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Essays on the Real Estate Market and Natural Experiments in Japan

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1. Introduction

This dissertation aims to estimate the impact of exogenous shocks on the real estate market in Japan. Exogenous shocks are single and large-scale events that are unpredictable and beyond our control. Exogenous shocks used in this dissertation are the inheritance the 2015 taxation reform, the COVID-19 outbreak in 2020, and the Great East Japan Earthquake in 2011. By using exogenous shocks, it is possible to overcome endogeneity issues that complicate the analysis of causal relationships in observational data. This is because the shocks are not affected by the behavior of individuals within the system. This is similar to the concept of randomized experiments, in which researchers randomly assign treatment to some individuals but not others. Using exogenous shocks allows for a clearer understanding of causal relationships, which is essential for policy evaluation and policy recommendations.

This dissertation is structured by three independent empirical studies based on Japanese real estate data. Each chapter addresses different exogenous shocks. In Chapter 2, I focus on the effect of the 2015 inheritance taxation reform on the rental housing market in Japan. This reform substantially increased the amount of tax levied on large inheritances. This potentially incentivized people to build inexpensive low-rise apartments to save on taxes, which increased the number of low-quality apartments and severely distorted the rental market. This chapter investigates the effect of the inheritance tax reform on housing rents. Using the difference-in-differences method, I reveal that the housing rents for wood or light steel-framed apartments decreased by 1.3% after the taxation reform. Moreover, the results indicate that while the housing rents of slightly older housing belonging to the treatment group decreased, the housing rents of new housing belonging to the treatment group did not change.

Chapter 3 investigates the COVID-19 outbreak. The outbreak has changed people's behavior, with people in Japan being encouraged to avoid unnecessarily outings and shift toward teleworking. Consequently, train congestion during commuting hours significantly reduced. This shift to teleworking may have reduced demand for proximity to urban centers and increased demand for housing in the suburbs. This shift to teleworking may have also been accompanied by a change in residential amenity preferences. This chapter uses rental apartment data to analyze whether demand for proximity to city centers and demand for floor space changed before and after the COVID-19 pandemic. We found that housing rents in the center of the Tokyo Metropolitan Area decreased, and increased in suburban areas, consistent with the theoretical predictions by the canonical closed-city monocentric city models. Additionally, rents increased for properties with larger private spaces after the COVID-19 pandemic, due to increased teleworking and longer time spent at home.

Finally, Chapter 4 examine the Great East Japan Earthquake of 2011. This earthquake significantly changed seismic activity across Japan. This change has affected people's response to earthquakes, even outside the affected area. This change might be heterogeneous and may depend on the seismic risk of the area where they live. To capture the variation in seismic risk, this chapter uses a new measure: ground classification, which assesses the strength of the ground. By using ground classification, I examine how variations in ground strength influence land prices after a catastrophe. Employing real estate transaction data and the hedonic approach, this study investigates the heterogeneous impact of the Great East Japan Earthquake on the real estate market in undamaged areas. Focusing on ground classification, it was found that land prices in the soft ground areas in Tokyo experienced a decline after the earthquake.

2. Does inheritance taxation reform promote to build inexpensive rental housing?[1]

2.1 Introduction

In Japan's inheritance tax system, inheritance through real estate, especially rental housing, is more advantageous than inheritance through financial assets, which leads to measures to reduce inheritance tax through real estate. Therefore, the inheritance tax system significantly impacts the rental housing market in Japan (Seshimo, 2019; Yamazaki, 2019). This study focuses on the effect of Japan's 2015 inheritance taxation reform on the rental housing market and addresses whether the inheritance taxation reform has increased the supply of tax-efficient rental housings leading to a decrease in rents.

Inheritance is a common phenomenon in Japan because Japan has become an aging society, with the percentage of older adults[2] as a part of the general population exceeding 28% in 2019 (Statistics Bureau, 2020a). As it is a natural part of life for many, changes in the inheritance policy have a substantial impact.

The inheritance taxation reform of 2015 reduced basic tax exemptions and increased tax rates. It increased the tax base and amount of tax levied. Figure 2-1 shows the amount of inheritance tax before and after the 2015 inheritance taxation reform. It indicates the following two aspects: First, people who are not required to pay the inheritance tax before the inheritance taxation reform have to pay the tax. Second, those who have been paying the tax even before the 2015 amendment have to pay increased tax.

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[1] The revised version of this chapter is in the *Journal of Japanese and International Economies*, coauthored with Norifumi Yukutake and Shohei Yasuda.

[2] Ages 65 and above.

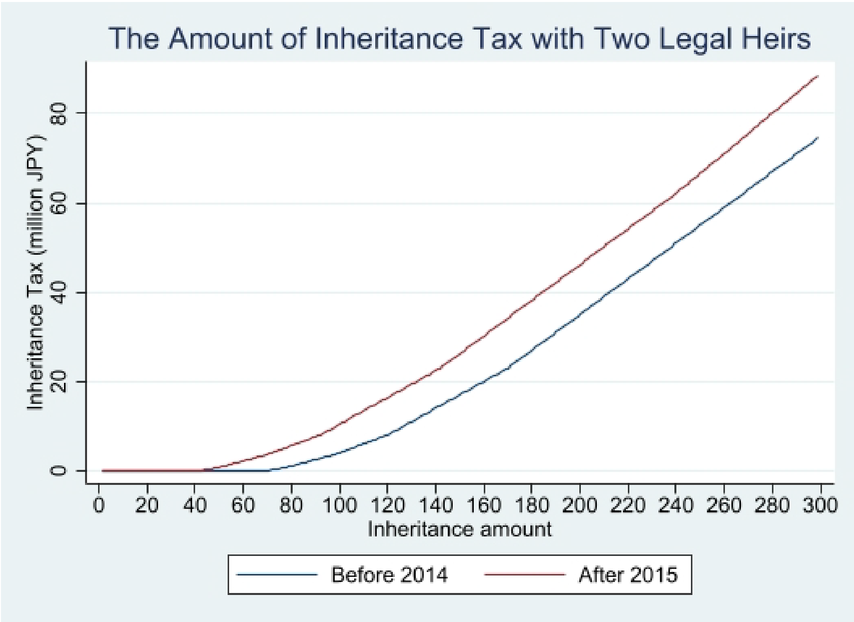

Figure 2-1 Amount of inheritance tax before and after the inheritance tax reform

Notes: This graph shows the case with two legal heirs.

In many countries, inheritance taxes were introduced, although their function remained controversial. According to the report by The Government Tax Commission (2000), inheritance tax is based on the successor's ability to pay taxes in the free acquisition of property by the death of their decedent. It is considered complementary to personal income tax and plays a role in the redistribution of wealth by applying a progressive tax rate. The growing debate on wealth and wealth inequality, as represented by Piketty (2014), has focused on the redistributive function of inheritance taxes. In 2012, Bill Gates, Warren Buffett, George Soros, and 32 other wealthy people in the U.S. announced a proposal to reduce the basic inheritance tax exemption and increase the applicable tax rate.[3]

However, the assessment of inheritance taxes is not necessarily positive. Several studies show that inheritance taxes affect saving behavior and make taxation less neutral (Chapman et al., 1996; Joulfaian, 2006). Historically, the tax has been abolished in some countries. For example, Australia abolished inheritance tax in 1978 in the interests of efficiency and equity: (1) the proportion of property subject to taxation is small, (2) taxation is concentrated in those industries where the unincorporated firm predominates

[3] See Americans for Tax Fairness (2012).

such as in farming and retailing, and (3) the tax system is regressive. The abolition was used to prevent the outflow of wealthy individuals from leaving the country and to encourage their attraction to the country (Thomson, 1972; Gilding and Glezos, 2014).[4]

In Japan, the basic exemption of inheritance tax was lowered during the bubble period in the late 1980s due to soaring land prices; however, the exemption level remained unchanged through the subsequent period of falling land prices. As a result, the number of taxable cases and the level of taxpayer burden declined compared to the pre-bubble and bubble periods, and the tax redistribution function continued to decline. To restore the redistributive function of the inheritance tax and prevent disparities, the 2015 inheritance taxation reform reduced basic tax exemptions and increased tax rates. It increased the tax base and amount of tax levied.

In this chapter, we focus on the Japanese inheritance taxation reform in 2015 and investigate the following: (1) Whether people have an incentive to reduce inheritance tax burden by operating low-cost apartments. (2) What is the mechanism behind the inheritance taxation reform that lowers housing rents. We use a difference-in-differences (DID) framework and identify the types of apartment structures that are built after the inheritance taxation reform. Then, we estimate the change in housing rent for the affected group of apartments with subgroups. We find that the rents of low-cost rental housing decreased after the inheritance taxation reform. However, no such effects are evident in the new low-cost apartments.

The remainder of the chapter is organized as follows: Section 2.2 presents a review of the literature. Section 2.3 explains how taxpayers tend to build wooden or light steel-framed housings to reduce their taxes. Section 2.4 introduces the theoretical model. Section 2.5 describes the data and basic model used in the empirical analysis. Section 2.6 presents our results, and finally, Section 2.7 discusses the results and concludes the chapter.

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[4] In addition to Australia as mentioned in the text, Canada integrated inheritance tax into its income tax on capital gains in 1971 (Duff, 2005). Furthermore, Israel abolished inheritance taxes in 1981, New Zealand in 1992, Portugal in 2004, Sweden in 2005, Austria and Singapore in 2008, and Norway in 2014.

2.2 Literature Review

Many studies have attempted to estimate the impact of changes in exogenous shocks in the rental housing market. Most of them focus on rent control (Autor et al., 2014; Diamond et al., 2019; Sims, 2007). Other studies have tried to estimate the impact of short-term rentals such as Airbnb (Horn and Merante, 2017; Lee, 2016; Peralta et al., 2020). These studies have found that increasing the number of short-term rentals (i.e., Airbnb) has increased rental housing prices because some rental housings have converted to short-term rentals leading to a decrease in the supply of rental housing.

Some studies have focused on the impact of taxation reform on housing market (Best and Kleven, 2018; Kopczuk and Munroe, 2015). These studies reveal that the discontinuity of the housing transaction tax rate distorts the housing market.

Further, some studies focus on inheritance taxation reform. Escobar (2017) found that, using regression discontinuity, the Swedish inheritance progressive tax system provided big incentives for people to underreport the size of estates. This indicates that taxation system distorts the market. Moreover, Thomson (1972) and Gilding and Glezos (2014) showed that tax payments were not determined by the ability to pay but were distorted by tax saving measure. Grossman (1990) showed that "fiscal competition among the states" in Australia led to inheritance tax abolition. However, few studies have focused on the impact of inheritance taxation reform empirically on the housing market in Japan.

Theoretical research has been done by Kanemoto (1989), Yamazaki (1999), and Seshimo and Yamazaki (2018). Kanemoto (1989) theoretically showed the economic effects of asset taxation in Japan using an overlapping generation model. The results indicate that real estates are more advantageous as inherited assets than financial assets, and that the inheritance tax increases land prices in the case that inheritance demand exceeds the total amount of land. Yamazaki (1999) concludes that increasing inheritance taxation results in higher land prices because demand for land increases as land is more favorable as an inheritance asset than financial assets. Seshimo and Yamazaki (2018) state that increasing inheritance taxation leads to a decrease in housing rent.

Niimi (2019)'s empirical study about Japanese taxation reform highlighted that the behavioral responses to the inheritance taxation reform in 2015 were few, while Yamazaki (2019) claimed that a combination of the property inheritance tax relief and the inheritance taxation reform of 2015 would increase the supply of rental housing and decrease housing rent. In the case of rental operation for inheritance tax measure, the tax-saving effect is added to the expected rate of return as a premium. When the inheritance tax burden increases, the supply of rental housing for tax-saving purposes increases, and the supply of rental housing by corporations, such as institutional investors, decreases. This is because investors would exit from the housing rental market due to reductions in housing rent and, consequently, the profit would be reduced. Additionally, Asada and Yamazaki (2010) simulated the land price when the taxation system was changed and emphasized that the Japanese inheritance taxation system would distort the land or housing markets.

The contributions of this study to the literature are twofold. First, we provide empirical evidence regarding the impact of tax policy change that distorts the housing markets. Some studies show that policy change can affect real estate prices. In the context of housing transaction tax, Kopczuk and Munroe (2015) noted that the discontinuity of the tax rate distorts the distribution of housing prices in New York and New Jersey, the U.S. rent control in the US is also referred to in the literature (Diamond et al., 2019; Sims, 2007), which proves that the taxation system can affect the rental housing market. In particular, Diamond et al. (2019) found that using the revision of the law, the rent control decreased the supply of rental housings because of redevelopment or selling. As a result, they also found that housing rent increased in the long run. However, to the best of our knowledge, few empirical analyses on the relationship between tax policy change and housing rent in Japan exist.

