual population growth rate during the bubble period (1985–1990) in $C3$ is 2.1 percentage points lower than that in the peripheral areas of the Tokyo MA, while $C8$ and CC are 1.2 and 0.6 percentage points lower, respectively (as a reference, the sample mean of the annual population growth rate is 0.7%). The more central the municipality, the lower the population growth rate. Then, shortly after the bubble burst, we find that the estimated coefficients became significantly positive. In the 1995–2000 period, $C3$'s annual population growth is 3.1 percentage points higher, followed by C8 of 1.4 percentage points and CC of 1.1. The pattern for the Osaka MA is again similar, although decentralization during the 1985–1990 period was observed in its $C3$ only.

A potential issue of the above estimates is the preexisting trends for population growth before the bubble boom. The municipality-level data series are not available before 1980, we therefore construct the pre-trends by using prefecture-level data. We first use prefecture-level data from 1970 to 1980 to construct a linear projection of the population growth rate in the 1980–2003 period for each sample prefecture. Next, the original municipality population data are detrended by subtracting them from the prefecture-level pre-1980 trends. By including the prefecture-specific linear trends, we find the patterns remained, as shown in columns 5–6; note that the estimated coefficients after 1995 become larger.

To examine the mechanism that post-1990 central city population growth was affected by the housing construction boom after the bubble burst, we re-estimate Eq. 2 and Eq. 3 by replacing the LHS variable with the housing starts (in m^2) per capita. Results, as shown in Table 3, imply that the changes in the intensity of housing development coincides with that in population growth; central locations had relatively lower (higher) housing construction intensity during the bubble period (after the bubble burst). For example, according to column 3, Tokyo $C3$'s annual housing starts per capita in the 1995–2000 period are 1.6 m^2 larger than the comparison group, equal to nearly 150% of the sample mean (1.1 m^2); for $C8$ and CC, the estimated effects equal to 27% and 16%, respectively.

To further explore the robustness of the baseline results, we examine many alternative specifications and samples, which are discussed in detail below. First, we add control variables to mitigate omitted variable problems. The area of all parks in a municipality, number of criminal offenses perceived, number of hospitals or clinics, and gender balance of the residential population are included for measuring amenity, public security, provision of public facilities, and demographic structure, respectively, which are expected to be associated with the residential location choice. Columns 1 and 2 of Table 4 report the related results for Tokyo and Osaka, respectively, which are largely consistent with our previous estimates, although the number of observations is less by about half. To ensure that the estimated results are not subject to the changes in sample size, we re-estimate our baseline regression model (Eq. 3) with the reduced sample size. The results, as shown in columns 3 and 4, do not appear to be significantly changed.

Second, our results are robust to the exclusion of the remote peripheral municipalities. As shown in Figure 2, the remote peripheral municipalities of the Tokyo and Osaka MAs are less populated; they are relatively extraneous regarding gentrification and commuter behavior in central cities. By excluding the Tokyo (Osaka) MA municipalities that are 30 *km* or further away from the Tokyo (Osaka) station, the positive impact on central locations during 1995 and 2003 remains, as presented in column 5 (6) of Table 4.

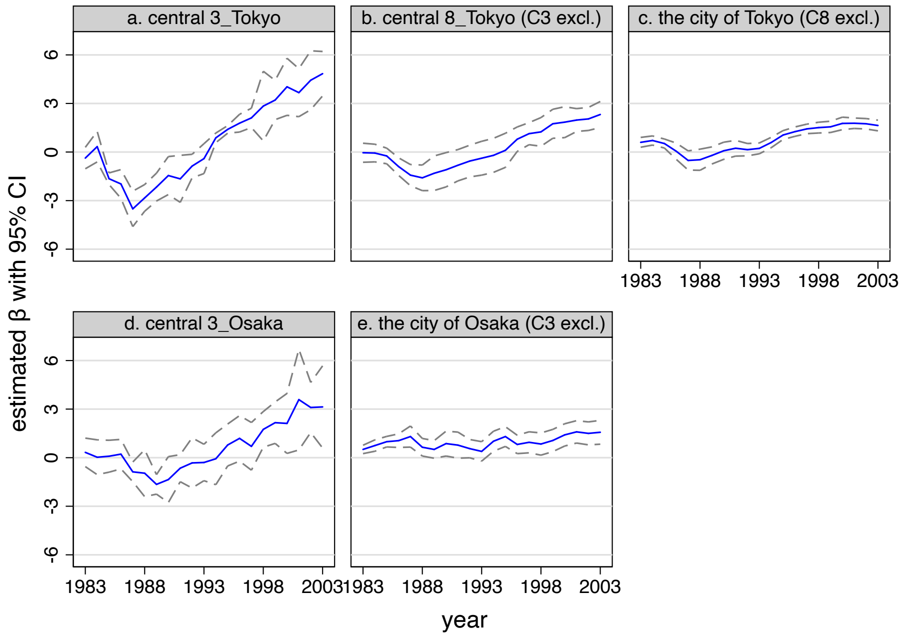


Figure 10: Year-by-year estimates.

Notes: The dashed lines are the 95% confidence interval. Population growth in the 1980–1982 period is set as the benchmark. "central 8_Tokyo (C3 excl.)" refers to the eight central wards of Tokyo, excluding the three central wards. "the city of Tokyo (C8 excl.)" refers to the city of Tokyo, excluding its eight central wards. "the city of Osaka (C3 excl.)" refers to the city of Osaka, excluding the three central wards.

To more accurately identify heterogeneity over time in the changes of population growth dynamics, we further introduce an augmented version of Eq. 3 by replacing P_t^a with a set of individual year dummies $time_t^a$; $time_t^a$ takes the value of one if $a = t$ and zero otherwise.

$$PopG_{i,t} = \alpha + \sum_{a=1983}^{2003} \beta_{1,a} C3_i \times time_t^a + \sum_{a=1983}^{2003} \beta_{2,a} C8_i \times time_t^a + \sum_{a=1983}^{2003} \beta_{3,a} CC_i \times time_t^a + \gamma_i + \sigma_t + \epsilon_{i,t}, \tag{4}$$

where the population growth in the 1980–1982 period is taken as the benchmark. Other terms are the same as those in Eq. 3. Plots *a*, *b*, and *c* of Figure 10 display the estimated interaction term coefficients $\beta_{1,a}$, $\beta_{2,a}$, and $\beta_{3,a}$, respectively, for the Tokyo MA; *d* and *e* refer to the related estimates for the Osaka MA. Within the 1985–1990 period, the estimated β are significantly negative for the central locations of Tokyo and Osaka. After that, they become positive, and the magnitude increases monotonically over time (plots a, b, and d). The time point of dynamic changes of population growth coincides with that of land prices; that is, the CBDs were relatively slower in population growth before 1990, but became faster after the bubble burst. Patterns shown in plots c and e are also in line with our point of view, although they are statistically less significant.

