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Aging City and House Prices: Impact of Aging Condominium Stock on the Housing Market in the Tokyo- Metropolitan Area

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Based on an analysis of the housing market in the Tokyo metropolitan area, this study focuses on the external diseconomies of aging condominiums. It is possible that the quality of the condominium stock deteriorates more rapidly than that of ordinary housing. This deterioration in quality leads to a reduction in the quality of housing services received by residents. Furthermore, this worsening of the residential environment may lead to external diseconomies. We run hedonic models to identify the external diseconomies of aging condominiums in the residential market of the Tokyo metropolitan area. The results of our estimated models indicate that such external diseconomies occur for detached housing in areas where detached houses and condominiums coexist. These external diseconomies exert downward pressure on prices. Specifically, detached housing prices are lowered by around 3.2% for each 1% increase in the proportion of total building floor area in neighborhoods where condominiums were built before 1990. In other words, aging condominiums begin to generate diseconomies in their vicinities approximately 20 years after they were built.

Keywords

Aging condominium, External diseconomies, Hedonic approach, Depreciation, Vacant house

1. Introduction

Japan is experiencing an unprecedented combination of a shrinking and aging population, unlike any other major developed country (Saita et al., 2016; Tamai et al., 2017). These demographic changes are expected to significantly impact the cities and housing markets of Japan, especially considering the limited supply elasticity. These issues are already causing various problems.

The rapid urbanization driven by postwar economic growth and the plan to remodel the Japanese archipelago led to social problems in the 1970s and 1980s, such as housing shortages and soaring land prices. The housing demand from the baby boomer generation was a key factor behind the real estate bubble that emerged in the mid-1980s (Shimizu and Watanabe, 2010).

To meet the demand, there was a surge in constructing unit ownership types of apartment buildings or condominiums [1], particularly in the urban areas. Condominiums became a popular housing choice in Japan as a large number of homes could be supplied while efficiently utilizing limited land. They have now become a common form of housing in Japan, where space is limited.[2]

While condominiums have been the crucial residential infrastructure, and supported economic and population growth in a land-restricted country, they are now aging along with other public infrastructures. Consequently, the maintenance and management of aging condominiums are anticipated to become major challenges for Japanese society in the near future.

From an investment perspective, three factors contribute to the depreciation of condominiums, as pointed out by Diewert and Shimizu (2016a, 2016b). The first factor is physical depreciation, which refers to the deterioration of the functionality of buildings. The second is economic depreciation, which occurs when older buildings become outdated compared to newer ones with better features. The third factor is deterioration resulting from damage. Given the short lifespan of housing in Japan (see Diewert and Shimizu, 2015; Diewert et al., 2016), the depreciation rate of Japanese housing may be considered high.

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[1] “Condominiums” can be defined as corresponding to the “non-wood apartment building” category of owned residential property used in the Housing and Land Survey of Japan. According to the 2008 Housing and Land Survey, condominiums built from 1971 onward account for 97% of all stock, with 16% constructed between 1971 and 1980, 21% between 1981 and 1990, 33% between 1991 and 2000, and 27% between 2001 and September 2008.

[2] In the 2008 Housing and Land Survey, the proportion of households nationwide residing in multi-unit dwellings (either owned or rented) surpassed the 40% level (42.8%). The ownership rate was 79.4%, of which 4,539,300 residences (equivalent to 22%) were dwellings in non-wooden multi-unit buildings.

The Act on Building Unit Ownership grants condominium owners rights to both exclusive and common elements. Consequently, any replacement of a condominium building requires the approval of four-fifths of the residents, and dissolving the unit ownership relationship requires the consent of all owners.[3] This system results in significant social costs associated with upgrading or repairing damaged condominiums. Therefore, the depreciation resulting from the third factor (damage) is limited, which leads to prolonging building lifespans despite physical and economic deterioration (Diewert and Shimizu, 2016b). However, the unique characteristics of condominiums may still give rise to new social issues.

One potential consequence of aging condominium buildings is the possibility of external diseconomies that affect entire cities. As buildings deteriorate, cities become less attractive, potentially leading to "slumification" and increased external diseconomies in certain areas.

Housing vacancies are emerging as a critical issue in housing planning and policy formulation (Monkkonen, 2019; Nadalin and Igliori, 2017; Zhang et al., 2016). Developed countries like the United Kingdom (UK; Couch and Cocks, 2013), Germany (Bernt, 2019), and the United States (US; Wiechmann and Pallagst, 2012) have seen an increase in vacant properties due to factors such as population decline (Döringer et al., 2020) and stringent land-use regulations (Cheshire et al., 2018). While a reasonable vacancy rate exists in the real estate market (known as the natural vacancy rate; Rosen and Smith, 1983), an excessive increase in vacancies can lead to district deterioration (Morckel, 2014) and negatively impacts neighboring properties (Han, 2014; Whitaker and Fitzpatrick, 2013). For example, inland cities in the US have experienced a negative spatial effect due to vacant detached houses (Han, 2014; Mikelbank, 2008). When the housing stock ages or becomes vacant, it is expected to result in a decline in housing prices in the area. For instance, Mikelbank (2008) found that housing prices near vacant homes in Columbus, Ohio are US$4,000 lower compared to other homes.

The condominium stock of Japan, which is difficult to upgrade or damage, is growing, but at what rate? How will this growth impact neighborhoods and cities? The quality of the condominium stock may deteriorate faster than that of ordinary housing, thus reducing the quality of housing services for residents and potentially leading to external diseconomies. The impact of these diseconomies will likely be greater for properties adjacent to inferior condominium stock. Therefore, the deterioration of neighborhoods and cities will vary depending on the density and concentration of aging condominiums.

[3] An amendment to the law in 2014 made it possible to approve dissolution of the unit ownership relationship by means of a special majority vote for condominiums built according to old earthquake-proofing standards.

To address these issues, this study focuses on forecasting the impact of increasing aging condominiums in the Tokyo area. To the best of our knowledge, there are no previous studies that have conducted this type of analysis in Tokyo/Japan. This paper is organized as follows. Section 2 examines the future state of aging condominium stock in the Tokyo area (Tokyo, Chiba, Saitama, and Kanagawa prefectures) in quantitative terms. Section 3 measures the impact of external diseconomies on land prices caused by aging condominiums at the neighborhood level (500 × 500 m grid cell). Finally, Section 4 summarizes the findings and concludes the paper.