Second, we focus on the inheritance taxation reform of 2015 and analyze people's inheritance tax-saving behavior. Niimi (2019) discussed that the Japanese transaction tax reform of 2015 deters people from transferring their wealth to their children to avoid increasing their children's inheritance tax burden. Moreover, using the regression discontinuity design method, Escobar (2017) noted that a considerable portion of the population underreported their inheritances in Sweden. Reportedly, no study has analyzed the impact of tax relief on the inheritance of land or property in Japan.

2.3 Inheritance Tax System and Rental Housing Market in Japan

We focus on the 2015 Japanese inheritance taxation reform and analyze the impact of the inheritance tax system on the rental housing market. According to Seshimo (2019), there are two negative effects of the inheritance tax system on the rental housing market. First, those who would build apartments to save taxes are less likely to build high-quality housing to save cost because the depreciation rate of high-quality housing is lower. Taxpayers are likely to build apartments that depreciate faster to reduce their tax. Legally durable years are determined by the structure of a building. The legally durable years for cheap and low-quality buildings are shorter. For example, the legally durable years for wood and steel-framed (thickness equal to or less than 3 mm) buildings are 22 and 19 years, respectively, and are considered economical because the construction cost is relatively cheaper. Therefore, apartment owners who want to reduce the assessment value for their apartments would not improve their apartments' quality by using high-quality materials.

Second, operating rental housing might not be the most efficient use for the land when supplying rental housing as an inheritance tax-saving measure. Therefore, it is desirable for the owners to ensure that the renter leaves the property after a short period so that the apartments could be demolished after serving their purpose. One way to ensure that the renters leave after a short period is to build apartments targeted to a single student because students tend to stay for short periods only. In the following, we explain the inheritance taxation reform of 2015.

2.3.1 Inheritance Tax in Japan

On January 1, 2015, significant changes were implemented to the inheritance tax system, which was announced on March 30, 2013. Table 2-1 summarizes the main points of the changes. One of the biggest changes was the reduction in basic relief from "JPY 50 million + JPY 10 million × number of legal heirs" to "JPY 30 million + JPY 6 million × number of legal heirs". Consequently, the number of people who had to pay an inheritance tax increased.

Figure 2-2 shows the number of taxpayers, amount of assessed value, and amount of inheritance tax in the Tokyo Area (Tokyo, Chiba, Saitama, and Kanagawa) by year. Although the number of inheritance taxpayers increased by 67% from 2014 to 2015, there is only a 22% increase in the inheritance tax revenue.

There could be two possible reasons why the inheritance tax revenue did not increase significantly. First, those who did not have to pay the inheritance tax before 2014 had to pay the inheritance tax after 2015. Such newly taxable people pay lower taxes. Figure 2-3 shows that the number of inheritance tax payers with an inheritance of less than 100 million JPY has dramatically increased since 2015. Second, those who were still required to pay the inheritance tax under the old law attempted to reduce the amount of their inheritance tax. The amount of inheritance tax has increased since the 2015 inheritance taxation reform (Figure 2-1).

This substantial increase in inheritance tax has incentivized people to reduce their inheritance tax burden by any possible means. One such way is to build and operate low-rise apartments on their land, as inheriting a rental apartment, rather than financial assets, can reduce tax burden. They can claim up to a 27%[5] reduction in the assessed value if they have constructed apartments on inherited land.

Hence, taxpayers are incentivized to build new low-rise apartments on their land to reduce their tax burden. Many websites[6] recommend building low-rise apartments for tax savings. For example, Sumaity (2021) recommends building low-rise apartments made of wood or light steel frame[7] to reduce the taxed amount. One of the reasons for constructing low-rise apartments is their cheap construction cost. The construction cost of wooden and light steel-framed apartments is less. The other reason for building low-rise apartments is their short legally durable years. Legally durable years for these two types of buildings are shorter than those for others due to the lower quality of materials. Apartments with shorter durable years are beneficial for those who want to save tax (especially inheritance tax or property tax) because these apartments depreciate faster, resulting in a lower assessment value.

[5] Details of this calculation are shown in page 13.

[6] One example is Sumaity (2021), which is a real estate information website operated by Kakaku.com, a company that runs several such websites, and is one of the biggest comparison-shopping websites in Japan (https://corporate.kakaku.com/?lang=en).

[7] Steel frame construction includes light steel frame construction and heavy steel frame construction. Light steel frame is a thickness of 6 mm or less, while a heavy steel frame has a thickness above 6 mm. Typically, a heavy steel frame is used for building high-rise apartments.

Table 2-1 Main points of inheritance taxation reform in 2015

Total Taxable Estate (million JPY)	Inheritance Tax Rate	Deduction (million JPY)
Before 2015		
to 10	10%	0
10 to 30	15%	0.5
30 to 50	20%	2
50 to 100	30%	7
100 to 200	40%	17
200 to 300	40%	17
300 to 600	50%	47
over 600	50%	47
Basic Relief		
JPY 50 million + JPY 10 million ×the number of heirs		
From 2015		
Total Taxable Estate (million JPY)	Inheritance Tax Rate	Deduction (million JPY)
to 10	10%	0
10 to 30	15%	0.5
30 to 50	20%	2
50 to 100	30%	7
100 to 200	40%	17
200 to 300	45%	27
300 to 600	50%	42
over 600	55%	72
Basic Relief		
JPY 30 million + JPY 6 million ×the number of heirs		

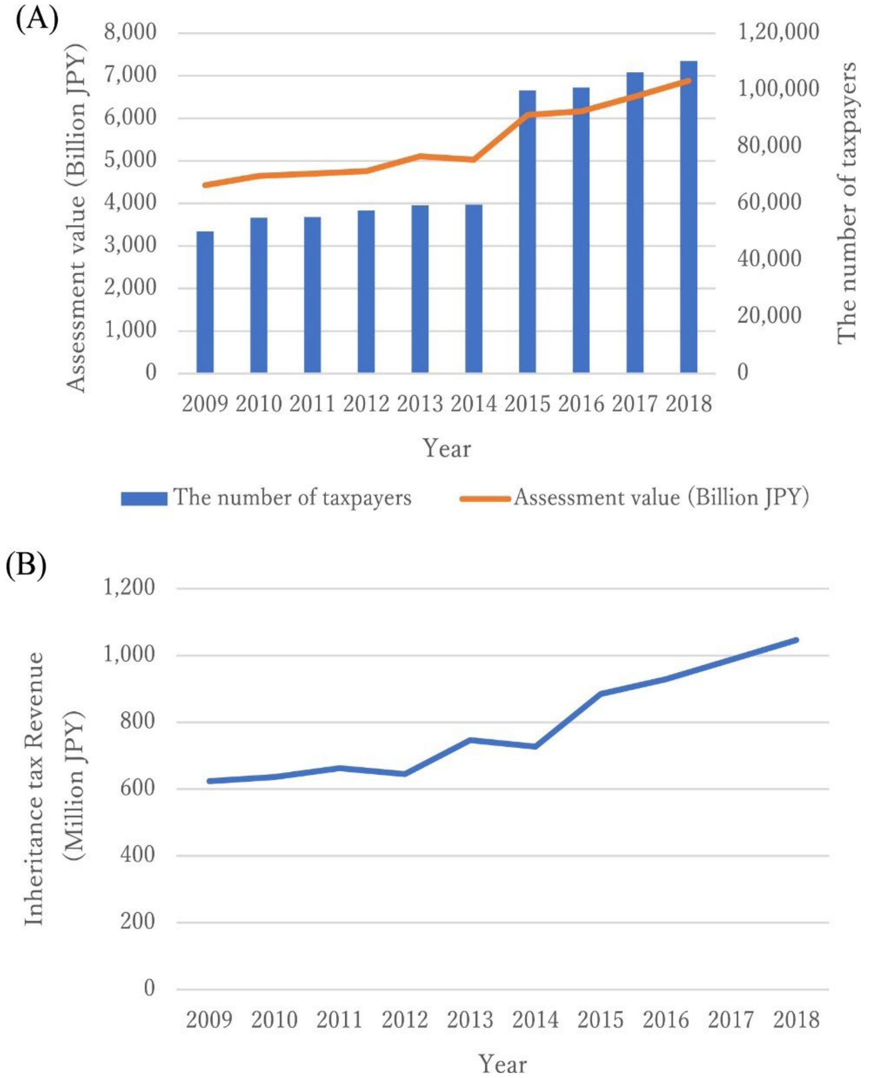

Figure 2-2 (A) Amount of assessment value and the number of taxpayers

(B) Amount of inheritance tax

Source: National Tax Agency (2021)

Notes: Panel (A) shows the number of taxpayers and amount of assessment value at the national level in the Tokyo Area on annual basis are shown. Assessment value indicates taxable price after discounting deduction. Panel (B) displays inheritance tax revenue at the national level in the Tokyo Area on annual basis is shown.

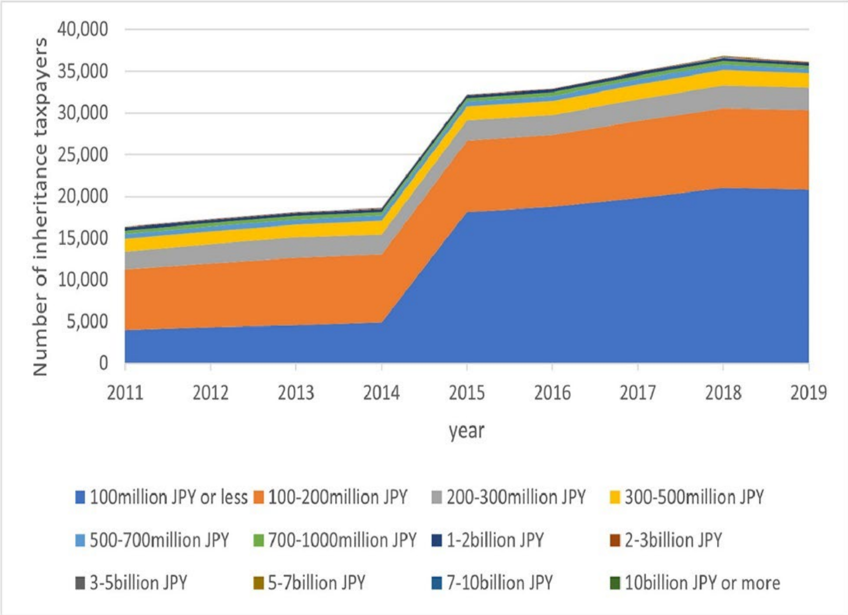

Figure 2-3 Number of inheritance taxpayers by class (Tokyo)

Source: National Tax Agency (2022)

Notes: This graph shows the number of taxpayers in Tokyo.

Building and renting out apartments are one of the best-known ways to reduce inheritance tax burden because the Japanese tax system undervalues land and property compared to financial assets. The value of the land subject to inheritance tax is approximately 80% of the posted land price, which aims to provide an index for land transaction prices (Kanemoto, 1997; Shimizu et al., 2012).[8] Furthermore, the valuation is discounted if an apartment has been constructed and is being operated on the land. Although building an apartment incurs significant construction costs, the amount of capital borrowed can be claimed as a relief against the total inheritance tax burden.

Suppose the decedent has one child, and their inheritance is worth JPY 200 million. With the basic relief reduced from JPY 60 million to JPY 36 million, the amount of inheritance tax charged to their child is JPY 48.6 million if the inheritance comprises entirely financial assets.[9] However, if the inheritance is land or property, the amount of the net taxable

[8] This indicates that the assessment value for real estate can be reduced up to (1−0.27)×0.8×100=58.4% of the market price.

[9] Calculated referring to Table 2-1.

amount is reduced to approximately JPY 160 million. They could potentially pay even less in taxes if they borrow JPY 100 million to build an apartment.

If you build a rental apartment on your own land, then the apartment is called a residential lot with rental housings. In this case, tax savings can be even greater because the assessed value is reduced by the part that the owner cannot freely use. The calculation to evaluate this type of property is as follows: $value\ of\ land - (value\ of\ land \times the\ ratio\ of\ leasehold\ value\ to\ land\ value \times the\ ratio\ of\ the\ value\ of\ tenant\ rights\ to\ the\ value\ of\ the\ house \times rental\ ratio\ )$.The ratio of leasehold value to land value, evaluated by the National Tad Bureau, varies from 0.3 to 0.9, and ratio of the value of tenant rights to the value of the house is 0.3 in our sample area. The ratio of leasehold value to land value is higher in the city center. For example, the rate of Tokyo station is 0.9. Rental ratio is the proportion of floor area rented as of the date of the decedent's death. One way to maximize rental ratio is to sublease. Thus, if you build apartments on your own land and there are no vacant rooms, the net taxable asset will be discounted by 27%.