4.3 Is the gentrification the cause, not the effect, of the housing boom?

We are concerned about the issue of reverse causality; that is, whether the housing boom led by the changes in the land-use pattern in central cities was simply the result of population growth there. However, it is hard to hold this view because the population influx occurred after, not before, the housing construction boom. According to Figure 6, the housing boom in central cities started to intensify during the 1993–1995 period (we will further present the number of housing starts by housing type in Section 5, where it will be clearer that the central city housing boom has started in the 1993–1995 period). However, population growth there was not significant until 2000 (Figure 8).

To formally examine the causal relationship between housing starts and population growth, we employ a simple regression model (Eq. 5) by taking the population growth rate of municipality i in year t as the dependent variable and the intensity of housing starts in the previous years, measured by the average of the housing starts in m^2 per capita (HS) in years $t-3$, $t-2$, and $t-1$, as the RHS variable (a time lag exists since housing investment and construction take a certain time):

$$PopG_{i,t} = \alpha + \beta_1 \sum_{a=t-3}^{t-1} \frac{1}{3} HS_{i,a} + \epsilon_i. \tag{5}$$

If population growth in the central cities was boosted by housing capital investment, we expect β_1 to be positive. Since the extra population growth after the bubble burst was mainly concentrated in the central cities, our regression analysis only focuses on the 23 and 24 wards of the Tokyo and Osaka cities, respectively. We regress each year's data separately; summary statistics are shown in panel C of Table A1. Due to a small number of observations, we report bootstrapped standard errors (500 bootstrap repetitions). Column 1 of Table 5 presents the estimated β_1, by year, for Tokyo (each regression has 23 observations), we find that the estimated coefficients are positive and statistically significant for most years since 1994. That is, the population growth rate of 1994 was positively associated with the intensity of housing starts in the previous three years (1990–1993), which were immediately after the bubble burst. Moreover, this positive correlation remained for the subsequent decade.

As a robustness test, we exchange the LHS and RHS variables of Eq. 5, and estimate the following equation:

$$HS_{i,t} = \alpha + \beta_2 \sum_{a=t-3}^{t-1} \frac{1}{3} PopG_{i,a} + \epsilon_i, \tag{6}$$

where the significance of β_2 examines whether past population growth affects the current housing construction intensity in a municipality. For instance, in the case where β_2 is significant for 1994, it implies that population growth in the previous three years

(1990–1993) affected the number of housing starts in 1994. If the reverse causality exists, β_2 will be significantly positive; however, column 2 shows that this coefficient is not significant in most years, whether before or after 1990. This result implies that housing starts after the bubble burst drove population growth in Tokyo city, not the reverse.

Note that results for the 1984–1993 period are insignificant for most regression tests of Eq. 5 (column 1) and Eq. 6 (column 2). This result is reasonable because there were intense land price fluctuations in this period; thus, housing development was comprehensively restrained in the central cities (see Figures 5–7), making it less correlated with the population growth. Moreover, β_2 is significantly positive for 2002 and 2003 (column 2); this is also not contradictory to our results. Taking the positive correlation between $PopG_{1998-2001}$ and HS_{2002} as an example, $PopG_{2001}$ is positively affected by $HS_{1997-2000}$ according to the estimates of Eq. 4 (column 1 of Table 4); the latter is, however, likely to be positively associated with HS_{2002} due to the inertia of population growth. Therefore, $PopG_{2001}$ and HS_{2002} are not necessary to be uninfluential to each other. Analogously, it is also possible for $PopG_{1999}$ and $PopG_{2000}$ to be associated with HS_{2002} via $HS_{1995-1998}$ and $HS_{1996-1999}$, respectively.

Results using data of Osaka are largely consistent. As exhibited in column 3 of Table 5, lagged HS can well predict $PopG$ after 1993, while the correlation between lagged $PopG$ and HS (Eq. 6) is not significant until 1998 (column 4). These simple tests provide evidence against the argument that the central city housing boom was simply the result of residential recentralization (gentrification).

4.4 Are condominiums in the central city becoming relatively cheaper?

Another argument against our hypothesis would be that the prevalence of high-rise buildings in recent decades promotes the advances in construction technology, thereby reducing the construction costs of high-rise condominium towers and making it relatively cheaper. Since the central city is the most suitable place to build such homes, advances in construction technology might have reduced the cost of buying a house there. One may expect that gentrification would still happen even without the burst of the real estate bubble. Moreover, high-rise condominiums are much more intensive in land use (higher in the floor-to-area ratio) than detached houses, which also allows homebuyers to incur a relatively lower costs for owning a home.[13]

However, we find this is not the case by checking the price changes in new condominium. Figure 11 displays the prices of residential land and new condominium for the Tokyo and Osaka MAs in the 1990–2017 period (data for the earlier years are not available). During the 1990–1995 period (immediately after the bubble burst), the prices for both condominium and residential land declined significantly compared to their price peaks. However, the price changes began to diverge after 1995, with condominium prices stabilizing, and then rebounding, whereas residential land prices declined continuously.[14] Obviously, condominium, whose construction is more inten-

[13]A condominium is on average smaller than a detached house, which further makes it relatively affordable.

[14]Note that the price index of new condominiums, as shown in Figure 11, does not consider the potential changes in average dwelling size. By considering the price per m^2, we find that the patterns

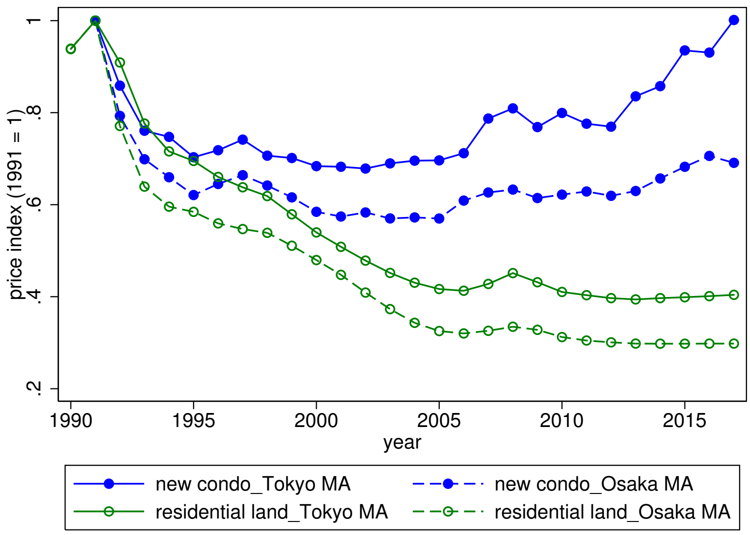


Figure 11: Residential land and condominium prices in the Tokyo and Osaka MAs.