2. Aging Condominium Stock

2.1 Data

To analyze aging condominiums, we create a comprehensive condominium database due to limitations in the availability and accuracy of government housing stock-related statistics obtained from the Housing and Land Survey of the Japanese government. The sampling nature of the survey results in significant errors and lacks detailed statistics at the individual neighborhood level (e.g., data sorted by census districts like towns and streets) in the summary tables. Additionally, crucial information on the attributes of individual buildings is missing. To overcome these limitations, we have gathered micro-level data from private companies for this study. Specifically, we use data provided by the Real Estate Economic Institute and Recruit, as well as residential map data from Zenrin. Each data source serves a distinct purpose.

The Real Estate Economic Institute data provide information about the supply of new condominiums, which dates back to 1975.[4] From 1995 onward, detailed data on individual units are available. The institute collects this information taken from pamphlets created during the development stages of new buildings. As the database is compiled with these pamphlets, the data are organized by sale period,[5] but it is likely that these data are incomplete because some buildings were not surveyed.[6]

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[4] All data from 1975 onward are converted into electronic data. In total, we obtain data on 35,262 buildings.

[5] For example, in the case of a large-scale condominium with 300 dwellings, the units may be sold in multiple phases. If there are three phases, with 100 units sold in each phase, these phases would be treated as three different buildings in the database. Consequently, if the results are aggregated across the three phases, the number of buildings will be overestimated. Therefore, we convert such data into information for a single building by combining the Phases One to Three data.

[6] The Real Estate Economic Institute captures around 90% of the condominium supply in the Tokyo metropolitan area.

The building-related database of Recruit contains information collected since 1986 through their real estate listings magazine. Recruit publishes listings of both new and existing condominiums. If information about a property is included in an advertisement at least once, it is used in the condominium-related database. We use individual data from Recruit in this study, which helps us to supplement our Real Estate Economic Institute data with those from the period before 1975.[7] However, although it is possible to obtain the total number of units from the building information provided by Recruit, the total floor area is not recorded, which we obtain by matching the Recruit data with the residential map data of Zenrin.[8]

The combination of both databases provides us with data on 159,770 buildings (26,421 of which are common to both the Real Estate Economic Institute and Recruit data). To capture aging condominium trends, we analyze total building numbers, the number of units, and total floor area.[9]

2.2 Condominium Supply Trends in the Tokyo Area

There are numerous methods for estimating future stock levels, such as cohort analysis, which is used in population forecasts, or the build-up method, based on new supply flow and depreciation. For this study, we estimate the number of aging condominiums from 2015 onward by defining the useful life of buildings and assuming that they would not be replaced during that period of time.[10]

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[7] For example, if a condominium completed in 1970 was included in a listings magazine published in 2005, the building data would also be included. From 1986 onward, there are advertisements run for approximately 863,000 units, which enable us to obtain data for 52,187 buildings in the Tokyo metropolitan area. When integrating the two databases, we adjust for buildings that are found in both the Real Estate Economic Institute and the Recruit building data. Therefore, we remove the redundant data to avoid duplication.

[8] In the residential maps of Zenrin, building shapes are surveyed and organized as polygon data. Information on the number of floors is also collected for each building. Therefore, we estimate the total floor area of a building by multiplying the floor plate (obtained from the shape) by the number of floors.

[9] In the case of data that cannot be matched with Zenrin data, we perform estimates of the total number of units or total floor area. For example, if we only have the total number of units but not the total floor area, we infer the total floor area by using techniques such as multiplying the average unit floor area by the total number of units. Conversely, if we only know the total floor area and not the total number of units, we obtain the latter by dividing the total floor area by the average unit floor area.

[10] This is a highly plausible hypothesis, given that most condominium buildings are not being replaced for the reasons discussed earlier. In addition, most condominiums that are currently being replaced are special cases that were affected by the Great Hanshin earthquake in 1995 or buildings where surplus capacity is being sold off through redevelopment. Cases of replacement driven by population decline may be considered extremely rare. Given that the database used for the analysis covers around 90% of the assumed stock, we deem that this hypothesis would not lead to overestimation.

Prior to the analysis, we aggregate the number of buildings and units for condominiums, and the total floor area by period of construction until December 2015. In total, the condominium stock covered by the database represents 159,770 buildings, 9,445,656 units and 477,838,743 m^2 of floor space. In terms of spatial changes, if we take condominiums built before 1970 as a starting point, the stock grew rapidly: it tripled over the following five years, doubled during the five-year span ending in 1980, and increased by 1.6 times during the five-year period ending in 1985. Since then, the condominium stock has grown by only 1.2 times; however, it has increased at a significantly faster rate than the population or gross domestic product (GDP), both of which have slowed down during the same period of time.

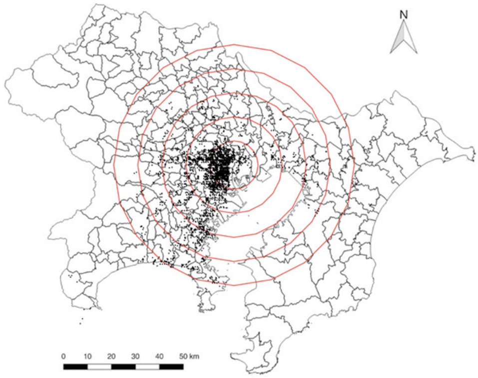
Figure 1 maps out the changes in condominium supply. As can be seen, condominium stock in the Tokyo area expanded rapidly toward the suburban areas throughout the 1980s and 1990s. Although condominiums were largely restricted to certain parts of central Tokyo in 1970, they spread out across an increasingly wider area through the 1980s, 1990s, and 2000s. To examine the distribution of aging condominiums across the region, we analyze the increase in their numbers based on distance zones. We focus on census districts within municipalities in the Tokyo metropolitan area. For the purpose of this research work, the Tokyo metropolitan area is defined as a perfect 70 km circle centered around the former Tokyo Metropolitan Government Building.[11]

A cross-tabulation by construction date and distance zone shows that almost 11% of the total floor area was supplied during the five years from 1981 to 1985. This period may be considered the first condominium boom period. Subsequent booms occurred following the collapse of the bubble, from 1996 to 2000 (15%) and 2001 to 2005 (18%).