2.3.2 Survey for Rental Housing Owners

Do taxpayers really build inexpensive low-rise apartments for tax savings? We conducted a survey (N = 2917) of people who own apartments or housings to rent in the Tokyo Metropolitan Area.[10] In Tokyo Metropolitan Area, about 2.6% of households have at least one housing for rent in addition to their own residential housing in 2018 (Statistics Bureau, 2020b). More than half of households with rental housings are 65 years old or more. The survey indicates that these owners are likely to live in Tokyo and Kanagawa city area.

The purpose of this survey was to identify the characteristics of apartment owners. This survey revealed three facts. First, 68.9% of owners who ranked tax saving[11] as the prime reason for managing a rental property owned one or more buildings, compared to 52.2% of those who did not. This shows that those who want to save tax are likely to own one or more buildings instead of buying rooms.

[10] The survey was conducted on the web by GMO Research, Inc. from February 25 to March 8, 2022.

[11] In this context, tax indicates not only inheritance tax but also property tax, gift tax, and other taxes.

Second, those who own one or more buildings are likely to construct the buildings using wood or light steel frame. Wood and light steel frame accounted for 65% of building construction materials among owners who owned one or more buildings to rent, whereas only 5.7% of buildings were wooden or light steel framed if these buildings were owned by the owner who did not have buildings but had a room or rooms to rent. Figure 2-4 depicts the construction cost of rental housing in Japan. It indicates that wooden and steel-framed apartments are less costly compared to other types of construction. Although the construction cost has been increasing recently, the construction cost for wooden and steel-framed housings remains economical.

Third, 28.9% of owners with intention of inheritance tax saving built their apartments after 2015, whereas only 12.5% of owners who did not intend to save inheritance tax built after 2015. This is probably because tax savers started to own one or more buildings to save tax after the taxation reform.

Hence, this survey indicates that apartment owners, who are likely to look to save tax, build their apartment with wood or light steel. Further, the number of such tax savers have increased after the taxation reform.

Moreover, as mentioned above, legally durable years of wood and light steel-framed apartments are comparatively shorter. Hence, people who have land have an incentive to operate wood and light steel-framed apartments and save tax.

Figure 2-5 presents the number of rental housing units by building structure in the Tokyo Area. The data contain the number of yearly constructions by prefecture and structure from 1995 to 2018. We use the number of rental housing units, excluding detached housings. The number of units is categorized by year and building structures are classified into six categories: wood, steel-reinforced concrete, concrete block, reinforced concrete, steel, and others. The solid line between 2014 and 2015 indicates the tax reform that began in 2015, while the dashed line between 2012 and 2013 indicates the announcement of the tax reform in 2013.

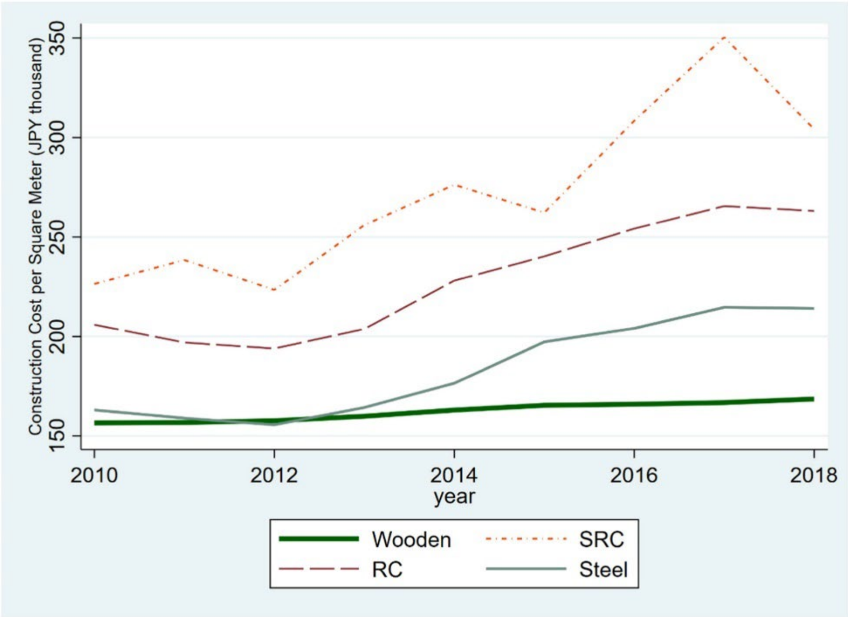

Figure 2-4 Construction cost by structure

Source: Ministry of Land, Infrastructure, Transport and Tourism (2021a).

Notes: This graph indicates the construction cost per square meter by construction. The sample period covers 2010–2018. The horizontal axis shows the year, and the vertical axis represents the construction cost per square meter. RC and SRC represent reinforced concrete and steel reinforced concrete, respectively. Steel includes light steel frame construction and heavy steel frame construction, but these data do not distinguish between the two types of construction.

According to Figure 2-5, the number of wood or steel-framed housing units increased after the announcement and the trend continues after the tax reform. As explained earlier, many taxpayers, to reduce their inheritance tax burden, build and operate apartments. They tend to choose wood or steel-framed building structures, as their structural costs are exceptionally low. Moreover, we provide analyses of a number of apartment constructions before and after the taxation reform in Appendix 2B. Table 2-5 in the appendix indicates that the number of units constructed with wood or light steel frames increased by about 25% after the taxation reform.

In the following, we use wood or light steel-framed housings as the treatment group for analyzing the impact of inheritance taxation reform on the rental housing market. Housings made of other materials are considered as the control group.

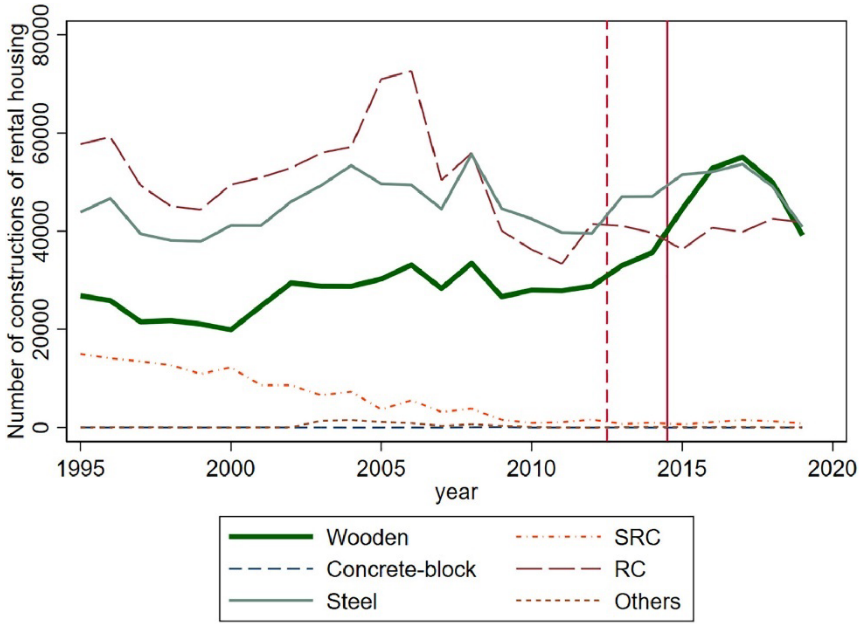

Figure 2-5 Number of constructions of rental housing (excluding detached houses)

Source: Ministry of Land, Infrastructure, Transport and Tourism (2021b).

Notes: The sample includes four prefectures in the Tokyo area. The sample period covers 1995–2018. The vertical axis shows the year, and the horizontal axis represents the number of constructions based on building structures. Building structures are classified into six categories: wood, steel-reinforced concrete (SRC), concrete block, reinforced concrete (RC), steel, and others.

2.4 Theoretical Model

We develop two-period consumption model that incorporates housing construction cost into the asset selection model when inheritance taxes are imposed using the theory by Seshimo and Yamazaki (2018).

Each generation lives for two periods, and those who was born in period *t* are called *t* generation. Hereafter, we consider about *t* generation. They maximize their lifetime utility U_t, which consists of consumption goods, c_t, housing services, h_t, and lifetime utility of child generation, u_{t+1} discounted by β.

$$U_t = u_t(c_t, h_t) + \beta u_{t+1}(c_{t+1}, h_{t+1})$$

We consider the case where all households own financial and land assets, and they are inherited by children's generation. Households can choose three different ways to inherit land: to inherit the land as is, to inherit the land with a rental housing of high construction cost (Type A) built on the land by using mortgage, and to inherit the land with a rental housing of low construction cost (Type B) built on the land by using mortgage. In such cases, budget constraint is given as follows,

$$c_t + w_t + {p_t}^j {H_t}^j + {\rho_t}^j {h_t}^j = y_t + {b_t}^j + {x_{t-1}}^j \quad \text{for } j \in (A, B),$$

where t indicates period, j indicates house cost. w_t is financial assets level; ${p_t}^j$ is market real estate price; ${H_t}^j$ is real estate owned; ${\rho_t}^j$ is market housing rents; ${h_t}^j$ is housing service for their residence; y_t is income; ${b_t}^j$ is mortgage payable, ${x_{t-1}}^j$ is inheritance level. If the inheritance tax rate is given by τ, we obtain housing rent ρ_t^j from the first-order condition.

$${\rho_t}^j = -(1-\tau)\left({p_t}^j - {p_{t-1}}^j\right) - i_t {p_{t-1}}^j - \tau d^j {p_t}^j,$$

where d^j is discount rates for the taxable assessed value of real estate (including land valuation, building valuation, and age reduction correction rates). Details are shown on Appendix 2A.

2.4.1 Empirical predictions

When inheritance tax rate increases, more and more people will build housings with low construction cost. Moreover, housing rents for lower construction housings will fall if inheritance taxation rate increases.

2.5 Main data and empirical model

We used data from the Real Estate Information Network Systems provided by the Real Estate Information Network for East Japan. This dataset contains housing rent and characteristics (e.g., layout, building year, and floor area) and detailed addresses and transaction dates. In our empirical analysis, we used apartment transactions from January 2011 to June 2018 in the Tokyo Area. Moreover, we focused on the rental apartment market, so detached houses were excluded. This is because there are less than 1% of detached houses in rental housing market.[12] Regarding outliers, we excluded houses with rents exceeding JPY 3 million or less than JPY 10 thousand, apartments located more than 100 min from the nearest station, and the top and bottom 1% of the floor area were excluded from the sample.[13] Table 2-2 presents the summary statistics for the variables.

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[12] Of the new rental housing units built between 2011 and 2018, only 0.8% were detached houses.

[13] There might be errors because the data are entered by the real estate agent.

Table 2-2 Basic Statistics

Variable		Mean	Std. Dev.	Min	Max
Housing rent (JPY)		80990.89	39339.54	10000	2210000
Floor area (Square Meter)		33.302	15.014	12.75	82.49
Structure					
	Wood	0.26	0.438	0	1
	Block	0.000595	0.0244	0	1
	Steel frame	0.502	0.5	0	1
	SRC	0.0823	0.275	0	1
	PC	0.00418	0.0645	0	1
	HPC	0.000324	0.018	0	1
	Light steel frame	0.123	0.328	0	1
	Others	0.0281	0.165	0	1
Layout					
	One room	0.145	0.352	0	1
	K	0.42	0.494	0	1
	DK	0.209	0.407	0	1
	LK	0.000636	0.0252	0	1
	LDK	0.214	0.41	0	1
	SK	0.00237	0.0486	0	1
	SDK	0.00201	0.0448	0	1
	SLK	0.0000632	0.00795	0	1
	SLDK	0.00713	0.0841	0	1
Walking time to the nearest station (Minute)		8.076	5.24	1	100
Building age (Year)		18.787	11.956	0	91
Observations		1,059,518			

Notes: The sample includes four prefectures (Tokyo, Kanagawa, Saitama, and Chiba). The sample period covers January 2011 to June 2018. RC, SRC, PC, and HPC represent reinforced concrete, steel reinforced concrete, precast concrete, and hard precast concrete, respectively. Top 1% and bottom 1% of area are excluded. 49 samples were dropped due to low housing rent, 2254 high housing rent, and 148 samples due to long distance from the nearest station. One room in the layout category has only one room and has no wall to separate the kitchen from the bedroom. K, D, L, and S in layout stand for kitchen, dining room, living room, and storage room respectively. These alphabets indicate the property has these rooms. Originally, data contained 1411772 transactions, but our main estimation uses1059518. Note that six singlation observations are dropped in Table 2-3 and Table 2-4, and sample size shown in these tables is 1059512.

2.5.1 Empirical model

To identify the effect of the inheritance taxation reform on housing rent, we used a DID method that applies the hedonic approach.[14]

The equation is as follows:

$$\ln y_{ijt} = \beta_0 + \beta_1 TREAT_i + \beta_2 AFTER_t \tag{2.1}$$

$$+\beta_3 TREAT_i \times AFTER_t + \boldsymbol{\delta}'\boldsymbol{X_{it}} + D_j + YEAR_t + MONTH_t + \varepsilon_{ijt},$$

where $\ln\ y_{ijt}$ is the logarithm of housing rent per square meter of transaction i in region j on day t; $TREAT_i$ is a dummy for the treatment group (wooden and light steel-framed housings); $AFTER_t$ is a dummy for the time after the taxation reform; $\boldsymbol{X_{it}}$ is a vector of housing characteristics; D_j is a set of region dummies; $YEAR_t$ is a set of year dummies; $MONTH_t$ is a set of month dummies; and ε_{ijt} is an error term. Standard errors are clustered at the city level.