Notes: Data are obtained from the Japanese Real Estate Statistics 2019, released by the Mitsui Fudosan Co.,Ltd. (Planning and Research Department). Data of new condominium (residential land) price index at the MA-level are available in the 1991–2017 (1990–2017) period.

sive in land use, did not become relatively cheaper than residential land (or detached house; the changes in price index for residential land and detached house are similar). Instead, they have become increasingly expensive.

Although it is beyond the scope of the current study, we propose a potential explanation for the diverged relative prices between residential land and new condominium. To construct high-rise condominiums, land developers are subject to the issue of land assembly, which is costly. Brooks and Lutz (2016) and Yamasaki et al. (2020) find that a large residential plot (or a to-be-assembled land parcel) trades at a significant premium in Los Angeles and Tokyo, respectively. Since most of the residential land transactions in the MA were for small plots (less than 200 m^2), which are applicable only for detached house construction, the reported residential land price index—calculated based on the average unit price for all land transactions—mainly reflects the price of small plots, and cannot precisely reflect the costs of assembled land parcels. The latter is, however, relatively more relevant to the price of condominiums.

4.5 Other contributing factors

Aside from the mechanisms we introduced, other factors could potentially account for our findings. We present several pieces of additional evidence that gentrification in the central city areas was driven by the land price fluctuations and land-use conversion, rather than by these alternative explanations.

First, advances in internal transportation facilities could play a role in reshaping

are largely similar; the unit price of a new (existing) condominium increased by 57% (54%) during the 2005–2017 period in the Tokyo MA (Global Property Guide, 2019).

urban spatial structure (Baum-Snow, 2007; Li and Xu, 2018). By checking the new starts and upgrades of major transportation infrastructures in Tokyo and Osaka, however, we find that both interregional (high-speed railroads and expressways) and the intraregional (city roads and urban rail transits) facilities currently in operation began operations before 1985. We have not found substantial development in this regard. Therefore, it is less likely to have motivated the post-1990 gentrification in Tokyo and Osaka.

Second, government policies on land-use regulation or zoning may be associated with city structure and variation of housing vacancies (Cheshire et al., 2018). Therefore, it affects the interpretation of our results. The Obuchi (1998–2000) and Koizumi Cabinet (2001–2006) treated urban regeneration as a way for large cities to regain their competitiveness and address the recession after the bubble burst (Hirayama, 2017). Thus, policies, including the deregulation of urban planning, have been implemented since 1998. However, these policies favoring central city regeneration and the trends of "Recentralization of Central City (*Toshin-Kaiki* in Japanese)" did not make substantial progress until the late 1990s, whereas the housing construction boom in the central cities began in the early 1990s. Therefore, it is safe to say that the observed central city housing boom was not triggered by government policies, although they might have pushed it forward to some extent.

Moreover, public housing policy may affect the intra-city neighborhood changes as well (Tach and Emory, 2017). As discussed in Xu and Zhou (2019), public housing in the major cities of Japan was mainly built before 1980. Since then, the main effort on public housing was to maintain the existing buildings. Since the vacancy rate of public housing in Tokyo and Osaka has been extremely low in recent decades, and the economic composition of tenants has been stable over time (Xu and Zhou, 2019), it is evident that the maintenance of public housing is powerless to accommodate the sharply growing population in the central city areas since the early 1990s.

5 Gentrification and central city housing structure

As an extension to our empirical results, we further examine whether land price fluctuations and gentrification have structurally changed the housing supply in the central cities, which will be informative to the decision-making on housing and zoning-related policies. We find that houses in the central cities are more likely to be in the form of high-rise condominiums and larger in floor area after the bubble burst.

5.1 A growing number of high-rise residential buildings

To be consistent with our hypothesis that the land-use conversion in central cities triggered gentrification, we expect that a large number of high-rise condominiums have been constructed there.[15] By contrast, the new construction of high-rise commercial and office buildings is expected to have declined relatively.

[15] Even if land prices fell a lot after the bubble burst, land in the CBDs is still too expensive to use for detached houses.

Table 6 displays the housing stock of Tokyo city and Osaka city. During the 1998–2013 period (data for the earlier years are not available), housing stock increased by 33% (22%) in Tokyo (Osaka) city, which is much more significant than its growth in residential population in the same period (12% for Tokyo and 3% for Osaka).[16] It is noteworthy that condominiums in buildings with six or more stories have been the biggest contributor to the new housing supply after 1998, among which the increase in the number of dwellings in the buildings of 15 or more stories was the most significant.

Table 7 further displays the stock and locations of the Tokyo prefecture's high-rise buildings (detailed data for other prefectures are not available) in the 1980–2010 period. The number of high-rise buildings has increased dramatically in these three decades; those of nine or more stories increased by 349%, and those with 13 or more stories increased by 702%. Although the number of high-rise buildings in peripheral areas (i.e., areas outside the city of Tokyo) has also been growing, 54% of the high-rise buildings are still in the eight central wards of Tokyo in 2010, which account for only 6.2% of the prefecture's land area; 91% are in the city of Tokyo. Regarding the new construction of buildings with 30 or more stories in this period, 77% (97%) are located in the eight central wards (the city of Tokyo). This pattern implies that the development of high-rise buildings in our study period has been concentrated in the central locations, which is consistent with the facts of gentrification.

Consistently, we find that the more central the location, the higher the proportion of residents living in high-rise buildings. According to the National Population Census 2015, for Chiyoda, Chuo, and Minato (the three central wards of Tokyo), 50%, 64%, and 46% of households, respectively, lived in buildings with 11 or more stories (longitudinal data are not available for this indicator). Regarding the remaining five of the eight central wards, this figure is slightly lower, ranging between 21% and 47%, which is still much higher than the average of the entire city of Tokyo (16%). This ratio for the areas outside Tokyo city is further lower, and the pattern for Osaka is similar.

The growth of high-rise buildings, as mentioned in Table 7, does not differentiate between the use of buildings (commercial or residential). We pay more attention to the latter because, according to our hypothesis, the former should have been relatively reduced due to land-use conversion. Table 8 gives evidence of our hypothesis by demonstrating that an increasing proportion of the super high-rise buildings (60 meters or higher) in the Tokyo prefecture (data for the Osaka prefecture are not public) are used for residential rather than for commercial purposes. Regarding the super high-rise buildings constructed during the bubble period (some of them completed in the 1990–1994 period, since the construction takes a few years to complete), approximately 15% were exclusively for residential use, and approximately 60% were for commercial and office use (the rest exhibited a combination of commercial and residential use). However, in the following decades, an increasing number of super high-rise buildings were constructed for residential use, whereas the share of buildings exclusively for commercial and office use was condensed. The latter coincides with the facts that the central city daytime population has declined after the bubble burst, as presented in Figure 9.

[16] Since housing construction takes a certain time, housing stock in 1998 only contains a small percentage of houses built after the bubble burst.