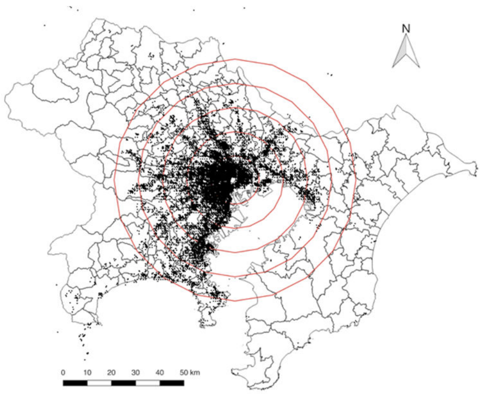
In spatial terms, the highest concentration of condominiums is in the 10–20 km zone from the center as of 2015, which accounts for 27% of the condominium stock. Although 75% of all stock is within 30 km of the center, there is a sizeable stock that should not be overlooked within 30–50 km (approx. 2.05 million units or 103.36 million m^2).

[11] This area comprises 14 wards (e.g., Chiyoda Ward) within 0–10 km; 27 wards and cities (e.g., Kawaguchi City, Ichikawa City, Ota Ward, Musashino City, and Kawasaki Ward in Kawasaki City) within 10–20 km, 48 cities and wards within 20–30 km (e.g., Omiya Ward in Saitama City, Hanamigawa Ward in Chiba City, Fuchu City, and Tsurumi Ward in Yokohama City), 47 wards and municipalities within 30–40 km (e.g., Nishi Ward in Saitama City, Kawagoe City, Chuo Ward in Chiba City, Kisarazu City, Tachikawa City, and Minami Ward in Yokohama City), 48 wards and municipalities within 40–50-km (e.g., Hanno City, Sakura City, Hachioji City, and Yokosuka City), 34 municipalities within 50–60 km (e.g., Gyoda City, Mobara City, Hinohara Village, and Hiratsuka City), and 41 municipalities within 60–70 km (e.g., Kumagaya City, Kamogawa City, Okutama Town, and Odawara City).

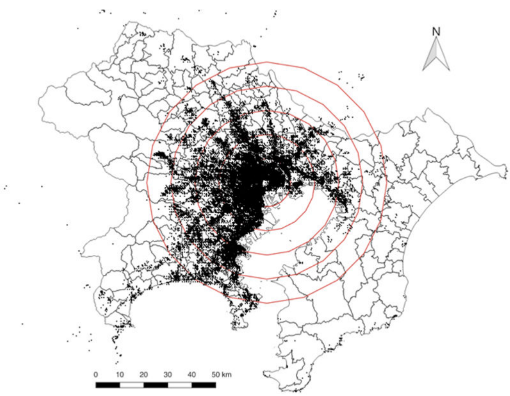
Figure 1 Condominium Supply Distribution by Period of Construction



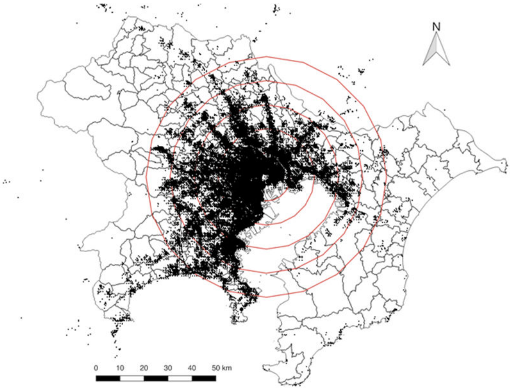
(1-a) Distribution of condominiums built before 1970



(1-b) Distribution of condominiums built before 1980



(1-c) Distribution of condominiums built before 1990



(1-d) Distribution of condominiums built before 2000

3. Neighborhood Externalities of Aging Condominiums

3.1 Estimation Model

This study uses a hedonic approach to estimate the external diseconomies and neighborhood externalities associated with aging condominiums.

The hedonic approach is a method that expresses the correspondence relationship between price and quality as a linear vector and analyzes the formation structure by estimating a price function. This approach has a wide range of applications, including to perform quality adjustments for price indexes, and estimate the economic value of non-market goods.

We wish to measure neighborhood externalities associated with the accumulation of aging condominiums. The most significant problem when considering this issue is that there is no precise definition of aging condominiums. Therefore, we analyze the impact on housing prices by specifying year t as the estimation time and diachronically changing the number of years T since the building was constructed.

When attempting to estimate neighborhood externalities associated with the accumulation of aging condominiums with a hedonic function, there is the tacit assumption that the market participants will verify these externalities, which will have an effect on location behavior. Accordingly, in this study, we use the proportion of the total building floor area within a 500 × 500 m grid cell[12] (block) in 2010 that is accounted for by condominiums built prior to year t as

[12] Grid cell statistics are obtained from the census. The subregional data of the census are generated on a 500-m grid. The 500-m unit is chosen to ensure consistency with the census statistics.

an indicator. In other words, we determine the impact of aging by assessing the proportion of aging condominiums within a specific locality.

Furthermore, to estimate the effect that the ratio of aging condominiums within a 500 × 500 m grid cell has on housing prices, it is necessary to first verify the difference between areas with and without condominiums within that grid cell. In areas with condominiums, it is necessary to control for whether they are conveniently located and, therefore, housing prices are inherently high, or whether the presence of condominiums has inherent external diseconomies, which has the effect of lowering housing prices.

To identify the impact of aging condominiums, we mitigate their influence by incorporating an area dummy variable for regions with a supply of condominiums. In other words, to assess the magnitude of price disparities influenced by the accumulation of aging condominiums within a specific area, we initially neutralize the effect of areas predestined for condominiums before year T through the use of an area dummy variable.