The definition of a steel-framed apartment was ambiguous in the original data, as shown in Table 2-2, and it is possible that some light steel-framed buildings were included in the category of "steel frame." Therefore, we excluded the category "steel frame" from our estimates. Thus, the control group did not include wood and light steel-framed apartments.

We are interested in β_3, which represents the differences in average housing rent between the treatment and control groups before and after the taxation reform. The vector of housing characteristics, $\boldsymbol{X_{it}}$, includes dummy variables (building structures, layout, and railway route of the nearest station), walking time to the nearest station, and building age.

[14] The DID model using a hedonic approach was discussed by Banzhaf (2021). These studies indicate that the DID model may have ambiguous results in a hedonic model if the intervention is large. Further they show that even if the intervention is large and price functions change, the model can identify the "average direct unmediated effect" on prices from a change in characteristics, and that the effect is interpreted as a lower bound on welfare, specifically the Hicksian equivalent surplus plus the change in profits.

2.6 Results

2.6.1 Main results

Table 2-3 shows the estimation results based on Equation (2.1). Steel-framed apartments are excluded from our estimate in the results to exclude light steel-framed apartments in the control group.[15]

Columns (1) to (4) of Table 2-3 illustrate the results obtained through the simple DID method. From Columns (5) to (8), we divide the treatment group into wood and light steel-framed housings. Additionally, Columns (1), (3), (5) and (7) use the city fixed effects, and Columns (2), (4), (6) and (8) use the block[16] fixed effects.

Although Columns (1), (2), (5) and (6) use year fixed effect and month fixed effect separately, Columns (3), (4), (7) and (8) use year-month fixed effect. This year-month fixed effect enables us to capture time trends more flexibly. Even after replacing year fixed effect and month fixed effect to year-month fixed effect, the results did not change greatly.

Columns (1) to (4) show that housing rent in the treatment group is cheaper even before the tax reform; housing rent in the treatment group is 3% – 4% lower when compared with the control group. Furthermore, housing rent in the treatment group dropped significantly by about 1.3% after the tax reform, which suggests that the inheritance taxation reform decreased housing rent in the treatment group. This is because, as Appendix 2A indicates, housing supply of wooden and light steel-framed apartments has increased, and this increasing supply leads to decreased housing rents of these housing structures.

The impact can be different for wood and light steel-framed housings. Therefore, Columns (5), (6), (7) and (8) show separate treatment effects for each structure. Coefficients of interactions between the wooden dummy and after dummy are significantly negative, and the rent of wooden housing is reduced by 1.2%–1.3% after the tax reform. Similarly, the rent of the light steel-framed apartments also decreased by approximately 1.3%. Therefore, both wood and light steel-framed housings are cheaper

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[15] Table 2-7 shows the results which include steel-framed apartments to estimate.

[16] Block is called *chome* or *aza* in Japanese.

after the tax reform.

There are two possibilities why housing rent in the treatment group decreased after the taxation reform. First, taxpayers prefer constructing treatment group apartments owing to their low construction cost. Second, the tax-saving effect is added to the expected rate of return as a premium.

Table 2-3 **Difference-in-differences estimation results**

Dependent variable: log(housing rent/㎡)	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
TREAT	-0.0426***	-0.0427***	-0.0306***	-0.0306***				
	(0.00166)	(0.00166)	(0.00149)	(0.00149)				
AFTER×TREAT	-0.0132***	-0.0132***	-0.0125***	-0.0124***				
	(0.00124)	(0.00124)	(0.00111)	(0.00111)				
Light Steel Frame					-0.0428***	-0.0427***	-0.0301***	-0.0301***
					(0.00174)	(0.00174)	(0.00156)	(0.00156)
AFTER×Light Steel Frame					-0.0130***	-0.0130***	-0.0134***	-0.0135***
					(0.00173)	(0.00173)	(0.00152)	(0.00152)
Wooden					-0.0295***	-0.0295***	-0.0203***	-0.0203***
					(0.00154)	(0.00154)	(0.00144)	(0.00144)
AFTER×Wooden					-0.0133***	-0.0132***	-0.0121***	-0.0120***
					(0.00140)	(0.00140)	(0.00127)	(0.00127)
Housing Attributes	YES	YES	YES	YES	YES	YES	YES	YES
Fixed effects								
City FE	YES	NO	YES	NO	YES	NO	YES	NO
Block FE	NO	YES	NO	YES	NO	YES	NO	YES
Year FE	YES	YES	NO	NO	YES	YES	NO	NO
Month FE	YES	YES	NO	NO	YES	YES	NO	NO
Year×Month FE	NO	NO	YES	YES	NO	NO	YES	YES
N	1059512	1059512	1058621	1058621	1059512	1059512	1058621	1058621
R-squared	0.775	0.776	0.815	0.815	0.775	0.776	0.815	0.815

Notes: Controls for housing attributes include dummies of building structures, dummies of layout, dummies of the railway route of the nearest station, walking time to the nearest station, and building age. Standard errors are clustered at the city level and are shown in parentheses. *** indicates that the estimated coefficient is significant at the 0.01 level.

2.6.2 Additional analysis

We implement three additional tests to confirm our main results are robust. First, we restrict sample. We assume wood or light steel-framed housings as housing for inheritance tax relief and define it as treatment group, but this definition may be vague. As noted above, housings for inheritance tax relief tend to be built of wood and lightweight steel, but naturally they also include reinforced concrete houses. The same is true for housings that are not for tax relief. Therefore, in the following, we restrict the sample to focus on apartments that are affected by the taxation reform. As Seshimo (2019) mentioned, one good option for tax savings is to operate apartments for students or single individuals.

For landowners, operating apartments may not be the best way to utilize land after inheritance. They may want to stop operating apartments immediately after inheritance and convert to a different land use. However, owners cannot evict residents easily in Japan. Hence, owners prefer residents such as single students who opt for short-term stay and will vacate apartments earlier than families.

Therefore, we restricted the sample to housings in which single students were likely to live. We identified such houses using floor space and layout. First, we restricted samples with floor space. According to the target housing area standard[17], the minimum floor space for a single person to lead a comfortable lifestyle is 40 square meters. Therefore, we considered only those buildings whose floor size was less than 40 square meters. Moreover, according to minimum housing area standard[18], the minimum floor space for a single person to lead a healthy and cultural lifestyle is 25 square meters. Hence, we restricted our sample to houses with floor space less than 25 square meters. Another way to identify people who live alone is using the floor plan. We restricted our sample to studio apartments and studios with a separate kitchenette.[19]

[17] The target housing area standard is “the level of housing area that should be attained by every household as a prerequisite for realizing comfortable housing conditions in response to varied lifestyles.” This definition is provided by the Statistics Bureau of Japan.

[18] The minimum housing area standard is “the level of housing area that should be attained by every household as a basis absolutely essential for healthy and cultural living depending on the number of household members.” This definition is from the Statistics Bureau of Japan.

[19] Seshimo (2019) mentioned that owners are likely to construct studio apartments that are meant for students, and students usually live not only in studio apartments but also in studios with a separate

Second, we consider the population moving. Some demand factors could affect rental housing prices. This is because young people, especially college students, are likely to rent treated apartments. This is because they tend to have one room or 1K room. This indicates that demand for treated rental housing would decrease if less college students move to Tokyo. This could happen, say, when Tokyo restricts university capacity in 2018. Therefore, controlling population inflow and outflow can control demand factor, and purely see the impact of the increase of supply. After controlling population of young people, results are still significant. Although the proportion of young people increases housing rent, the magnitudes of the effect of the inheritance taxation reform do not change much.

Finally, in addition to the inheritance taxation reform, components of the user cost of capital may also have an impact on housing rents. User cost is the ratio of housing rent and land price, and it indicates housing rent is determined by land price, maintenance cost, depreciation rate, interest rate, tax rate, and inflation rate.[20] It is necessary to consider these components, but only the inflation rate is considered for the following reasons.

Although we cannot observe apartments' land price and maintenance cost, these components are partly captured by block fixed effect and housing attributes. We do not have to consider depreciation rate because it is fixed. Also, interest rate and tax rate should be the same for properties transacted in the same year. So, these are captured by year-month fixed effects. There is no change regarding tax rate around 2015, and, if any, year-month fixed effects can capture this component.

To control inflation rate, we use real housing rent using CPI instead of nominal housing rent which we use in main results. This is because price fluctuations may have affected the main results. The results are mostly the same as the main results.

The results for the small floor space sample are shown in Columns (1) to (4) of Table 2-4, and those for the two floor plans sample, in Columns (5) and (6) of Table 2-4. These results are not significantly different from the main results.

As with Table 2-3, we use two kinds of time fixed effects in Table 2-4. The odd-numbered columns use year fixed effect and month fixed effect; the even-numbered columns present results which use year-month fixed effect.

kitchenette. Therefore, we restricted the sample to housings with these two floor plans.

[20] One example discussing user cost is Potarba (1984).

Table 2-4 **Additional tests**

	Floor<40		Floor<25		Restricting floor plan		DDD	
Dependent variable: log(housing rent/㎡)	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
TREAT	-0.0426***	-0.0426***	-0.0435***	-0.0435***	-0.0347***	-0.0347***	-0.00765*	-0.00768*
	(0.00166)	(0.00166)	(0.00200)	(0.00200)	(0.00192)	(0.00192)	(0.00407)	(0.00406)
AFTER×TREAT	-0.0106***	-0.0106***	-0.0136***	-0.0135***	-0.0110***	-0.0109***	0.00697	0.00707
	(0.00123)	(0.00123)	(0.00140)	(0.00140)	(0.00140)	(0.00140)	(0.00566)	(0.00565)
AFTER×TREAT×OLD							-0.0136**	-0.0136**
							(0.00574)	(0.00573)
Housing Attributes	YES	YES	YES	YES	YES	YES	YES	YES
Fixed effects								
City FE	NO	NO	NO	NO	NO	NO	NO	NO
Block FE	YES	YES	YES	YES	YES	YES	YES	YES
Year FE	YES	NO	YES	NO	YES	NO	YES	NO
Month FE	YES	NO	YES	NO	YES	NO	YES	NO
Year×Month FE	NO	YES	NO	YES	NO	YES	NO	YES
N	732003	732003	416034	416034	597334	597334	902543	902543
R-squared	0.760	0.761	0.759	0.759	0.717	0.718	0.814	0.814

Notes: Columns (1) to (6) of Table 2-4 present the results of the difference-in-differences specification in Equation (2.1), which compares housing rent before and after the taxation reform. Controls for housing attributes include dummies of building structures, dummies of layout, dummies of the railway route of the nearest station, walking time to the nearest station, and building age. Columns (7) to (8) present the results of the triple differences specification in Equation (2.3), which compares housing rent before and after the taxation reform. Controls for housing attributes include dummies of building structures, dummies of layout, dummies of the railway route of the nearest station, and walking time to the nearest station. Standard errors are clustered at the city level and are shown in parentheses. ***, **, and * indicate that the estimated coefficient is significant at the 0.01, 0.05, and 0.10 levels, respectively.

Two possibilities could adversely affect our results. First, the number of new constructions of wood and light steel-framed apartments might increase regardless of tax savings when construction costs are low enough to be able to expect profit. However, this concern does not change our conclusion. If the construction cost is the main factor behind rent reduction, then the taxation reform will not affect the housing rent for wood and light steel-framed apartments and the results in Table 2-3 and Table 2-4 would be insignificant. However, our results indicate a significant effect. Therefore, we can say that the taxation reform reduced housing rents. Although we cannot eliminate the possibility that construction costs matter. In a case where construction costs affect rents, the actual effect would be smaller than 1.3%.

Second, the increase in wood and light steel-framed construction cost affects the housing rents for the control group. If so, the Stable Unit Treatment Value Assumption (SUTVA) would be violated. If SUTVA is violated, rents of the control group should decrease because of increased supply. This would mean that housing rents for the treatment and control groups would decrease due to the increase in housing supply if apartments of the treatment and control groups exist in the same rental market.

Moreover, our result can be interpreted as the lower bound if SUTVA is violated. This is because rents of the control group decrease if the number of treatment apartments increases. Even if the taxation reform affects rents of the control group, our results indicate that the magnitude of rent reduction in the treatment group is greater than that in the control group. Therefore, SUTVA cannot disregard our finding that the taxation reform decreased housing rents of the treatment group.

So far, the reduction of rent of the treatment group is due to the taxation reform, rather than by other factors.