Although seemingly fragmented, the discussion above can partially verify that, after the bubble burst, land development in the central locations was increasingly focused on high-rise condominiums, which absorbed the post-1990 inflow of residents. Note that, since the reported figures in Tables 6–8 are obtained from different raw data sources, and data availability is limited, they differ in the definition of high-rise buildings (Table 6 (7) refers to the buildings with six (nine) or more stories, and Table 8 denotes the buildings with 60 meters or more in height) and the geographic boundary of the sample area (Table 6 refers to the cities of Tokyo and Osaka, and Tables 7 and 8 refer to the Tokyo prefecture). However, we can ensure that the reliability of the above discussion will not be essentially undermined since all the stylized facts are compatible with each other.

5.2 Houses are on average larger

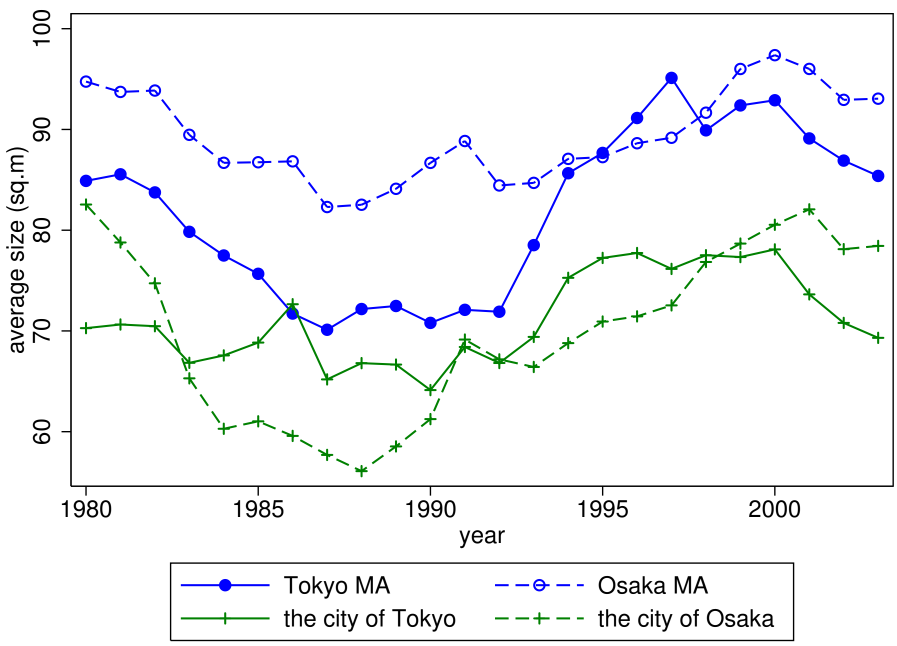


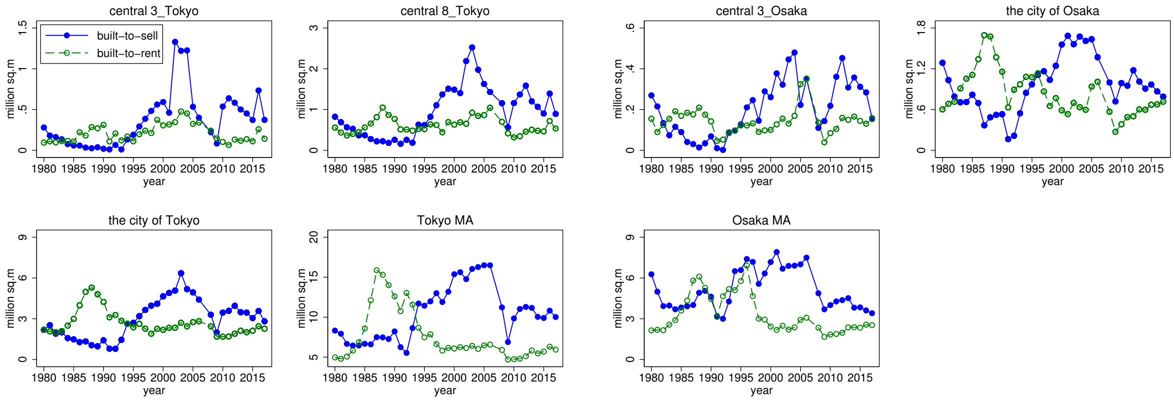
Figure 12: The average floor area of housing starts.

Notes: The reported figures refer to the municipality mean by year. See data sources in Table A1.

The structure of housing starts has changed substantially after the bubble burst. Figure 12 shows the average floor area of all housings starts in the Tokyo (Osaka) MA and the city of Tokyo (Osaka); they firstly declined in the late 1980s and then increased with the burst of the real estate bubble. Figure 13 further shows the number of housing starts in the Tokyo and Osaka MAs and their central cities, by separating the "built-to-sell" dwellings (mainly condominiums) and "built-to-rent" ones (mainly single-bedroom apartments).[17] Note that there are substantial differences between

[17]There are other types of housing construction (though limited), such as owner-occupied homes built by the landowners and issued houses for employees built by the employers; "built-to-sell" and

the two types of housing: "built-to-sell" dwellings (70–100 m^2 on average) are larger than "built-to-rent" ones (40–60 m^2), although they are all smaller than owner-occupied houses (110–140 m^2) (see Figure 14).



(a) The Tokyo MA

(b) The Osaka MA

Figure 13: Number of housing starts, by house type.

Notes: See data sources in Table A1. Data for 2007 are missing.

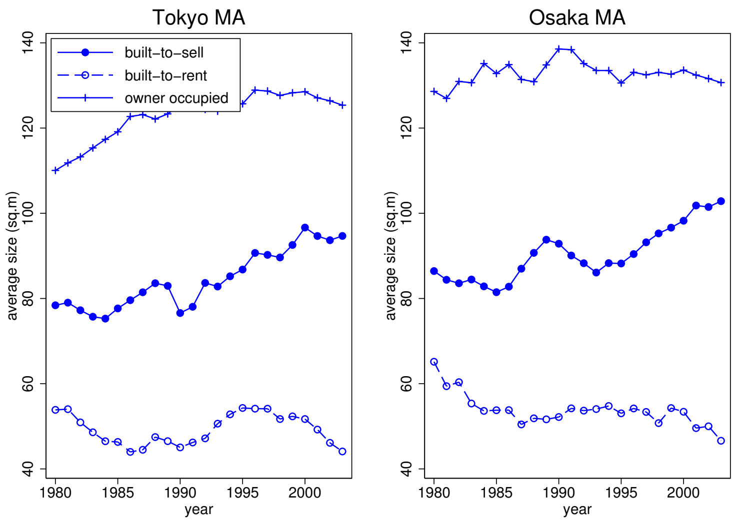


Figure 14: The average floor area of the three types of houses.

Notes: See data sources in Table A1.