In addition, as a means of checking robustness, we restrict the determination of external diseconomies from aging condominiums to areas where condominiums are present, and measure the external diseconomies associated with the presence of aging condominiums. The measurement method is as follows.

First, we derive the effect of the presence of condominiums (Model 1).

$$\begin{aligned} \mathrm{Log}P_{(i,j,t)} = a_0 + a_1 O_{T=2010,i} + \sum_m a_2^m \, logX_{t,j}^m + \sum_n a_3^n \, MK_{t,j}^n \\ + \sum_q a_4^q \, NE_{t,k}^q + \sum_s a_5^s H_{t,k}^s + \varepsilon_{(i,j)} \end{aligned} \tag{1}$$

Here, the price of detached housing i in area j in period t is denoted by $P_{(i,j,t)}$, with area j being a 500 × 500 m grid cell. $O_{T=2010,\,j}$ is a factor that reflects the effect of aging condominiums, with 2010 as the starting point. More specifically, we examine the effect of the presence of condominiums by analyzing condominium stock built prior to 2010 (T=2010) and investigating the total condominium floor area (i.e., for all condominiums that existed in 2010) as a proportion of the total building floor area because the detached house prices aggregated here are based on cross-section data that cover Tokyo in 2010. This indicates the strength of the price-lowering effect when the ratio of condominiums to buildings within a small area increases. X are the attributes of detached housing (e.g., time to the nearest station, building age, occupied area), *NE* is the neighborhood effect within area *k*, and *H* is a proxy variable for examining the attributes of the buyer who is purchasing a given property.

Next, we examine the cohort effect by period of construction (Model 2). Here, $O_{T=2010,\,j}$ is changed to $O_{Tt,\,j}$. In other words, we examine the impact on detached housing prices by investigating various periods that begin a specified amount of time t prior to 2010. For example, if t=10, we examine the period up to 10 years before 2010 (i.e., as far back as 2000) to determine the proportion of the total building floor area in a given district that is accounted for by the total floor area of condominiums constructed in that period of time. If t=20, we examine the proportion of the total building floor area in a given district that is accounted for by the total floor area of condominiums constructed 20 years or more prior to 2010 (i.e., as far back as 1990). The assumption is that when t is varied in this way, we can determine how far back one must investigate, prior to 2010, to find a negative impact on detached housing prices.

$$\begin{aligned}\log P_{(i,j,t)} = a_0 + \sum_{l} a_1^l\, O_{Tt,j} + \sum_{m} a_2^m\, logX_{t,j}^m + \sum_{n} a_3^n\, MK_{t,j}^n \\ + \sum_{q} a_4^q\, NE_{t,k}^q + \sum_{s} a_5^s H_{t,k}^s + \varepsilon_{(i,j)}\end{aligned} \quad (2)$$

Using this model enables us to determine when consumers became aware of condominium externalities. That is, assuming that consumers have a medium- to long-term perspective, they may consider that there is the strong possibility that the environment in which condominiums are located will deteriorate eventually, regardless of whether the condominiums have actually aged. In that case, from the time they are built, condominiums may lower the price of real estate in their area. Furthermore, if the impact of condominiums on the surrounding environment is based solely on their disaster-resistance capabilities (or lack of them), then it is likely that there will be a marked difference for condominiums built after 1982, the year in which new earthquake-proofing standards were adopted. However, if the impact is not based solely on disaster-resistance capabilities, then their influence on real estate asset values should not be defined by the change in standards in 1982.

We examine the effect of a given proportion of the total floor area within the condominium stock that is constructed in a specific time period for different time periods. Specifically, we determine the effect of the proportion of the total building floor area in a given grid cell that is accounted for by condominiums built in three periods: before 1990, from 1991 to 2000, and from 2000 to 2010. This enables us to examine the housing price-lowering effect according to the degree of aging of the condominiums.

After evaluating the presence of an external effect for condominiums built before a specific time frame in Model 2, we proceed to estimate the decrease in price associated with the floor area of condominiums constructed prior to year T (Model 3), while also ensuring the reliability of the findings. We verify the extent of external diseconomies associated with aging condominiums by adding variables such as the effective floor area ratio (the total building floor area within a district divided by the land area), total building floor area, total apartment floor area, total floor area of non-wood apartment buildings, and the total floor area of wood apartments.

3.2 Data

For the purpose of calculating the model, we collect the condominium, detached house price, building and market attributes, and surrounding environment variable.

3.2.1 Condominium Data ($O_{Tt,i}$)

To analyze the condominium data, we use the Tokyo metropolitan area condominium database that we constructed, as described previously. We aggregate data by condominium age in 500 × 500 m grid cells—that is, by the degree of aging (number of years since construction) at the time of analysis.

3.2.2 Detached House Price Data ($P_{(i,j,t)}$), Building Attributes ($X_{t,j}^{m}$), and Market Attributes (MK)

To analyze housing price data, we collect data on transactions concluded during the three-year period from January 2009 to December 2011 in the 23 wards of Tokyo and the Tama region ($P_{(i,j,t)}$). The primary data information source is detached house price information from a weekly residential real estate listings magazine published by Recruit. This magazine supplies information about quality and asking price on a weekly basis. For this study, we use price information published in the magazine at the point when the listing was removed because the property was sold.

3.2.3 Surrounding Environment Variable ($NE_{t,k}^{q}$, $H_{t,k}^{s}$)

When estimating a hedonic function for data that cover a large area, it is necessary to account not only for the land and building attributes but also for spatial disparities (Chen and Rosenthal, 2008; Yasumoto et al., 2014). The most representative spatial disparity-related factor in the surrounding environment is the accessibility of public transportation where housing is located. In the Tokyo area, which is served by an extensive train network, housing prices vary significantly based on the convenience of the nearest station, as measured by "time to the nearest station" (*TS*) and "time to the city center" (*TT*).

For the surrounding environment attributes, we create a surrounding environment indicator for housing located within a 500 × 500 m grid cell. Specifically, we create a variable based on three factors: urban planning restrictions (based on public regulations), the urban environment (based on the usage status of land and buildings), and household attributes (based on census data).