2.6.3 Persistence of rent reduction

We were also interested in the long-term rent reduction. By adding leads and lags into DID, we estimated the duration of the taxation reform and implemented a placebo test. Therefore, we used year dummies instead of after dummies. The equation is as follows:

$$\ln y_{ijt} = \beta_0 + \beta_1 TREAT_i + \sum_k \gamma_k TREAT_i \times YEAR\_k_t + \boldsymbol{\delta' X_{it}} + D_j + YEAR_t + MONTH_t + \varepsilon_{ijt}, \quad (2.2)$$

where $YEAR_k_t$s are year dummies that are equal to 1 if the transaction occurred in year k. The baseline is set to the year 2012, one year before the announcement. Therefore, γ_k can be interpreted as the differences of rents compared to the rent of the treatment group in 2012. Other variables in Equation (2.2) are the same as in Equation (2.1). The estimation results of γ_k are summarized in Figure 2-6. The coefficients of intersections between year dummies and the control dummy are plotted in Figure 2-6. The coefficients for 2011 and 2013 indicate a parallel trend because the coefficients are estimated insignificantly. The coefficient for 2014 is negative and significant, indicating that there is indeed an announcement effect because the announcement of the tax reform was made in March, 2013.[21] The coefficients for the years 2015–2018 indicate that housing rents of

[21] We estimated that the effect dropping transactions occurred in 2013 and 2014 to exclude the announce effect. See Table 2-8.

the treatment group are still reduced after the tax reform introduction, and the effect lasted 3 years after the reform.

2.6.4 Impact on existing housing

In this subsection, we examine the kinds of apartments most influenced by the taxation reform. The objective of this additional estimation is to see the heterogeneous effect of the taxation reform within the treatment group. When the number of new apartments sharply increases, the decrease in rentals may occur; not directly in new ones, but in older ones.

There is a possibility that before the taxation reform, some residents who wanted to live in new apartments continue to live in existing apartments due to the short supply of new rental apartments. However, after the taxation reform, the supply of new apartments increased, and such people could then move into new apartments. As a result, it is likely that demand for older apartments decreased and their rents also decreased.

To capture how building age affects heterogeneous impact, we added OLD_t, which represents the existing home dummy, equal to 1 if an apartment i on date t is not newly built. The equation is as follows:

$$\begin{aligned} \ln y_{ijt} = {} & \beta_0 + \beta_1 TREAT_i + \beta_2 AFTER_t + \beta_3 OLD_t \\ & + \beta_4 TREAT_i \times AFTER_t + \beta_5 TREAT_i \times OLD_t + \beta_6 AFTER_t \times OLD_t \\ & + \beta_7 TREAT_i \times AFTER_t \times OLD_t + \boldsymbol{\delta}' \boldsymbol{X_{it}} + D_j + D_t + \varepsilon_{ijt}. \end{aligned} \tag{2.3}$$

The coefficient of interest is β_7, which captures the effect of the taxation reform for existing houses compared with new houses. Namely, this estimator indicates the difference in housing rent change due to the tax reform between new and pre-existing housing within the treatment group. This captured the heterogeneous impact of taxation reforms in the treatment group.

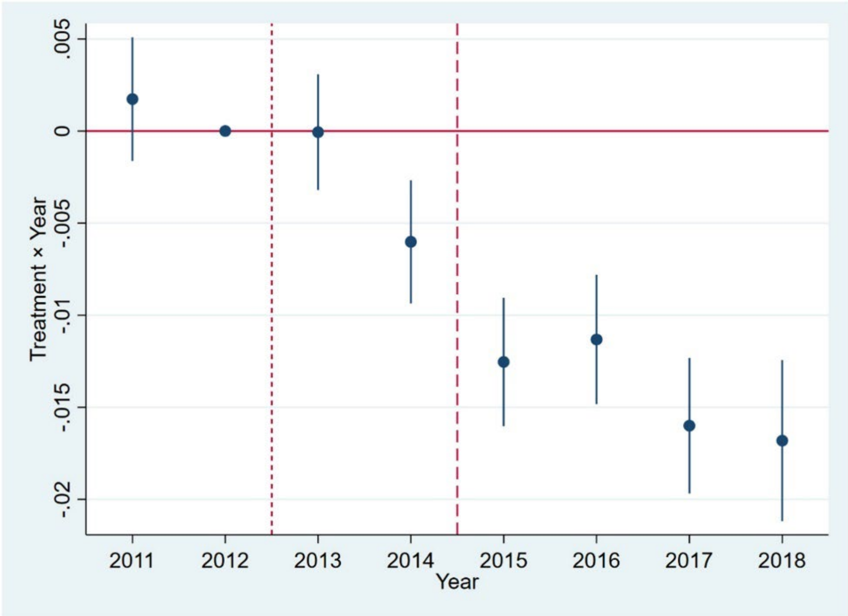

Figure 2-6 Long-term effect of inheritance taxation reform.

Notes: This graph shows the estimation result of Equation (2.2). The coefficients of the intersection of the treatment dummy and year dummy are plotted. Standard errors are clustered at the city level. Dots show coefficients and bars indicate 95% confidence intervals.

Columns (7) and (8) of Table 2-4 show the result using the regression specification shown in Equation (2.3). In Columns (7) and (8), only samples whose building age is equal to or less than 30 years are used. This restriction comes from the result explained in Figure 2-7. This figure indicates which age of apartments in the treatment group is affected by the taxation reform and reveals that housing rent of the newly built treatment group does not change significantly. Only the rent of the treatment group apartments that were not newly built decreased after the taxation reform.

Next, we examined the degree of rent reduction by building age. Columns (7) and (8) of Table 2-4 highlights that existing apartments are more affected by the taxation reform, but it does not indicate the age at which apartments suffer the largest decrease in rent. Therefore, we used housing age dummies instead of the existing housing dummy, OLD_t. The results are summarized in Figure 2-7. This result illustrates that the rent of relatively new apartments (age range 4–13) is affected the most and reduced by approximately 4%. It is likely that long-term repair mitigates the impact of the housing rent reduction. Although some coefficients of the age range 40–50 are significantly negative, the sample size of such old apartments is quite small and, therefore, not important. The number of new apartments in our sample was about 64,000, but the number of transactions whose building age was, say, 45 was only 4,800.

Thus, we can conclude that the rental of new apartments in the treatment group reduced because of the increase in the supply of new apartments due to the taxation reform and the obvious desire for people to live in newer apartments. Ordinarily, these people might not be able to do so due to a lack of supply, but the taxation reform of 2015 enabled more people to live in new apartments. This led to a reduction in demand for relatively new houses because those who normally live there are those that cannot afford new apartments, which has a trickle-down effect of reducing housing rents in new houses. The rent of relatively old apartments is hardly affected because such apartments are not substitutes for new housing.

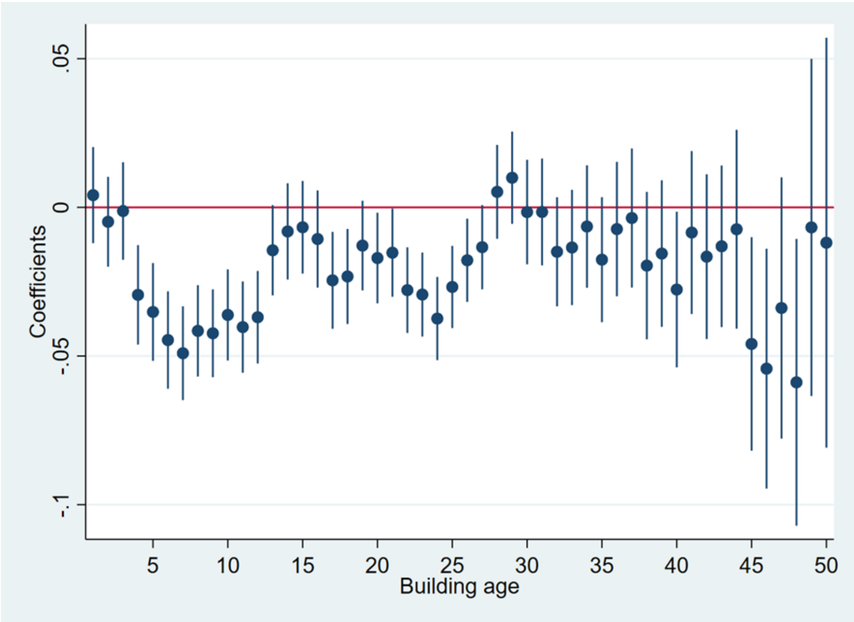

Figure 2-7 Heterogeneous impact in the treatment group on building age

Notes: Coefficients of interaction terms of the treatment dummy, after dummy, and building age dummies are plotted. Standard errors are clustered at the city level. Dots show coefficients and bars indicate 95% confidence intervals.

2.7 Discussion and Conclusion

This study tries to find whether the inheritance taxation reform in 2015 distorts the rental housing market. To see this, we focus on housing constructions. This is because those who want to save inheritance tax reduce the cost of construction by using cheap materials. We first analyze the change of the number of housing constructions by structures of the buildings. Then, we see the change of housing rent by structures. These analyses indicate that the number of buildings starts of cheap structures increased, and housing rents of these structures fell after the inheritance tax reform. This indicates that the increase of the rental housing leads to the decrease of the housing rent. Without the inheritance taxation reform, this would not happen. For, the increase of the housing supply comes from the incentive of tax saving. This means those who built apartments after the inheritance taxation reform of 2015 are not likely to maximize their profit through real estate management. Instead, they maximize profit by tax savings. Such low rent apartments drive out investors who are not looking to save on the inheritance taxes. This is how tax savers distort the rental housing market.

This study suggests, through empirical evidence, that the taxation reform has increased the number and decreased the rental of low-quality housing apartments. The rent of wood and light steel-framed housing decreased by approximately 1% after the tax reform, compared with housings built using other materials; this lasted the entire year of 2018. Further, the rental of newly constructed apartments in the control group decreased.

Moreover, our theory and main results indicate that housing rent has changed due to the inheritance taxation reform. There is no motivation for houseowners to maximize their revenue from running apartments. Instead, they maximize revenue in total, including the effect of the inheritance taxation reduction, as well as revenue from housing rents.

Our study affirms what Yamazaki (2019) claimed earlier—those who want to reduce their tax burden are likely to build apartments at a low cost. The increase in the number of low-quality rental housing after the tax reform, thus blocks the supply of quality housing and negatively distorts the housing market. It is highly likely that newly taxed people, whose taxable estate is small, started building low-cost apartments to save inheritance tax. Wood and light steel-framed apartments are being built owing to the relatively low construction cost of these materials (Figure 2-4).

The assessment value for real estate is cheaper than that of financial assets. Therefore, taxpayers have an incentive to possess real estate rather than financial assets for two reasons. First, they might be able to avoid inheritance tax if their estate is depreciated below basic deduction. Second, they might be able to reduce the tax rate. Since the Japanese inheritance taxation system is based on progressive taxation, depreciating assessment value can reduce the tax rate.

Future work should investigate a theoretical framework explaining how tax reductions affect housing rent and the housing market, with a focus on the effect of inheritance tax on housing quality.

Appendix 2A Theoretical Model

Seshimo and Yamazaki (2018) theoretically prove that when inheritance tax is imposed, consumers necessarily own real estate as an asset. In this section, we build a model that introduces housing quality (or, housing construction cost) into the model of asset selection when inheritance tax is imposed, referring to Seshimo and Yamazaki (2018).

We explain two-period consumption model, which consider consumers born in period t (t generation) earn income in same period but not in period $t+1$. Therefore, there are two generations in each period, and t generation can enjoy the lifetime utility U_t in period t. We assume that consumers maximize lifetime utility U_t, which consist of the sum of consumption goods c_t, housing services h_t, and lifetime utility of child generation u_{t+1} discounted by β.

$$U_t = u_t(c_t, h_t) + \beta u_{t+1}(c_{t+1}, h_{t+1}) \qquad (2.\mathrm{A1})$$

We assume that utility functions have the following properties,

$$\frac{\partial u_k}{\partial c_k} > 0, \qquad \frac{\partial u_k}{\partial h_k} > 0, \qquad \text{for } k \in \{t, t+1\} \qquad (2.\mathrm{A2})$$

We consider the case where all households own financial and land assets, which are inherited by children's generation. Households can choose three different ways to inherit land. The first way is to inherit the land as is, the second way is to inherit the land with a high quality rental house (Type A) built on the land by using mortgage, and the last way is to inherit the land with a low quality rental house (Type B) built on the land by using mortgage. In this case, budget constraint is given as follows,

$$c_t + w_t + {p_t}^j {H_t}^j + {\rho_t}^j {h_t}^j = y_t + {b_t}^j + {x_{t-1}}^j \quad \text{for } j \in (A, B) \qquad (2.\mathrm{A3})$$

where t indicates period, j indicates house quality. w_t is financial assets level; ${p_t}^j$ is market real estate price; ${H_t}^j$ is real estate owned; ${\rho_t}^j$ is market housing rents; ${h_t}^j$ is housing service for their residence; y_t is income; ${b_t}^j$ is mortgage payable, ${x_{t-1}}^j$ is inheritance level. If the inheritance tax rate is given by τ, then ${x_{t-1}}^j$ is as follows,

$$\begin{aligned} {x_{t-1}}^j = &\left\{(1+r_t)w_{t-1} + \left({p_t}^j + {\rho_t}^j\right){H_{t-1}}^j - (1+i_t){b_{t-1}}^j\right\} \\ &- \tau\left\{w_{t-1} + \left(1-d^j\right){p_t}^j {H_{t-1}}^j - {b_{t-1}}^j\right\} \qquad (2.\mathrm{A4}) \end{aligned}$$

r and i are the interest rates on financial assets and borrowings, respectively. d^j is discount rates for the taxable assessed value of real estate (including land valuation, building valuation, and age reduction correction rates).