The proportion of "built-to-rent" dwellings peaked during the bubble period. This result may be because the house price is too high for most people to afford large-sized homes. After the bubble burst, with the improving housing affordability, land

"built-to-rent" dwellings account for, on average, 70% of the Tokyo and Osaka MAs' new housing supply in the 1980–2017 period (the more recent the year, the higher the proportion). Regarding the Tokyo and Osaka cities, this proportion has stabilized above 80%.

developers began to build larger dwellings in central cities, targeting those who can afford the central city property. Thus, "built-to-sell" dwellings have been dominant since the early 1990s.

Moreover, we find that the more central the locations, the more significant the changes in the average dwelling size of housing starts during and after the bubble economy. By replacing the LHS variable of Eq. 3 with the ratio of "built-to-sell" dwellings in total housing starts, we find that this figure declined in the central cities during the bubble period. However, the pattern was reversed after the bubble burst (columns 1 and 2 of Table 9 for Tokyo and Osaka, respectively). To avoid the bias from the changes in the starts of owner-occupied homes that are built by the landowner, which are less market-driven, we replace the LHS variable with the proportion of the "built-to-sell" in the sum of "built-to-sell" and "built-to-rent" dwellings (real estate developers built both); the results remained the same (columns 3–4). This changing housing development strategy is consistent with the increasing population and the increasing income level of residents in the central cities accompanied by gentrification.

This trend in housing development strategy was, however, not nationwide. By examining the changes in the share of "built-to-sell" dwellings in the sum of "built-to-sell" and "built-to-rent" dwellings, we find that prefectures in the Tokyo and Osaka MAs are the main areas that exhibit the trend of shifting from the development of "built-to-rent" toward "built-to-sell" dwellings (Table 10). This proportion increased by 30 and 11 percentage points, respectively, in the Tokyo and Osaka MAs, but it is basically unchanged in the remaining prefectures. This result implies that the trend of housing investment transformation that occurred in the Tokyo and Osaka MAs was not caused by factors, such as the changes in national building standards, taxes, and residents' preferences; otherwise, other prefectures should show similar patterns.

6 Concluding remarks

We identify a new supply-side cause of gentrification by studying the effects of a real estate bubble and its burst on the intra-MA residential location choice in the Tokyo and Osaka MAs. In response to the land price fluctuations in the central cities, land developers tend to increase (decrease) housing construction and decrease (increase) commercial development when land prices fall (rise). This situation will increase (decrease) the supply of decent homes in central cities and encourage gentrification (suburbanization). The endogenous changes in land development strategy will affect a city's residential location and spatial structure.

From a policy perspective, such a possibility provides a rationale for government interventions, such as land-use regulation to encourage (or suppress) market-led land-use conversion in the central cities. The results also suggest that the effect of exogenous land price fluctuations on land-use conversion should be considered in housing and zoning policy formulation to avoid policy ineffectiveness. It is worth emphasizing that, due to the limitations on data availability, our analysis of land-use conversion and resident income changes in the central cities is qualitative rather than quantitative, which makes our mechanism analysis potentially less reliable.

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Table 1: Commercial-residential segregation during the bubble period and population growth after the bubble burst.

	(1)	(2)	(3)	(4)	(5)	(6)
	Annualized pop. growth rate (%)					
	1990–2015					1980–90
Panel A	Tokyo prefecture					
$NDPR_{1990}$	-0.811			-0.473	-0.589	
	(0.293)			(0.244)	(0.341)	
	[0.294]			[0.226]	[0.344]	
ln(Pop. density$_{1990}$)		-0.183		-0.539	-0.786	
		(0.110)		(0.167)	(0.347)	
		[0.124]		[0.189]	[0.407]	
Dist. Tokyo Station			-0.011	-0.023	-0.014	0.038
			(0.006)	(0.007)	(0.026)	(0.015)
			[0.006]	[0.008]	[0.028]	[0.016]
$NDPR_{1980}$						2.241
						(0.394)
						[0.403]
ln(Pop. density$_{1980}$)						-0.452
						(0.289)
						[0.307]
N	49	49	49	49	23	49
R^2	0.325	0.056	0.081	0.524	0.658	0.787
Panel B	Osaka prefecture					
$NDPR_{1990}$	-1.465			-1.871	-2.560	
	(0.235)			(0.242)	(0.433)	
	[0.278]			[0.272]	[0.439]	
ln(Pop. density$_{1990}$)		-0.107		-0.338	0.293	
		(0.084)		(0.147)	(0.262)	
		[0.083]		[0.142]	[0.339]	
Dist. Osaka Station			-0.004	0.002	0.011	-0.036
			(0.008)	(0.012)	(0.041)	(0.026)
			[0.009]	[0.012]	[0.042]	[0.025]
$NDPR_{1980}$						0.721
						(0.588)
						[0.580]
ln(Pop. density$_{1980}$)						-1.021
						(0.235)
						[0.230]
N	56	56	56	56	24	56
R^2	0.421	0.018	0.005	0.593	0.808	0.495

Notes: NDPR: Nighttime-to-daytime population ratio. The constant term coefficients are not reported. Robust standard errors are given in parentheses. To relieve the limitations arising from a small number of observations, the significance using bootstrapped standard errors (500 bootstrap repetitions) is also reported (in bracket).

Table 2: Baseline estimation results.

	(1)	(2)	(3)	(4)	(5)	(6)
			Pop. growth rate (%)			
	Tokyo pref.	Osaka pref.	Tokyo MA	Osaka MA	Tokyo MA	Osaka MA
$[NDPR_{1990} < 0.8] \times$ yr 85–90	-1.492	-0.122				
	(0.265)	(0.415)				
$\times$ yr 90–95	-0.099	0.069				
	(0.216)	(0.310)				
$\times$ yr 95–00	1.556	1.245				
	(0.374)	(0.309)				
$\times$ yr 00–03	2.118	2.520				
	(0.513)	(0.504)				
C3 $\times$ yr 85–90			-2.050	-1.014	-1.542	-0.641
			(0.291)	(0.255)	(0.294)	(0.256)
$\times$ yr 90–95			0.206	-0.200	1.235	0.544
			(0.248)	(0.411)	(0.261)	(0.414)
$\times$ yr 95–00			3.129	1.494	4.699	2.605
			(0.455)	(0.409)	(0.469)	(0.417)
$\times$ yr 00–03			4.650	3.184	6.689	4.588
			(0.514)	(0.950)	(0.533)	(0.955)
C8 $\times$ yr 85–90			-1.196		-0.688	
			(0.302)		(0.306)	
$\times$ yr 90–95			-0.301		0.728	
			(0.358)		(0.367)	
$\times$ yr 95–00			1.420		2.990	
			(0.264)		(0.288)	
$\times$ yr 00–03			2.181		4.219	
			(0.225)		(0.266)	
CC $\times$ yr 85–90			-0.584	0.425	-0.076	0.798
			(0.248)	(0.211)	(0.252)	(0.212)
$\times$ yr 90–95			0.081	0.358	1.110	1.103
			(0.144)	(0.258)	(0.166)	(0.264)
$\times$ yr 95–00			1.134	0.566	2.704	1.676
			(0.159)	(0.279)	(0.196)	(0.290)
$\times$ yr 00–03			1.352	1.104	3.391	2.509
			(0.155)	(0.311)	(0.209)	(0.328)
two-way FEs	Y	Y	Y	Y	Y	Y
de-trend	N	N	N	N	Y	Y
N	1,133	1,270	3,690	2,806	3,690	2,806
R^2	0.413	0.204	0.329	0.085	0.679	0.536