First, for urban planning restrictions, we use an urban planning area dummy,[13] the legally designated floor area ratio, and building-to-land ratio. For the land and building usage conditions, we use individual building data from the Tokyo Metropolitan Land Use Survey. We research conditions in 2006 for the wards of Tokyo and 2007 for the Tama region and summarize data for a total of 2,762,226 buildings in the form of geographic information system data, including data on the building usage status, building area, and structure. Then, for each 500 × 500 m grid cell, we calculate the number of buildings, average area of one floor for each building and standard deviation, average building height (number of floors) and standard deviation, total industrial use floor area, and floor area ratio of wood buildings (i.e., the proportion of the total floor area that is accounted for by the floor area of wood buildings).

As average floor area is a variable that is related to the level of build-up or density, we assume that the standard deviation of the building floor area can serve as a proxy variable for the urban landscape in a given neighborhood. The same applies to building height. In other words, in neighborhoods where there is a small standard deviation of the floor area and building height, the urban landscape should be more orderly. Furthermore, we consider that the floor area ratio in wood buildings would be closely related to the probability of building collapse or fire in the event of a disaster.[14]

Regarding the census data, we use the number of households with individuals aged 75 years or over and the number of office workers (specialized/skilled workers + workers in management positions + clerical workers). The number of office workers is a strong proxy for education level and income within a given area because, generally speaking, specialized/skilled workers, workers in management positions, and clerical workers have a higher level of education and average income than workers in other categories.[15] The summary statistics for the key variables are shown in Table 1.

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[13] For urban planning areas, we create three dummy variables related to residential, commercial, and industrial uses. For the residential-use dummy, we combine Category 1 exclusive low-rise, Category 2 exclusive low-rise, Category 1 exclusive medium- and high-rise, Category 2 exclusive medium- and high-rise, Category 1, Category 2, and quasi-residential area dummies. For the commercial-related use dummy, we combine neighborhood commercial and commercial areas, whereas for the industrial-use dummy, we include quasi-industrial, industrial, and exclusive industrial areas.
[14] The Tokyo earthquake risk map is calculated by using these data as the primary data sources. The probability of collapse and fire is obtained based on building structure and the level of build-up. As these are represented as indexes, it can be difficult to interpret them for the purposes of analysis; however, the fact that the indexes calculated here involve continuous quantities simplifies the interpretation.
[15] It has been pointed out that the estimation of hedonic models faces the problem of "omitted variable bias" when not controlling for buyer attributes (Ekeland et al., 2004).

Table 1 Summary Statistics

Variable	Mean	Std. Dev	Min	Max
P: Detached house price (10,000 yen)	4848.71	2255.80	460.00	29900.00
S: Structure area (square meter)	96.65	27.91	30.56	819.15
L: Land area (square meter)	91.05	36.85	30.02	485.68
A: Age of building (year)	13.57	7.69	0.00	36.46
W: Road width (square meter)	5.15	2.46	2.10	40.00
TS: Time to station (minutes)	10.31	5.50	0.00	28.00
TT: Time to Tokyo station (minutes)	20.72	10.95	1.00	79.00
FAR: Floor area ratio (%)	168.39	72.78	60.00	800.00
LAR: Building to land area ratio (minutes)	56.31	10.17	20.00	100.00
Or(-90): "Ratio of condominiums built before 1990 (share: 0-1.000)	0.04	0.05	0.00	0.47
Or(91-00): Ratio of condominiums built from 1991-2000 (share: 0-1.000)	0.03	0.03	0.00	0.55

3.3 Hedonic Function Estimation Result

Before estimating the hedonic function, we examine the data characteristics. First, the average detached housing price is 48.5 million yen (US $1 = 150 yen, or US $320,000), with a minimum of 4.6 million yen (US $30,600) and a maximum of 299.9 million yen (US $30,600). There is significant variation, with a standard deviation of 22.58 million yen (US $2,000,000). Therefore, housing includes everything from “bargain properties” to “billionaire homes”. The occupied floor area (S) is on average 96.65 m^2, with a minimum of 30.56 m^2 and a maximum of 819.15 m^2. This means that housing ranges widely from so-called “tiny houses” to large homes.

The average building age (A) is 13.57 years old, primarily due to the existence of a substantial number of new properties. However, there are some buildings that are over 36 years old, which result in a distribution that skews heavily toward the right (Table 1).

In terms of the distribution of the condominiums based on period of construction (i.e., the total floor area in each 500 × 500 m grid cell in the

Fuerst and Shimizu (2016) add a hedonic model by investigating buyer income and family characteristics through a questionnaire survey and clarify its significance. In this study, we use the aggregate measure of the neighborhood in which the buyer purchased a home as a proxy variable as buyer characteristics for individual transactions are not available,.

analysis data that are accounted for by condominium floor area, based on construction time), only 9,252 (15%) of the 62,480 condominiums are in areas with condominiums built before 1970. The figures rise to 28,311 for condominiums built prior to 1980, 40,382 for condominiums built prior to 1990, and 47,581 for condominiums built prior to 2000.

In addition, with regard to the distribution of the proportion of the floor area of the condominiums according to the period of construction, the average is 2.4% for condominiums built prior to 1970, and 6% at the 95th percentile point. The average value changes as follows: 4.3% for pre-1980 condominiums, 5.8% for pre-1990 condominiums, and 7% for pre-2000 condominiums. Although a distribution of the proportion of the floor area of 10% or more is only around 1% for pre-1970 condominiums, the percentage increases to around 10% for pre-1980 and pre-1990 condominiums, and reaches 25% for pre-2000 condominiums.

The hedonic function estimation results are shown in Tables 1 and 2. It can be observed that when the occupied area (S), land area (L), and front road width (W) are increased, the housing prices also increase. Conversely, S, L and W decrease with increase in A, TS, and TT. In addition, prices are lower in areas served only by buses, and relatively lower for wood structures or properties with a private road. Transaction prices are relatively higher for properties that have been on the market for a long period of time (MR). These findings are consistent with previous studies and the rule of thumb for housing prices.

Next, regarding the urban planning area dummy for the surrounding environmental attributes (NE), the results show that prices are relatively high for housing in residential usage areas, whereas commercial and industrial areas have a price-lowering effect. Residential environments in commercial and industrial areas tend to be lower in quality, which is likely to lower property prices. Furthermore, higher floor area ratios are found to have a negative and significant effect because buyers assume that the residential environment will be poor. However, no significant results are obtained for the effect of the building-to-land ratio.