The higher quality rental house requires higher construction costs and more mortgage, and therefore market real estate price and market housing rents will also higher. And the lower quality houses have a higher age reduction correction rate. We assume the following properties,

$$p_t{}^A > p_t{}^B, \qquad \rho_t{}^A > \rho_t{}^B, \qquad H_t{}^A > H_t{}^B, \qquad b_t{}^A > b_t{}^B, \qquad d^B > d^A$$

The first-order condition is given as follows:

$$c_t: \quad \frac{\partial u_t}{\partial c_t} - \lambda_t = 0$$

$$c_{t+1}: \quad \beta \frac{\partial u_{t+1}}{\partial c_{t+1}} - \lambda_{t+1} = 0$$

$$h_t{}^j: \quad \frac{\partial u_t}{\partial h_t{}^j} - \rho_t{}^j \lambda_t = 0$$

$$h_{t+1}{}^j: \quad \frac{\partial u_{t+1}}{\partial h_{t+1}{}^j} - \rho_{t+1}{}^j \lambda_{t+1} = 0$$

$$w_t: \quad \{\lambda_{t+1}(1 + r_{t+1} - \tau) - \lambda_t\} = 0$$

$$H_t{}^j: \quad \left[\lambda_{t+1}\left\{1 - \tau\left(1 - d^j\right)p_{t+1}{}^j + \rho_{t+1}{}^j\right\} - p_t{}^j \lambda_t\right] = 0$$

$$b_t{}^j: \quad \{-\lambda_{t+1}(1 + i_{t+1} - \tau) + \lambda_t\} = 0$$

From first-order condition, we obtain the following market real estate price:

$$p_t{}^j = \frac{(1-\tau)p_{t+1}{}^j + \tau d^j p_{t+1}{}^j + \rho_{t+1}{}^j}{(1 + r_{t+1} - \tau)} \qquad (2.\mathrm{A5})$$

or

$$p_t{}^j = \frac{(1-\tau)p_{t+1}{}^j + \tau d^j p_{t+1}{}^j + \rho_{t+1}{}^j}{(1 + i_{t+1} - \tau)} \qquad (2.\mathrm{A6})$$

From Equation (2.A6), we obtain the following market housing rents:

$$\rho_t{}^j = -(1-\tau)\left(p_t{}^j - p_{t-1}{}^j\right) - i_t p_{t-1}{}^j - \tau d^j p_t{}^j \qquad (2.\mathrm{A7})$$

Proposition 1.

Rising inheritance tax rate will lead to lower market housing rents.

Proof.

From Equation (2.A7), we obtain the following equation

$$\frac{\partial \rho_t{}^j}{\partial \tau} = p_t{}^j - p_{t-1}{}^j - d^j p_t{}^j \qquad (2.\mathrm{A8})$$

When the condition $\frac{p_t{}^j - p_{t-1}{}^j}{p_t{}^j} < d^j$ is satisfied, rising inheritance tax rate will lead to lower market housing rents. Furthermore, market housing rents may be lower for low quality housing compared to high quality housing. Its conditions are as follows[22]:

$$(p_t{}^B - p_t{}^A) - (p_{t-1}{}^B - p_{t-1}{}^A) - (d^B p_t{}^B - d^A p_t{}^A) < 0 \qquad (2.\mathrm{A9})$$

Since deterioration over time is greater for low quality houses than for high quality houses, the following inequality holds

$$(p_t{}^B - p_t{}^A) < (p_{t-1}{}^B - p_{t-1}{}^A) \qquad (2.\mathrm{A10})$$

When $d^A p_t{}^A \leq d^B p_t{}^B$ is satisfied, Equation (2.A9) holds. When $d^A p_t{}^A > d^B p_t{}^B$ is

[22] $p_t{}^B - p_{t-1}{}^B - d^B p_t{}^B - (p_t{}^A - p_{t-1}{}^A - d^A p_t{}^A) < 0$

$$\leftrightarrow (p_t{}^B - p_t{}^A) - (p_{t-1}{}^B - p_{t-1}{}^A) - (d^B p_t{}^B - d^A p_t{}^A) < 0$$

satisfied, then Equation (2.A9) holds if $(p_t{}^B - p_t{}^A) - (p_{t-1}{}^B - p_{t-1}{}^A)$ is sufficiently small.

Proposition 2.

The inheritance tax system encourages real estate investment and provides incentives to build low quality housing.

Proof.

If consumers don't invest in real estate and have all of their assets in financial assets $w_t{}^T$, the gains are as follows:

$$(1 + r_{t+1} - \tau)w_t{}^T \qquad (2.\mathrm{A}11)$$

If consumers split their assets between rental housing and financial assets, the gains are as follows:

$$\begin{aligned}&\left(p_{t+1}{}^j - p_t{}^j\right)H_t{}^j + (1 + r_{t+1})w_t{}^S \\ &\qquad - \tau\left\{w_t{}^S + \left(1 - d^j\right)p_{t+1}{}^j H_t{}^j - b_t{}^j\right\} \qquad (2.\mathrm{A}12)\end{aligned}$$

Then the difference π between Equations (2.A11) and (2.A 12) is as follows:

$$\begin{aligned}\pi = &\left(p_{t+1}{}^j - p_t{}^j\right)H_t{}^j + (1 + r_{t+1})w_t{}^S - \tau\left\{w_t{}^S + \left(1 - d^j\right)p_{t+1}{}^j H_t{}^j - b_t{}^j\right\} \\ &- (1 + r_{t+1} - \tau)w_t{}^T \qquad (2.\mathrm{A}13)\end{aligned}$$

From Equation (2.A 13), and when the condition $p_t{}^j > \left(1 - d^j\right)p_{t+1}{}^j$ and $w_t{}^T = p_t{}^j H_t{}^j + w_t{}^S$ is satisfied, we obtain the following inequalities

$$\frac{\partial \pi}{\partial \tau} = \left\{p_t{}^j - \left(1 - d^j\right)p_{t+1}{}^j\right\}H_t{}^j + b_t{}^j > 0 \qquad (2.\mathrm{A}14)$$

As a result, rising inheritance tax rate encourages real estate investment. Additionally, there may be incentives to build low quality housing in the following cases[23]:

[23] $\{p_t{}^B - (1 - d^B)p_{t+1}{}^B\}H_t{}^B + b_t{}^B - \left[\{p_t{}^A - (1 - d^A)p_{t+1}{}^A\}H_t{}^A + b_t{}^A\right] > 0$

$$\left(p_t{}^B H_t{}^B - p_t{}^A H_t{}^A\right) + \left\{(1-d^A)p_{t+1}{}^A H_t{}^A - (1-d^B)p_{t+1}{}^B H_t{}^B\right\}$$

$$+\left(b_t{}^B - b_t{}^A\right) > 0 \qquad (2.\mathrm{A15})$$

From $p_t{}^A > p_t{}^B,\ H_t{}^A > H_t{}^B,\ b_t{}^A > b_t{}^B,\ d^B > d^A$, the following condition is satisfied,

$$p_t{}^B H_t{}^B - p_t{}^A H_t{}^A < 0 \qquad (2.\mathrm{A16})$$

$$b_t{}^B - b_t{}^A < 0 \qquad (2.\mathrm{A17})$$

$$(1-d^A)p_{t+1}{}^A H_t{}^A - (1-d^B)p_{t+1}{}^B H_t{}^B > 0 \qquad (2.\mathrm{A18})$$

Thus, there is an incentive to build low quality housing if the decline in assessed value of low-quality housing is sufficiently large compared to high quality housing.

$\leftrightarrow \left(p_t{}^B H_t{}^B - p_t{}^A H_t{}^A\right) + \left\{(1-d^A)p_{t+1}{}^A H_t{}^A - (1-d^B)p_{t+1}{}^B H_t{}^B\right\} + \left(b_t{}^B - b_t{}^A\right) > 0$

Appendix 2B Housing starts

To check how the number of apartment constructions has changed after the taxation reform, we consider four common structures, although the data contains six categories. Two structures, namely concrete and other structures, are excluded because these structures are uncommon. Using simple DID in Equation (2.B1), we observe the change in number of apartments constructed in the treatment group after the taxation reform.

$$\begin{aligned} \ln\left(Construction_{sjt}\right) \\ &= \alpha_0 + \alpha_1 TREAT_s + \alpha_2 AFTER_t \\ &+ \alpha_3 TREAT_s \times AFTER_t + D_j + D_t + \varepsilon_{sjt}, \end{aligned} \tag{2.B1}$$

where $Construction_{sjt}$ is the number of constructions of structure s in city j and year t; $TREAT_s$ is 1 if the structure is wood or light steel-framed; $AFTER_t$ is a dummy for the time after the taxation reform; D_j is a set of city dummies; D_t is a set of year dummies; and ε_{sjt} is an error term. The treatment of interest is α_3, which captures the increase in construction in the treatment group after the taxation reform, when compared with the other group.

Furthermore, to deal with the zero value, we use Equation (2.B2):

$$\begin{aligned} arcsin\left(Construction_{sjt}\right) \\ &= \alpha_0 + \alpha_1 TREAT_s + \alpha_2 AFTER_t \\ &+ \alpha_3 TREAT_s \times AFTER_t + D_j + D_t + \varepsilon_{sjt}. \end{aligned} \tag{2.B2}$$

Inverse hyperbolic sine transformation is used in the dependent variable to solve the problem of zero values. As Bellemare and Wichman (2020) indicated, this transformation can generate a good approximation of the logarithm; this transformation changes the variable x to $\tilde{x}$ as follows:

$$\tilde{x} = arcsinh\,(x) = \; ln\left(x + \sqrt{x^2 + 1}\right),$$

where $\tilde{x}$ is the approximate value of $ln\,ln\,(x)$ when $x > 0$ and $\tilde{x} = 0$ when $x = 0$. Therefore, it becomes possible to handle the problem of zero values in the number of constructed units.

Table 2-5 includes the estimated results of Equations (2.B1) and (2.B2). Columns (1) to (3) and Columns (4) to (6) show the results of Equations (2.B1) and (2.B2), respectively. α_3 is positive and significant, indicating that the number of units constructed with wood or light steel frames increased by about 25% after the taxation reform. This result remains the same even after considering city fixed effects, year fixed effects, and structure. This result suggests that wood or light steel-framed apartments are built more often after the taxation reform.

In addition, we implement dynamic DID event study to estimate dynamic treatment effect. This enables us to check whether parallel trend assumption is hold before the enforcement of the inheritance taxation reform. Figure 2-8 shows the results of dynamic treatment effect and there are two findings. First, it is found that there is little announcement effect. Second, the effect of the increased number of wood or light-steel framed building construction is significant, although the magnitude is diminishing.

Moreover, we additionally control the proportion of young people and population growth rate of young people. Results are shown in Table 2-6.

Table 2-5 Difference-in-differences estimation for the number of apartment constructions

Dependent variable:	ln(the number of constructions)			arcsin(the number of constructions)		
	(1)	(2)	(3)	(4)	(5)	(6)
TREAT	-0.0507	0.660***	0.223***	2.433***	2.433***	1.023***
	(0.0885)	(0.0822)	(0.0853)	(0.0971)	(0.0986)	(0.101)
AFTER	-0.0149	-0.223***	-0.230***	-0.159***	-0.300***	-0.300***
	(0.0679)	(0.0786)	(0.0761)	(0.0378)	(0.0584)	(0.0584)
TREAT×AFTER	0.148*	0.267***	0.258***	0.251***	0.251***	0.251***
	(0.0776)	(0.0691)	(0.0634)	(0.0488)	(0.0495)	(0.0495)
City FE	NO	YES	YES	NO	YES	YES
Year FE	NO	YES	YES	NO	YES	YES
Structure Dummies	NO	NO	YES	NO	NO	YES
N	4167	4167	4167	7508	7508	7508
R-squared	0.00138	0.643	0.745	0.203	0.653	0.745

Notes: This table presents the results of the difference-in-difference specification in Equations (B2.1) and (B2.2), which compare the number of constructions of rental housing (excluding detached housings) before and after the taxation reform. Standard errors are clustered at the city level and are shown in parentheses. ***, **, and * indicate that the estimated coefficient is significant at the 0.01, 0.05, and 0.10 levels, respectively.