Notes: NDPR: Nighttime-to-daytime population ratio. There are nine municipalities in the Tokyo prefecture with NDPR smaller than 0.8 (column 1); this figure for the Osaka prefecture is seven (column 2). *C3*: the three central wards of Tokyo/Osaka city; *C8*: the eight central wards of Tokyo city, by excluding the three central wards; *CC*: the city of Tokyo (excluding the eight central wards), or the city of Osaka (excluding the three central wards). Constant term coefficients are not reported. Heteroskedasticity robust standard errors (clustered at the municipality level) in parentheses.

Table 3: Examining the changes in the intensity of housing construction.

	(1)	(2)	(3)	(4)
	Housing starts per capita			
	Tokyo prefecture	Osaka prefecture	Tokyo MA	Osaka MA
$[NDPR_{1990} < 0.8] \times$ yr 85–90	-0.115	-0.222		
	(0.105)	(0.136)		
$\times$ yr 90–95	-0.275	-0.566		
	(0.096)	(0.169)		
$\times$ yr 95–00	0.639	0.045		
	(0.236)	(0.065)		
$\times$ yr 00–03	1.338	0.701		
	(0.547)	(0.229)		
C3 $\times$ yr 85–90			-0.097	-0.595
			(0.277)	(0.094)
$\times$ yr 90–95			-0.273	-1.033
			(0.245)	(0.200)
$\times$ yr 95–00			1.638	0.021
			(0.222)	(0.085)
$\times$ yr 00–03			3.663	0.961
			(0.583)	(0.404)
C8 $\times$ yr 85–90			-0.129	
			(0.079)	
$\times$ yr 90–95			-0.207	
			(0.046)	
$\times$ yr 95–00			0.288	
			(0.063)	
$\times$ yr 00–03			0.470	
			(0.144)	
CC $\times$ yr 85–90			0.032	-0.039
			(0.044)	(0.064)
$\times$ yr 90–95			-0.083	-0.240
			(0.042)	(0.064)
$\times$ yr 95–00			0.174	-0.046
			(0.054)	(0.070)
$\times$ yr 00–03			0.299	0.206
			(0.048)	(0.095)
two-way FEs	Y	Y	Y	Y
N	1,185	1,326	3,876	2,931
R^2	0.303	0.272	0.335	0.202

Notes: NDPR: Nighttime-to-daytime population ratio. There are nine municipalities in Tokyo prefecture with NDPR smaller than 0.8 (column 1); this figure for Osaka prefecture is seven (column 2). *C*3: the three central wards of Tokyo/Osaka city; *C*8: the eight central wards of Tokyo city, by excluding the three central wards; *CC*: the city of Tokyo (excluding the eight central wards), or the city of Osaka (excluding the three central wards). Constant term coefficients are not reported. Heteroskedasticity robust standard errors (clustered at the municipality level) in parentheses.

Table 4: Robustness checks.

	(1)	(2)	(3)	(4)	(5)	(6)
	Pop. growth rate (%)					
	with controls		symmetry sample		30 *km* radius	
	Tokyo MA	Osaka MA	Tokyo MA	Osaka MA	Tokyo MA	Osaka MA
C3 × yr 85–90	-1.907	-1.289	-1.901	-1.281	-2.039	-0.932
	(0.462)	(0.301)	(0.452)	(0.308)	(0.310)	(0.242)
× yr 90–95	-0.692	-0.374	-0.735	-0.402	0.333	0.155
	(0.725)	(0.249)	(0.703)	(0.237)	(0.279)	(0.426)
× yr 95–00	3.271	1.429	3.129	1.397	2.833	1.564
	(0.519)	(0.309)	(0.408)	(0.293)	(0.478)	(0.433)
× yr 00–03	4.891	3.134	4.754	3.092	4.248	3.249
	(0.795)	(0.838)	(0.719)	(0.816)	(0.539)	(0.965)
C8 × yr 85–90	-0.683		-0.673		-1.185	
	(0.199)		(0.199)		(0.321)	
× yr 90–95	-0.203		-0.187		-0.174	
	(0.354)		(0.357)		(0.381)	
× yr 95–00	1.818		1.828		1.124	
	(0.232)		(0.227)		(0.299)	
× yr 00–03	2.566		2.584		1.779	
	(0.248)		(0.239)		(0.271)	
CC × yr 85–90	-0.519	0.394	-0.523	0.393	-0.573	0.508
	(0.259)	(0.253)	(0.257)	(0.254)	(0.270)	(0.195)
× yr 90–95	0.083	0.159	0.067	0.165	0.209	0.714
	(0.213)	(0.273)	(0.205)	(0.275)	(0.191)	(0.279)
× yr 95–00	1.405	0.537	1.382	0.527	0.838	0.636
	(0.216)	(0.297)	(0.195)	(0.300)	(0.210)	(0.310)
× yr 00–03	1.772	1.374	1.734	1.369	0.951	1.169
	(0.253)	(0.327)	(0.215)	(0.327)	(0.215)	(0.335)
two-way FEs	Y	Y	Y	Y	Y	Y
N	1,913	1,712	1,913	1,712	1,870	1,552
R^2	0.404	0.137	0.403	0.134	0.358	0.168

Notes: *C*3: the three central wards of Tokyo/Osaka city; *C*8: the eight central wards of Tokyo city, by excluding the three central wards; *CC*: the city of Tokyo (excluding the eight central wards), or the city of Osaka (excluding the three central wards). For columns 1–2, control variables include: ln(area of parks+1), ln(number of hospitals+1), ln(number of clinics+1), ln(number of criminal offenses perceived+1), and the absolute value of (female pop./pop.−0.5). Constant term coefficients are not reported. Heteroskedasticity robust standard errors (clustered at the municipality level) in parentheses.

Table 5: Testing the reverse causality.