In terms of the average building floor area per the 500 × 500 m grid cell, we find that larger average floor areas have a price-raising effect, but when variation (i.e., standard deviation) becomes significant, larger average floor areas lower prices. The most likely reason is that greater variations in floor area mean that the neighborhood does not have an orderly appearance, which is detrimental to the local urban landscape. In addition, price levels tend to be lower in areas with a high proportion of wood buildings. This phenomenon can be attributed to the increased probability of collapse due to disasters and fires, as well as the presumed lower quality of the residential environment, which is often characterized by smaller average floor areas and higher proportions of wood buildings. Furthermore, in areas where factories account for a large amount of the floor space, the price-lowering effect tends to be stronger than the effect of urban planning.

In terms of buyer attributes, in areas where there are many elderly residents (75 years old and over), prices are relatively low; conversely, in areas where there are many specialized/skilled workers, prices are relatively high. "Specialized/skilled workers" is an employment category in the national census that is known to have a comparatively high income level. Therefore, this variable may be considered a proxy for the income level of the residents in the area.

To account for territorial effects that are not captured by these variables, we introduce longitude and latitude coordinates and their squares, but none of the results are significant.[16]

3.4 Effect of External Diseconomies Associated with Aging Condominiums

First, Model 1 analyzes the externality of the effect associated with the presence of condominiums (Model 1 in Table 2). Specifically, we examine the effect of the proportion of the total building floor area in a given 500 × 500 m grid cell that is accounted for by condominiums supplied until 2010. We refer to this as the "condominium effect". The estimation results show that when the ratio of the condominium floor area to the total building floor area increases by 1%, there is a corresponding detached house price-suppressing effect of –1.5%.

When the effect estimation results are considered by age (i.e., the condominium development period), as shown in Model 2 of Table 2, the price-lowering effect is the highest in the case of condominiums supplied before 1990 (–4.6%). This result is statistically significant. No significant results are obtained for the effect of condominiums supplied from 1991 to 2000. With regard to these findings, Shimizu et al. (2014) point out that the depreciation curve of the condominium price over time between 10 to 23 years after construction becomes steeper. Assuming that it takes some time for the decline in the convenience of condominiums to impact the surrounding area, it makes sense that the pre-1990 condominium stock has a greater negative effect.

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[16]The estimation method, known as the parametric polynomial expansion model, was proposed by Jackson (1979). The method increases the flexibility of fit based on a higher-order polynomial equation with the use of coordinate values (latitude and longitude). The square and cube of the coordinate values and a multidimensional cross-term are introduced into the explanatory variable. When determining an effect that has strong territoriality, such as the effect of aging condominiums, it is necessary to avoid the issue of omitted variable bias as much as possible. Therefore, we factor in the coordinate values.

Table 2 Estimated Results of Aging Condominium Effects

	Tokyo: include: Ratio of Condominium=0				**(Condominium area) Ratio of Condominium>0**	
	Model.1 Existing effect		**Model.2 Time effect**		**Model.3 Time effect**	
	Coefficient	*t*-value	Coefficient	*t*-value	Coefficient	*t*-value
Constant	-57572.91	-28.71	-57302.06	-28.53	-61060.46	-24.04
O: Condominium effect						
Effect of existing condominiums	**-0.015**	**-1.79**	-	-	-	-
Or(-90):Ratio of condominiums built before 1990	-	-	**-0.046**	**-3.33**	**-0.032**	**-2.31**
Or(91-00):Ratio of condominiums built from 1991-2000	-	-	**-0.007**	**-0.32**	**-0.008**	**-0.42**
Zone fixed effects	0.042	21.45	0.042	21.59	-	-
***X*: Building Characteristics**						
S: Structure area	0.584	142.25	0.584	142.29	0.580	134.40
L: Land area	0.295	101.97	0.295	101.96	0.294	95.43
A: Age of building	-0.065	-112.72	-0.065	-112.75	-0.060	-92.00
W: Road width	0.033	14.03	0.033	14.02	0.028	10.69
TS: Time to station	-0.075	-49.51	-0.075	-49.58	-0.080	-47.71
Bus: Bus zone dummy	-0.074	-19.04	-0.074	-19.02	-0.099	-17.42
NR: Number of rooms	-0.005	-7.34	-0.005	-7.35	-0.003	-3.90
WD: Wood dummy	-0.073	-21.57	-0.073	-21.61	-0.069	-19.54
CD: Car garage dummy	0.015	4.15	0.015	4.13	0.012	3.26
PR: Private road dummy	-0.002	-1.07	-0.002	-1.06	-0.002	-1.10

(Continued…)

(Table 2 Continued)

	Tokyo: include: Ratio of Condominium=0				(Condominium area) Ratio of Condominium>0	
	Model.1 Existing effect		Model.2 Time effect		Model.3 Time effect	
	Coefficient	*t*-value	Coefficient	*t*-value	Coefficient	*t*-value
***MK*: Market**						
MOT: Market on time (×1000)	0.199	27.69	0.199	27.69	0.190	24.21
***NE*: Neighborhood characteristics**						
TT: Time to Tokyo station	-0.100	-17.460	-0.099	-17.40	-0.121	-19.36
Urban zoning dummy: residential area	0.006	1.900	0.006	1.88	0.001	0.16
Urban zoning dummy: commercial area	-0.011	-2.580	-0.011	-2.58	-0.005	-1.13
Urban zoning dummy: industrial area	-0.012	-3.470	-0.012	-3.45	-0.016	-4.18
FAR: Floor area ratio	-0.021	-12.420	-0.021	-12.36	-0.017	-9.71
EFAR: Effective Floor area ratio	0.029	11.830	0.028	11.78	0.016	6.18
LAR: Building to land area ratio	0.003	0.270	0.003	0.26	-0.061	-4.50
500 m grid cell: average floor number	-0.006	-1.670	-0.006	-1.65	0.001	0.28
500 m grid cell: floor area / average	0.117	6.400	0.117	6.38	0.238	8.41
500 m grid cell: floor area / standard deviation	-0.018	-4.180	-0.018	-4.14	-0.022	-3.57
500 m grid cell: wood floor ratio	-0.087	-4.300	-0.089	-4.38	-0.080	-2.75
500 m grid cell: industrial area ratio	-0.005	-12.420	-0.005	-12.44	-0.006	-13.19
***HH*: Household characteristics**						
500 m grid cell: 75 over age + ratio	-0.015	-13.85	-0.014	-13.75	-0.016	-14.27
500 m grid cell: specialized skill worker ratio	0.050	38.37	0.050	38.43	0.044	31.69