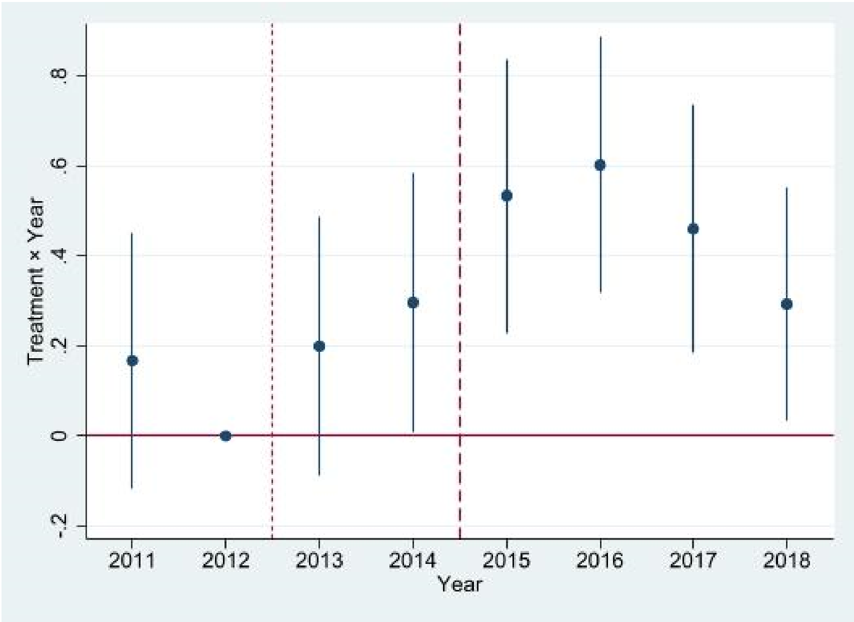

Figure 2-8 **Dynamic treatment effects for the number of apartment constructions**

Table 2-6 Difference-in-differences estimation for the number of apartment constructions with demand factors.

Dependent variable: ln(the number of constructions)	(1)	(2)	(3)	(4)	(5)	(6)
TREAT×AFTER	0.0773	0.658***	0.214**	-0.0658	0.651***	0.224***
	(0.0897)	(0.0901)	(0.0889)	(0.0897)	(0.0821)	(0.0846)
AFTER	-0.0777	-0.122	-0.109	0.00244	-0.0833	-0.0682
	(0.0811)	(0.0838)	(0.0769)	(0.0703)	(0.0785)	(0.0748)
TREAT×AFTER	0.188**	0.316***	0.293***	0.163**	0.320***	0.298***
	(0.0831)	(0.0788)	(0.0662)	(0.0821)	(0.0718)	(0.0662)
Percentage Increase in Young	16.91***	-1.130	-0.562			
	(2.546)	(0.882)	(0.746)			
Proportion of Young				13.25*	9.793*	10.39**
				(7.929)	(5.111)	(5.042)
City FE	NO	YES	YES	NO	YES	YES
Year FE	NO	YES	YES	NO	YES	YES
Structure Dummies	NO	NO	YES	NO	NO	YES
N	3248	3248	3248	3719	3719	3719
R-squared	0.0841	0.649	0.755	0.00908	0.644	0.748

Notes: This table presents the results of the difference-in-difference specification in Equations (2.B1) and (2.B2), which compare the number of constructions of rental housing (excluding detached housings) before and after the taxation reform. Standard errors are clustered at the city level and are shown in parentheses. ***, **, and * indicate that the estimated coefficient is significant at the 0.01, 0.05, and 0.10 levels, respectively.

Appendix 2C Data definition and announcement effect

2C.1 Data setting

We execute two other approaches to address the concern that the category “steel frame” in our dataset may include both light steel-framed apartments and heavy steel-framed apartments.

First, the category “steel frame” is included in the control group. If some light steel-framed apartments are included in the control group by this method, the estimated results should not be overestimated. Second, the category “steel frame” is included in the treatment group. Thus, we can eliminate the possibility that part of the treatment group transactions is included in the control group.

The results of the above treatments are shown in Table 2-7. Results did not change significantly even after we treat “steel frame” apartments as the control group rather than treatment group.

Table 2-7 Other definitions of the treatment group and the control group

	Control Group				Treatment Group			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
TREAT	-0.0446***	-0.0319***	-0.0446***	-0.0319***	-0.0443***	-0.0319***	-0.0443***	-0.0320***
	(0.00161)	(0.00144)	(0.00161)	(0.00144)	(0.00161)	(0.00143)	(0.00161)	(0.00143)
AFTER×TREAT	-0.0105***	-0.0102***	-0.0105***	-0.0101***	-0.0112***	-0.0103***	-0.0112***	-0.0102***
	(0.00113)	(0.00102)	(0.00113)	(0.00102)	(0.00110)	(0.000974)	(0.00110)	(0.000973)
Housing Attributes	YES	YES	YES	YES	YES	YES	YES	YES
Fixed effects								
City FE	YES	NO	YES	NO	YES	NO	YES	NO
Block FE	NO	YES	NO	YES	NO	YES	NO	YES
Year FE	YES	YES	NO	NO	YES	YES	NO	NO
Month FE	YES	YES	NO	NO	YES	YES	NO	NO
Year×Month FE	NO	NO	YES	YES	NO	NO	YES	YES
N	1297799	1296966	1297799	1296966	1297799	1296966	1297799	1296966
R-squared	0.771	0.809	0.771	0.809	0.771	0.809	0.771	0.809

Notes: This table presents the results of the difference-in-differences specification in Equation (2.1) by changing the definition of the treatment group and the control group. Controls for housing attributes include dummies of building structures, dummies of layout, dummies of the railway route of the nearest station, walking time to the nearest station, and building age. Standard errors are clustered at the city level and are shown in parentheses. ***, **, and * indicate that the estimated coefficient is significant at the 0.01, 0.05, and 0.10 levels, respectively.

2C.2 Announcement effect

As Figure 2-6 indicates, there may be an announcement effect. To remove this effect, we dropped the transactions that occurred in 2013 and 2014 and ran the analysis again. The results are shown in Table 2-8. Although the magnitude of the effect increased slightly, the results are mostly the same as the main results (Table 2-3).

Table 2-8 Results for estimation without announcement effect

Dependent variable: log(housing rent/㎡)	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
TREAT	-0.0399***	-0.0400***	-0.0269***	-0.0270***				
	(0.00192)	(0.00192)	(0.00177)	(0.00177)				
AFTER×TREAT	-0.0149***	-0.0148***	-0.0150***	-0.0149***				
	(0.00156)	(0.00156)	(0.00143)	(0.00142)				
Light Steel Frame					-0.0406***	-0.0406***	-0.0261***	-0.0261***
					(0.00220)	(0.00220)	(0.00199)	(0.00199)
AFTER×Light Steel Frame					-0.0140***	-0.0141***	-0.0161***	-0.0161***
					(0.00232)	(0.00232)	(0.00204)	(0.00204)
Wooden					-0.0263***	-0.0264***	-0.0166***	-0.0167***
					(0.00182)	(0.00182)	(0.00174)	(0.00174)
AFTER×Wooden					-0.0153***	-0.0151***	-0.0146***	-0.0144***
					(0.00173)	(0.00173)	(0.00160)	(0.00160)
Housing Attributes	YES	YES	YES	YES	YES	YES	YES	YES
Fixed effects								
City FE	YES	YES	NO	NO	YES	YES	NO	NO
Block FE	NO	NO	YES	YES	NO	NO	YES	YES
Year FE	YES	NO	YES	NO	YES	NO	YES	NO
Month FE	YES	NO	YES	NO	YES	NO	YES	NO
Year×Month FE	NO	YES	NO	YES	NO	YES	NO	YES
N	775434	775434	774431	774431	775434	775434	774431	774431
R-squared	0.779	0.779	0.819	0.819	0.779	0.779	0.819	0.819

Notes: This table presents the results of the difference-in-differences specification in Equation (2.3) without announcement period. Transactions occurred in 2013 and 2014 are excluded to omit the announcement effect. Controls for housing attributes include dummies of building structures, dummies of layout, dummies of the railway route of the nearest station, walking time to the nearest station, and building age. Standard errors are clustered at the city level and are shown in parentheses. ***, **, and * indicate that the estimated coefficient is significant at the 0.01, 0.05, and 0.10 levels, respectively. Columns (1) to (4) regard both wood and light-steel framed apartments as the treatment group, whereas Columns (5) to (8) separate these two structures.

3. Covid-19, teleworking, and the real estate market[24]

3.1 Introduction

The COVID-19 pandemic has drastically changed the patterns of job commuting worldwide by the rise of teleworking and reductions in urban traffic congestion. According to the American Community Survey (ACS), the percentage of U.S. workers working from home rose from 5.7% in 2019 to 17.9% in 2021. Telework also has the potential to reduce traffic congestion by decreasing the number of commuters during peak hours. The ACS reports that average one-way commuting time decreased from its historical high of 27.6 minutes in 2019 to 25.6 minutes in 2021. The shift to teleworking and reduced traffic congestion may have decreased the demand for proximity to urban centers and increased the demand for housing in the suburbs.

In addition, the rise of teleworking during and after the pandemic may have changed the residential preferences of workers. Since more people shift toward teleworking and spend longer hours at home, they need houses with extra rooms that can be converted into a home office. As a result, demand for private floor spaces may have increased, particularly in the suburbs.

Consequently, the rise of teleworking can affect the urban structure by changing the demand for proximity to urban centers and the demand for residential floor spaces. This paper provides empirical evidence on the impact COVID-19 pandemic and the spread of teleworking by looking at rental housing market in Tokyo. Specifically, we address following three questions: (1) Does demand for proximity to urban centers decrease after the pandemic? (2) How does teleworking affect local housing rent? (3) Does demand for residential floor spaces increase after the pandemic?

The Japanese situation provides a unique opportunity to answer these questions. First, the health-related impact of COVID-19 in Japan was less severe compared to other countries. According to Johns Hopkins University (2023), the number of deaths per 100,000 population in Japan was only 57.7, which was far below the number in the U.S. of 341.1 and the lowest among twenty countries most affected by COVID-19 worldwide. Additionally, since the Japanese government did not enforce stringent movement restrictions such as lockdowns, the direct economic impact of the pandemic also remained

[24] This Chapter is coauthored with Michio Naoi and Shohei Yasuda.

modest. These features largely, though not entirely, eliminate the impact of health concerns and economic shocks due to the pandemic, and help identify the effect of teleworking and reduced commuting costs on the housing market.

Second, teleworking expanded rapidly in Japan during the COVID-19 pandemic. In January 2020, immediately prior to the pandemic, the proportion of workers implementing telework in Tokyo was only 10% (Okubo, 2022). This figure increased dramatically in the early stages of the pandemic, reaching approximately 38% between April and May 2020, and subsequently remained around 30% until the end of 2021. Furthermore, it is well documented that the degree of teleworkability varies substantially across jobs and places (Dingel and Neiman, 2020; Okubo 2022). The rapid and spatially heterogeneous adoption of teleworking provides an exogenous variation for identifying the impact of teleworking and commuting costs on urban structure.

The primary contribution of this chapter is to provide additional empirical evidence to the expanding body of literature on the relationship between the COVID-19 pandemic and the housing market. The impact of the COVID-19 pandemic on the housing market has been investigated in various countries (D'Lima et al, 2021; Liu and Tang, 2021; Batalha et al., 2022). These papers examined the short-run impact of the pandemic, focusing on the demand-side shocks induced by the public health concerns or government policies such as lockdowns. We show that the pandemic can affect housing market in the longer-run even in the country without severe public health concerns and economic shocks of the pandemic. Our results highlight the role of teleworking and worker's residential preferences that can change urban structure in the longer-run.

This chapter is closely related to recent studies on the spatial implications of the pandemic. Building on the traditional Alonso-Mills-Muth framework, recent studies examine the within-city housing price responses varying across locations (Liu and Su, 2021; Gupta et al., 2022). They find that expansion of teleworking during the pandemic has flattened the housing bid-rent curve in the US, implying a shift in housing demand away from city centers. On top of these findings, our paper also demonstrates that the expansion of teleworking during the pandemic shifted worker's residential preferences toward larger homes, which gives another channel through which the recent rise in teleworking can change urban spatial structure (Duranton and Handbury, 2023). The traditional Alonso-Mills-Muth framework suggests that this shift in preferences would also contribute to the flattening of the bid-rent curve.