	(1)		(2)		(3)		(4)	
Specification	Eq. 5		Eq. 6		Eq. 5		Eq. 6	
# LHS variable	PopG_t		HS_t		PopG_t		HS_t	
# RHS variable	$\text{HS}_{MeanLag3}$		$\text{PopG}_{MeanLag3}$		$\text{HS}_{MeanLag3}$		$\text{PopG}_{MeanLag3}$	
	the city of Tokyo		the city of Tokyo		the city of Osaka		the city of Osaka	
Year t=	coeff.	s.e.	coeff.	s.e.	coeff.	s.e.	coeff.	s.e.
1984	-0.106	[0.992]	-0.003	[0.063]	1.260	[0.691]	0.025	[0.079]
1985	-2.222	[1.574]	-0.005	[0.054]	0.581	[0.755]	0.027	[0.108]
1986	-3.446	[1.674]	-0.068	[0.050]	0.392	[0.627]	-0.006	[0.084]
1987	-5.683	[2.980]	0.010	[0.040]	-0.635	[0.760]	-0.056	[0.064]
1988	-1.785	[2.033]	-0.058	[0.054]	-0.775	[0.435]	-0.098	[0.115]
1989	-0.814	[1.402]	-0.020	[0.045]	-0.472	[0.812]	-0.124	[0.094]
1990	0.362	[1.179]	-0.059	[0.061]	0.966	[1.563]	-0.147	[0.071]
1991	0.215	[1.634]	0.028	[0.036]	-0.008	[0.736]	-0.010	[0.072]
1992	0.572	[1.203]	-0.004	[0.075]	0.298	[0.543]	0.067	[0.042]
1993	1.606	[1.154]	0.015	[0.049]	0.902	[0.645]	-0.004	[0.084]
1994	2.367	[0.643]	0.068	[0.064]	1.414	[0.502]	0.008	[0.119]
1995	2.418	[0.548]	-0.099	[0.081]	0.981	[0.432]	-0.158	[0.156]
1996	0.840	[1.325]	-0.274	[0.216]	0.938	[0.350]	0.137	[0.249]
1997	0.733	[0.299]	0.015	[0.220]	1.224	[0.232]	0.433	[0.316]
1998	1.342	[0.637]	0.200	[0.355]	1.692	[0.508]	0.554	[0.119]
1999	0.889	[0.294]	0.468	[0.503]	1.977	[0.330]	0.348	[0.172]
2000	1.056	[0.417]	0.423	[0.595]	1.567	[0.239]	0.402	[0.116]
2001	0.580	[0.396]	0.528	[0.421]	2.566	[0.294]	0.649	[0.198]
2002	0.826	[0.347]	1.966	[0.798]	1.502	[0.500]	0.634	[0.106]
2003	0.757	[0.161]	1.236	[0.757]	1.576	[0.232]	0.699	[0.137]

Notes: Each point estimate stems from a separate OLS regression (20×4=80 regression tests in total); for columns 1–2 (3–4), each regression has 23 (24) observations, as Tokyo (Osaka) city consists of 23 (24) municipality-level wards. HS_t: Housing starts (m^2) per capita in year t; $PopG_t$: Population growth rate (%) in year t. $MeanLag3$ refers to the mean of the specific variable in year $t-3$, $t-2$, and $t-1$. Bootstrapped standard errors (500 bootstrap repetitions) are reported (in bracket); the constant term coefficients and R-squared are not reported.

Table 6: Housing stock in Tokyo and Osaka.

Year	Housing stock	Detached house	Condominium (# stories) 1–5	6–10	11–14	≥15	Tenement house	Others
			the city of Tokyo					
1998	3,468.8	925.1	1,718.0	714.6			75.0	36.0
2003	3,842.4	996.6	1,747.6	565.0	368.7	73.3	68.1	23.2
2008	4,177.7	1,012.2	1,807.9	672.7	468.0	134.0	61.6	21.2
2013	4,601.6	1,060.7	1,880.9	800.8	556.0	203.2	75.8	24.1
Δ1998–2013	1,132.8	135.6	162.9	845.4			0.8	-11.9
(%)	(33%)	(15%)	(9%)	(118%)			(1%)	(-33%)
			the city of Osaka					
1998	1,102.7	233.7	336.9	392.1			132.1	7.9
2003	1,186.9	298.9	314.1	259.6	172.1	49.1	88.4	4.6
2008	1,262.1	303.6	294.3	301.2	201.3	87.5	70.4	3.8
2013	1,343.2	334.1	283.3	331.4	234.4	112.8	43.7	3.4
Δ1998–2013	240.5	100.4	-53.6	286.5			-88.4	-4.5
(%)	(22%)	(43%)	(-16%)	(73%)			(-67%)	(-57%)

Notes: Data are obtained from the Housing and Land Survey (HLS; various years). The reported data are the number of dwellings units in thousand. Data containing detailed dwelling structure are only available at the major city level from the HLS. The figures in the areas denoted gray refer to the sum of condominium units in the buildings of "6–10 stories," "11–14 stories," and "15 or more stories," because separate data are not available for 1998. "Condominium" here also includes the small-sized single-bedroom apartments.

Table 7: Locations of high-rise buildings in the Tokyo prefecture.

		Number of buildings			Proportion		
		# stories			# stories		
Year	Area	9–12	13–29	≥30	9–12	13–29	≥30
1980	central 3	2,095	176		40%	26%	
	central 8	3,476	359		66%	53%	
	the city of Tokyo	4,966	666		95%	99%	
	Tokyo prefecture	5,236	672		100%	100%	
1990	central 3	3,793	287	12	36%	23%	38%
	central 8	6,464	599	26	62%	49%	81%
	the city of Tokyo	9,925	1,174	32	94%	96%	100%
	Tokyo prefecture	10,506	1,223	32	100%	100%	100%
2000	central 3	4,854	489	34	31%	19%	39%
	central 8	8,967	1,131	66	57%	45%	75%
	the city of Tokyo	14,578	2,263	86	92%	90%	98%
	Tokyo prefecture	15,811	2,517	88	100%	100%	100%
2010	central 3	6,023	1,090	134	28%	21%	50%
	central 8	11,587	2,451	207	55%	48%	78%
	the city of Tokyo	19,315	4,640	260	91%	91%	97%
	Tokyo prefecture	21,157	5,121	267	100%	100%	100%

Notes: The reported data refer to the number of all high-rise buildings in the Tokyo prefecture, including both the residential buildings and buildings for other purposes. Data are obtained from the Tokyo Prefectural Statistical Yearbook (various years). Related data for the other prefectures in our sample are not available. The figures in the areas denoted gray refer to the sum of the number of buildings of "13–29" and "30 or more" stories because separate data are not available for 1980.

Table 8: The purposes of super high-rise buildings in the Tokyo prefecture.

	Number of buildings			
Completion time of the building	All purposes	Residential	Combination of residential & commercial, office	Commercial, office, and others
1980–1984	45	4	0	41
1985–1989	55	10	14	31
1990–1994	140	20	34	86
1995–1999	118	20	36	62
2000–2004	213	75	49	89
2005–2009	273	108	68	97
2010–2014	174	48	53	73

Notes: The data shown in the table refer to the building stock in 2015. Super high-rise buildings refer to the buildings over 60 meters in height. Data are summarized based on the Annual Report of Architectural Statistics 2016, which is released by the Tokyo Metropolitan Urban Development Bureau (Building Planning Division, Urban Architecture Department).

Table 9: Examining the changes in the housing structure.