(Continued…)

(Table 2 Continued)

	Tokyo: include: Ratio of Condominium=0				(Condominium area) Ratio of Condominium>0	
	Model.1 Existing effect		Model.2 Time effect		Model.3 Time effect	
	Coefficient	*t*-value	Coefficient	*t*-value	Coefficient	*t*-value
Spatial coordinates						
Longitude	761.540	28.31	757.392	28.11	749.098	21.96
Latitude	246.009	9.73	247.054	9.77	489.188	15.72
Longitude square	-2.725	-28.27	-2.710	-28.07	-2.680	-21.93
Latitude square	-3.463	-9.78	-3.477	-9.82	-6.863	-15.74
***D*: Time fixed effects #**	Yes		Yes		Yes	
Other dummy variables						
Municipality dummy ##	Yes		Yes		Yes	
Railway line dummy ###	Yes		Yes		Yes	
Number of observations:	62,478		62,478		49,870	
Adjusted R-square	0.852		0.852		0.843	

Notes: #2010 & 2011 time dummies, ##47 municipalities dummies, ###27 railway line dummies

The fact that only condominiums supplied before 1990 have a downward impact on real estate values in the area is likely to signify that buyers only begin to view condominiums to have a negative effect once they reach a certain age. Furthermore, it is clear from this empirical analysis that all condominiums at a certain age have a negative impact on the surrounding area, not just those built according to old earthquake resistance standards.

Model 3 examines the effect of condominium stock age solely in areas with a supply of condominiums. Although the results obtained are similar to those in Model 2, the price-lowering effect of condominiums built prior to 1990 declines from –4.6% to –3.2%.

To check the robustness of Model 3 in Table 3, we re-estimate the model with the analysis restricted to areas with a supply of condominiums with variables added that are assumed to influence the proportion of aging condominiums. More specifically, in Model 3, we restrict the effect to the proportion of condominiums built before 1990 (Model 4-1). Additionally, we consider the effective floor area ratio in Model 4-2, total building floor area in the neighborhood in Model 4-3, total apartment floor area in the neighborhood in Model 4-4, total floor area of non-wood apartments in the neighborhood in Model 4-5, and the total floor area of wood apartments in the neighborhood in Model 4-6.

The effect of condominiums built before 1990 is –4.2% in the baseline model, but the aging condominium effect becomes –3.2% when the effective floor area ratio and total building floor area are factored in, with both results being statistically significant. No significant effects are found for apartments, non-wood apartments, or wood apartments, so the aging condominium effect is equivalent to the baseline model.

In addition, we verify the robustness of Model 3 by examining the old condominium effect by space and the non-linearity of the elasticity of value. The supply of condominiums in Tokyo initially started in the central region and later expanded to the suburbs. Additionally, there may be a disconnect between the detached housing areas in the metropolitan and suburban Tokyo markets. Therefore, we introduce a cross effect that considers the ratio of old condominiums per j grid cell and region zone, as shown in Equation (3). The region L is estimated for three different distance zones (30 km, 40 km, and Figure 1) with the Tokyo Special District and Tokyo Station as the center points. The results are compared with the base model estimated as Model 4 and organized as Models 5-1, 5-2, and 5-3 (Table 4). First, the elasticity of the aging ratio for each block is estimated to be -12.7%, while the cross effect for the Tokyo metropolitan area is significantly estimated at +11.4%. In other words, the elasticity in central Tokyo is lower by -1.3% (-12.7%+11.4%) even if the age of condominiums in the region increases. However, in the 30 km zone and the suburbs, the elasticity is -5.2% (-4.2% -1%), and -35.2% (-0.7% -34.5%) in the 40 km zone, which are extremely high, although not statistically significant.

The 40 km zone is not estimated at a statistically significant level because the supply of condominiums expanded only recently and the number of old condominiums is still low. Meanwhile, the 30 km zone, which is within an hour from central Tokyo and developed as a zone for Tokyo bedroom towns, has a large stock of condominiums, which indicates the presence of a serious problem.

$$\log P_{(i,j,t)} = a_0 + \sum_l a_1^l (O_{Tt,j} \times zone_L) + \sum_m a_2^m \log X_{t,j}^m + \sum_n a_3^n MK_{t,j}^n + \sum_q a_4^q NE_{t,k}^q + \sum_s a_5^s H_{t,k}^s + \varepsilon_{(i,j)} \tag{3}$$

Next, one may be question the linear increase in the ratio of deteriorated condominiums and its constant effect on prices. However, there is no issue with the calculation as an elastic value, because prices are ascertained as logarithms in relation to ratios, and the aging ratio is also examined in terms of ratios. In this study, the aging ratio is logit transformed ($\log(O_{Tt,j}/(1-O_{Tt,j}))$ as in Equation (4) for confirmation purposes to check the change in elasticity values (Model 6). Model 6-1, which has an added logit-transformed old-age ratio variable $O_{Tt,j}$, does not allow for statistically significant estimation. In Model 6-2, where $O_{Tt,j}$is introduced simultaneously, we find that the detached home price depreciation rate is reduced by +1% as $O_{Tt,j}$ increases, based on a base of -23.7%.

$$\log P_{(i,j,t)} = a_0 + \sum_l a_1^l (O_{Tt,j}, Logit(O_{Tt,j}) + \sum_m a_2^m \log X_{t,j}^m + \sum_n a_3^n MK_{t,j}^n + \sum_q a_4^q NE_{t,k}^q + \sum_s a_5^s H_{t,k}^s + \varepsilon_{(i,j)} \tag{4}$$

To summarize the above findings, external diseconomies for detached housing resulting from aging condominiums occur in areas where detached houses and condominiums coexist, and these exert a downward pressure on prices. Detached housing prices are lowered by around 3.2% for each 1% increase in the proportion of the total building floor area in a neighborhood where the condominiums were built before 1990. In other words, aging condominiums begin to generate diseconomies in their vicinity around 20 years after they are built (i.e., 1990 or earlier in our study).

Table 3 Estimated Results with Block Building Conditions

	Model 4-1 Base Model (BM)	Model 4-2 BM+EFAR	Model 4-3 BM+Total floor area	Model 4-4 BM+Apartment floor area	Model 4-5 BM+Non-wood floor area	Model 4-6 BM+Wood floor area
Constant	-60382.230 ***	-61033.490 ***	-61033.490 ***	-60301.850 ***	-60295.850 ***	-60682.930 ***
Or(-90):Ratio of condominiums built before 1990	**-0.043** ***	**-0.032** ***	**-0.032** ***	**-0.043** ***	**-0.043** ***	**-0.042** ***
FAR: Floor area ratio	-0.017 ***	-0.017 ***	-0.017 ***	-0.017 ***	-0.017 ***	-0.016 ***
LAR: Building to land ratio	-0.062 ***	-0.061 ***	-0.061 ***	-0.062 ***	-0.062 ***	-0.063 ***
EFAR: Effective floor area ratio	-	0.016 ***	-	-	-	-
Total floor area (×1000)	-	-	0.633 ***	-	-	-
Apartment floor area (×1000)	-	-	-	-0.105 ***	-	-
Non-wood floor area (×1000)	-	-	-	-	-0.114 ***	-
Wood floor area (×1000)	-	-	-	-	-	0.038 ***
***MK*: Market**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**
***NE*: Neighbourhood characteristics**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**
***HH*: Household characteristics**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**
Spatial coordinates	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**
***D*: Time fixed effects #**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**
Other dummy variables	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**
Number of observations:	49,870	49,870	49,870	49,870	49,870	49,870
Adjusted R-square	0.8425	0.8425	0.8427	0.8427	0.8425	0.8426

Notes: # 2010 & 2011 time dummies, 47 municipalities dummies, 27 railway line dummies
*** 1% significance, **5%significance, and * 10% significance

Table 4 Estimated Results with Spatial and Non-linear Effects

	Model 4-1 Base Model (BM)	Model 5-1 BM+Tokyo Special District	Model 5-2 BM +30 km zone	Model 5-3 BM +40 km zone	Model 6-1 Logit transformation	Model 6-2 BM +Logit transformation
Constant	-60382.230 ***	-60259.940 ***	-60388.260 ***	-60011.030 ***	-70733.650 ***	-68480.270 ***
Or(-90):Ratio of condominiums built before 1990	**-0.043** ***	**-0.127** ***	**-0.042** ***	**-0.007**	-	**-0.237** ***
Logit Or(-90)	-	-	-	-	**0.000**	**0.010** ***
× Tokyo Special District	-	**0.114** ***	-	-	-	-
× 30 km zone from CBD dummy	-	-	**-0.010** ***	-	-	-
× 40 km zone from CBD dummy	-	-	-	**-0.345** ***	-	-
× Logit Or(-90)	-	-	-	-	-	-
FAR: Floor area ratio	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**
LAR: Building to land ratio	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**
***MK*: Market**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**
***NE*: Neighborhood characteristics**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**
***HH*: Household characteristics**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**
Spatial coordinates	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**
***D*: Time fixed effects** #	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**
Other dummy variables	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**
Number of observations:	49,870	49,870	49,870	49,870	49,870	49,870
Adjusted R-square	0.8425	0.8426	0.8425	0.8427	0.8451	0.8454

Notes: #2010 & 2011 time dummies, 47 municipalities dummies, 27 railway line dummies
*** 1% significance, **5%significance, and * 10% significance

4. Conclusion

In recent years, the appearance of large numbers of vacant houses has become a social issue in Japan, especially in regional cities. This has distorted the distribution of resources in the housing market, which is a spatial market. Although it is expected that this distortion will be resolved via market mechanisms, there are limits to the capabilities of the market, and policy-based intervention has become necessary.

The presence of unmanaged housing, such as vacant homes, causes external diseconomies in the city where such housing is located. The area in the vicinity of vacant homes deteriorates, which has a ripple effect that is detrimental to the city as a whole. For example, if condominiums can be demolished after they are abandoned, the land can be converted to meet new space demand. However, condominiums that are legally difficult to demolish will continue to exist in the area even though they have deteriorated and their functions have declined significantly.

The problems of vacant houses and distorted resource distribution in the housing market are now becoming more severe in regional cities, and with the passage of time, they will also have an effect on the major urban centers. The issue is likely to be particularly serious in the Tokyo metropolitan area from 2030 onward.

In Tokyo and other major cities, there has been a large supply of condominiums since 1970. Given that it is more difficult to replace or convert the use of these condominiums than is the case for normal detached housing, the condominiums will make adjusting resource distribution a more difficult policy issue. That is, the vacant house problem that is already occurring in regional cities will expand to include condominiums in major cities, which will likely make the problem more severe. This study has made it clear that the problems associated with aging condominiums will increase at an accelerating rate over time. In Japan, the importance of the management of condominiums has been prioritized and policy measures have been implemented to deal with the aging of condominiums.[17]

However, there are many challenges remaining. This study has analyzed the impact of the aging of condominiums on the local housing stock market. In the future, the aging of the housing stock and the population will occur

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[17] For the government to intervene in the market, the existence of "negative externalities" in the market must be clear. The authors have participated in discussions with the Japanese government and presented the results of this study. A series of results from this research have contributed substantially to the revision of the “Law Concerning the Promotion of Proper Condominium Management and Facilitation of Reconstruction of Condominiums (Law No. 62, 2020)”; see https://elaws.e-gov.go.jp/document?lawid=412AC1000000149.

simultaneously. Population aging is also expected to have a negative impact on the housing market. Extending the model to take these issues into consideration is a topic for future work.

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