	(1)	(2)	(3)	(4)
	"built-to-sell" / total housing starts		"built-to-sell" / "built-to-sell"+"built-to-rent"	
	Tokyo MA	Osaka MA	Tokyo MA	Osaka MA
C3 × yr 85–90	-0.278	-0.243	-0.332	-0.209
	(0.037)	(0.051)	(0.070)	(0.065)
yr 90–95	-0.201	-0.126	-0.283	-0.050
	(0.024)	(0.067)	(0.058)	(0.072)
yr 95–00	0.107	0.173	-0.038	0.194
	(0.016)	(0.049)	(0.057)	(0.062)
yr 00–03	0.169	0.188	0.020	0.189
	(0.046)	(0.050)	(0.061)	(0.060)
C8 × yr 85–90	-0.137		-0.101	
	(0.050)		(0.050)	
yr 90–95	-0.064		-0.027	
	(0.036)		(0.037)	
yr 95–00	0.127		0.106	
	(0.032)		(0.040)	
yr 00–03	0.149		0.120	
	(0.048)		(0.049)	
CC × yr 85–90	-0.105	-0.135	-0.079	-0.119
	(0.017)	(0.023)	(0.019)	(0.032)
× yr 90–95	-0.051	-0.108	-0.003	-0.042
	(0.011)	(0.026)	(0.015)	(0.032)
yr 95–00	0.077	0.059	0.103	0.096
	(0.012)	(0.022)	(0.016)	(0.031)
yr 00–03	0.109	0.126	0.123	0.164
	(0.017)	(0.028)	(0.023)	(0.034)
two-way FEs	Y	Y	Y	Y
N	3,882	2,933	3,882	2,933
R^2	0.370	0.334	0.440	0.297

Notes: *C*3: the three central wards of Tokyo/Osaka city; *C*8: the eight central wards of Tokyo city, by excluding the three central wards; *CC*: the city of Tokyo (excluding the eight central wards), or the city of Osaka (excluding the three central wards). Constant term coefficients are not reported. Heteroskedasticity robust standard errors (clustered at the municipality level) in parentheses.

Table 10: Changes in the types of housing starts before and after the bubble burst.

Region	Number of prefectures	$\frac{\text{"built-to-sell"}}{\text{"built-to-sell"}+\text{"built-to-rent"}}$		
		mean 1985–1990 (A)	mean 1995–2000 (B)	B – A
Tokyo MA	4	37.8%	68.1%	30.3%
Osaka MA	5	50.6%	61.8%	11.2%
The remaining pref.	38	36.0%	36.4%	0.4%

Notes: The reported data refer to the prefecture mean of the proportion of "built-to-sell" dwellings in the total floor area of housing starts of "built-to-sell" and "built-to-rent" dwellings in the 1985–1990 period (during the bubble boom) and the 1995–2000 period (after the bubble burst) for the specific groups.

Table A1: Summary statistics.

Variable	Obs.	Mean	Std.Dev.	Min.	Max.	Obs.	Mean	Std.Dev.	Min.	Max.
Panel A	Tokyo prefecture (cross-section)					Osaka prefecture (cross-section)				
Annualized pop. growth 1990–2015 (%)	49	0.608	0.504	-0.116	2.945	56	0.154	0.615	-0.904	1.974
Annualized pop. growth 1980–1990 (%)	49	0.277	1.368	-3.319	4.084	56	0.269	0.923	-1.212	3.251
NDPR 1990	49	1.022	0.354	0.038	1.531	56	1.014	0.272	0.097	1.372
NDPR 1980	49	1.023	0.304	0.058	1.433	56	1.007	0.251	0.131	1.285
Dist. from Tokyo/Osaka station (km)	49	18.7	12.9	0.0	44.9	56	13.6	10.0	0.0	45.5
Population per km^2 1990	49	10,259	4,990	1,091	20,506	56	8,522	5,337	977	19,552
Population per km^2 1980	49	10,390	5,772	956	22,710	56	8,592	5,770	706	21,244
Panel B	Tokyo MA (1980–2003)					Osaka MA (1980–2003)				
Pop. growth rate (%)	3,690	0.732	1.184	-4.836	8.045	2,806	0.212	1.332	-13.350	13.657
Total housing starts (mil. m^2)	3,882	0.188	0.161	0.011	1.160	2,933	0.126	0.119	0.013	1.624
Housing starts (m^2) per capita	3,876	1.071	0.422	0.246	8.706	2,931	0.948	0.479	0.247	5.998
Proportion "built-to-sell" (1)	3,882	0.294	0.167	0.000	0.897	2,933	0.298	0.182	0.000	0.890
Proportion "built-to-sell" (2)	3,882	0.527	0.216	0.000	1.000	2,933	0.541	0.240	0.000	1.000
Area of parks (ha)	1,913	86.5	87.6	0	681	1,712	87.1	122.6	0	977
Number of hospitals	1,913	9.1	7.8	1	46	1,712	8.8	7.8	1	46
Number of clinics	1,913	126.0	137.4	10	808	1,712	117.0	113.3	12	740
Number of criminal offenses perceived	1,913	3,659	3,642	0	29,155	1,712	3,015	3,295	175	30,917
abs(female pop./pop.−0.5)	1,913	.008	.006	0	0.034	1,712	0.014	0.010	0	0.094
Panel C	the city of Tokyo (1980–2003)					the city of Osaka (1980–2003)				
Pop. growth rate (%)	529	-0.221	1.210	-4.836	4.256	552	-0.104	1.033	-3.417	4.486
Housing starts (m^2) per capita	529	1.102	0.697	0.246	8.706	552	0.994	0.510	0.247	4.235

Notes: NDPR: Nighttime-to-daytime population ratio. Proportion "built-to-sell" (1): "built-to-sell" dwellings relative to the total housing starts (in m^2). Proportion "built-to-sell" (2): "built-to-sell" dwellings relative to the sum of "built-to-sell" and "built-to-rent" dwellings (in m^2). abs(female pop./pop.−0.5): the absolute value of (female population/population−0.5). Residential population data are obtained from the Residential Population Survey conducted by the Local Administration Bureau, Ministry of Internal Affairs and Communications. Data on daytime population are obtained from the Tokyo Prefectural Statistical Yearbook and the Osaka Prefectural Statistical Yearbook (various years). Data on housing starts are obtained from the Annual Report of Architectural Statistics, which is released by the Ministry of Land, Infrastructure, Transport, and Tourism (Department of Information Management, Policy Bureau); data for 2007 are missing. Data on the area of parks are obtained from the Prefectural Statistics by the Prefectural Statistical Bureau. Data on the number of hospitals and clinics are obtained from the Health Statistics Office, the Ministry of Health, Labour, and Welfare. Data on the number of criminal offenses perceived are obtained from the Metropolitan Police Department. A municipality's distance from the core of the central city is based on the longitude-latitude-based distance measure.