More broadly, this chapter also contributes to the literature on commuting and internal structure of cities. Prior studies on this topic typically focus on the transportation infrastructure, which directly determines the commuting cost within cities. A key empirical challenge in this literature is that the allocation of transportation infrastructure is not random, causing various endogeneity issues. To address this issue, the reduced-form literature employs instrumental variables methods using historical/planned routes as instruments (Baum-Snow, 2007; Duranton and Turner, 2012), or difference-in-differences design comparing treated and control areas (Gibbons and Machin, 2005). Another strand of literature employs structural approach based on quantitative urban models (Ahlfeldt et al., 2014). Our paper provides additional reduced-form evidence on this topic by using the COVID-19 pandemic and the resulting rise of teleworking as a source of exogenous changes in commuting costs.

We use large-scale rental transaction data to examine whether the relationship between housing rent and the distance from the city center changed after the COVID-19 pandemic. We also test this hypothesis for housing floor space to examine whether the pandemic changed worker's residential preferences. In addition, we compile a novel teleworking index from mobile phone data that varies across time and space to estimate its impact on local housing rents. We also examine whether changes in housing rents and floor space gradients differ depending on the degree of teleworking.

Our empirical results are summarized as follows. First, we show that the pandemic has flattened the bid-rent curve, a similar finding as in the US and other countries (Liu and Su, 2021; Gupta et al., 2022). We also show that the flattening of bid-rent curve is larger in places with higher teleworking index and for smaller units. Second, we find that housing rent has increased in places with higher teleworking index, suggesting that the rise of teleworking has increased the local housing demand. Third, we find that willingness to pay for private floor space increased after the pandemic, and that average floor space of the transacted units became larger, particularly in locations away from the city center. These findings are consistent with the notion that demand for private floor spaces increased after the COVID-19 pandemic, particularly in the suburbs.

The remainder of this chapter is organized as follows. Section 3.2 presents basic information regarding the COVID-19 pandemic in Japan. Section 3.3 summarizes the existing research. Section 4 presents the data used in this study. Section 3.5 presents the empirical models and descriptive statistics. Section 3.6 presents the estimation results and interpretations. Finally, Section 3.7 presents the conclusions and scope for future studies.

3.2 Basic Information for COVID-19

The World Health Organization (WHO) declared an end to the "public health emergency of international concern" on May 5, 2023. This triggered the transition of COVID-19 to a category 5[25] infectious disease in Japan, with life returning to pre-pandemic levels.

The initial global instance of the COVID-19 pandemic was noted in early December 2019, following an outbreak of viral pneumonia of unknown origin in Wuhan, China; on January 30, 2020, the WHO declared a "public health emergency of international concern," and as of March 11 of the same year, the cumulative number of infected people worldwide was over 110,000. On the same day, the WHO recognized that the disease had become a pandemic, with more than 8,000 cases and 4,000 deaths worldwide.

In Japan, the first case of COVID-19 was confirmed on January 15, 2020, and on February 4, 2020, a mass infection was confirmed on the Diamond Princess cruise ship. In response to these events, the government compiled emergency response measures for the new coronavirus infection and established the Expert Committee on Countermeasures for COVID-19 Infections, and on April 7, 2020, it declared a state of emergency, considering the fact that there were areas where the medical supply system was under strain. The emergency covered seven prefectures: Tokyo, Kanagawa, Chiba, Saitama, Osaka, Hyogo, and Fukuoka. On April 16, 2020, 40 prefectures were added to the list of areas where emergency measures should be implemented, with emergency measures being implemented in all prefectures. On May 25, 2020, the emergency declaration was lifted when it was deemed no longer necessary, but emergency declarations were issued four times thereafter.

During the states of emergency, the public was asked to refrain from leaving their homes unnecessarily, and the organizers of facilities and events were asked to suspend the use of their facilities. Additionally, each prefecture issued priority measures to prevent the spread of the disease and, as with the declaration of a state of emergency, requested voluntary restraint from various activities. Table 3-1 summarizes events regarding COVID-19 in Japan, while Figure 3-1 displays the number of COVID-19 cases in Tokyo.

Thus, the pandemic facilitated a deeper comprehension of public health and prompted the implementation of diverse measures for infectious disease control. Policies, such as

[25] This category is the same as flu. Due to the change of categorization, those who had been infected with COVID-19 were no longer asked to refrain from going out.

the declaration of a state of emergency and priority measures to prevent the spread of the disease, have significantly impacted people's behavior, including the shortening of restaurant hours, restrictions on the serving of alcoholic beverages, restrictions on events, and simultaneous closure of elementary, junior high, and high schools. In terms of work styles, as face-to-face contact with others was restricted, a shift to teleworking was encouraged, and teleworking and satellite office work became common.

Table 3-1 Overview of COVID-19 in Japan

Year	Month	Date	Event
2020	January	15	1st COVID-19 case in Japan
	January	30	WHO declared "public health emergency of international concern"
	March	11	WHO declared Pandemic
	April	7	**(#1) State of Emergency declared** * in 7 prefectures
	April	16	State of Emergency declared throughout Japan
	May	25	State of Emergency ends
	July	22	"Go to travel" campaign starts
2021	January	8	**(#2) State of Emergency declared** *in Tokyo, Kanagawa, Saitama,& Chiba
	March	21	State of Emergency ends
	April	12	semi-state of Emergenct declared in Tokyo
	April	20	semi-state of Emergenct declared in Saitama, Chiba & Kanagawa
	April	24	semi-state of Emergenct ends in Tokyo
	April	25	**(#3) State of Emergency declared** ※in Tokyo, Osaka, Hyogo & Kyoto
	June	20	State of Emergency ends in Tokyo
	June	21	semi-state of Emergenct declared in Tokyo
	July	11	semi-state of Emergenct ends in Tokyo
	July	12	**(#4) State of emergency declared** ※in Tokyo & Okinawa
	September	30	State of Emergency ends

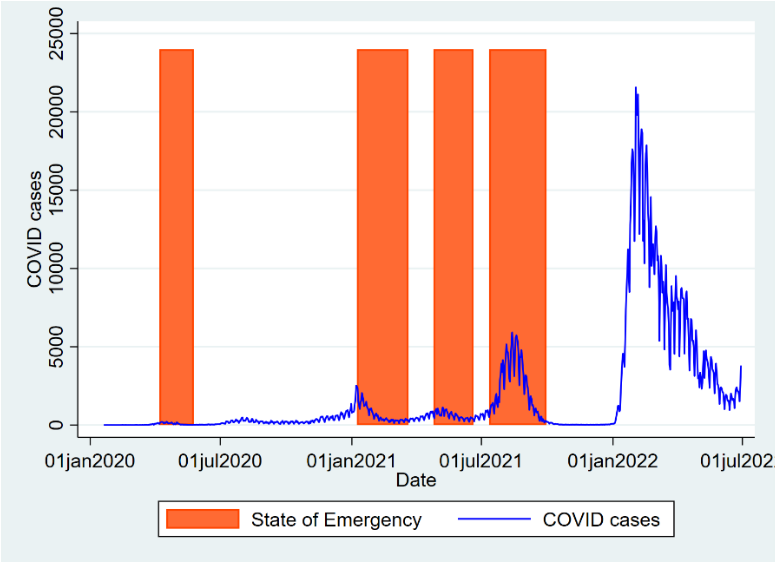

Figure 3-1 The number of COVID-19 cases in Tokyo

Notes: Highlighted areas indicate the states of emergency.

3.3 Previous Studies

The impact of the COVID-19 pandemic on the housing market has been examined since the early stages of the pandemic. Liu and Tang (2021) used transaction data from 34 cities in China to examine the impact of confirmed infections within urban residential communities on transaction prices. They found that transaction prices fell by approximately 1.3% in residential areas where infected persons were confirmed, compared to those in non-infected areas. In Japan, Kutsuzawa, Akai, and Takemoto (2021) analyzed official land prices and reported that an increase in the number of infected persons and deaths causes a decline in land prices, and that such an effect is greater in commercial areas than in residential ones.

Building on these studies, more recent theoretical investigations have examined the long-term effects on urban structure and housing prices of changes in people's mobility patterns, such as the increase in teleworking due to the COVID-19 pandemic.[26] For

[26] The progress of teleworking in the COVID-19 pandemic is discussed in Dingel and Neiman (2020) and Brynjolfsson et al. (2023). In Japan, several studies have presented the current landscape of teleworking through worker questionnaires. (Morikawa 2022; Tomiura and Ito, 2024; Okubo, 2020, 2022; Okubo and

example, Brueckner et al. (2023) discussed the impact of teleworking development on city size and housing prices based on the standard Rosen-Roback model. As teleworking allows workers to maintain their jobs and move to areas with lower housing prices and better living conditions, housing prices fall in cities with higher productivity and rise in cities with better amenities.[27] Nakagawa et al. (2020) examined these arguments in Japan.

For changes in the pattern of housing prices and rent within the metropolitan area, Delvanthal et al. (2022) presented predictions based on a quantitative urban model. Their simulation results show that the development of teleworking will cause housing prices to fall in the city center and rise in the periphery. A similar prediction was presented by Duranton and Handbury (2023) using a standard monocentric city model.

An increasing number of empirical studies have been conducted, especially using U.S. data. For example, Gupta et al. (2022) examined how housing price/rent gradients with distance from metropolitan centers changed before and after the COVID-19 pandemic for residential real estate. Housing prices and rent gradients flattened after the COVID-19 pandemic. Furthermore, they found that the development of teleworking and lower commuting costs, rather than the loss of urban amenities and housing supply constraints, were the main factors contributing to the flattening of the housing price/rent gradient.[28] Similar results were reported by Liu and Su (2021) for residential real estate, and by Rosenthal et al. (2022) for commercial real estate[29]. Van Nieuwerburgh (2023) presented a survey of studies on the development of teleworking and changes in housing prices and urban structures owing to the COVID-19 pandemic, including the results of these analyses.

In addition to lowering commuting costs, the development of teleworking may have affected consumer preferences for certain housing characteristics and urban amenities. For example, D'Lima et al. (2022) reported that, in the post-COVID-19 period, the

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NIRA, 2020). In the U.S., 53.5 % of workers worked from home as of October, 2020 (Brynjolfsson, 2023); in Japan, about 25 % of workers worked from home from April to May, 2020, and the proportion of teleworking decreased (Okubo, 2022; Okubo et al., 2021).

[27] This projection depends on the relationship between teleworking, productivity, and wages. The impact of teleworking on productivity is discussed by Bloom et al. (2015) for the U.S. and Okubo (2020), Morikawa (2021), and Morikawa (2023) for Japan.

[28] Comparisons of the changes in housing prices and rents also show that the flattening of the slope is more pronounced for rents.

[29] Huang et al. (2023) reported similar results using Chinese housing transaction data.

demand for larger suburban square footage housing increased. Specifically, they found that the price of a three-bedroom house fell by 1.4% in densely populated areas and rose by 1.5% in less densely populated areas. Van Vuuren (2023) also estimated the impact of consumption amenities, such as bars and restaurants, on apartment prices in Sweden. The results showed that the willingness to pay for amenities decreased, but the results were not stable because of the estimation model.

This study focuses on three factors: (i) the decline in commuting costs associated with the development of teleworking, (ii) the change in housing preferences, and (iii) the impact of the spread of teleworking to determine the impact of the COVID-19 pandemic on the housing market in Japan. Changes in housing prices and rent gradients with distance have been examined in other countries, such as by Gupta et al. (2022). However, to the best of our knowledge, only a few studies have used large-scale rent data to examine this issue in Japan. Regarding changes in housing preferences, we examine the hypothesis that changes such as the development of teleworking and demand for staying in homes have prompted an increase in the willingness to pay for housing space. Changes in housing characteristics and demand for amenities in the COVID-19 pandemic have been examined by D'Lima et al. (2022) and Van Vuuren (2023), but only a few empirical analyses have been conducted in Japan.

Considering this, we believe that this study makes an academic contribution by clarifying the medium- to long-term effects of the COVID-19 pandemic on the housing market in Japan.

3.4 Data

3.4.1 Housing Rent Data

We used rental apartment data contracted between January 2018 and June 2022 from the Real Estate Information Network for East Japan (REINS), which is one of the largest multiple listing services in Japan. The study area was the Tokyo Metropolitan Area, which comprises Tokyo and three neighboring prefectures (Saitama, Chiba, and Kanagawa), where residents mainly commute to Tokyo. The data included rental apartment transactions recorded at the property level, from registration to contract, and detailed property attributes (area, building structure, year built, floor plan, nearest station, walking time to nearest station, etc.) in addition to contract date, rent, and address. The initial sample size was 773,696; however, due to missing values, the sample size used in the following empirical analysis was 738,359. Table 3-2 shows the summary statistics.

By using housing rent data, we can capture the impact of COVID-19 on those who rent houses. In Japan, people are less likely to move once they buy a house because of family or mortgage. In contrast, those who rent houses are relatively more likely to move. Therefore, housing rent captures the impact of the risk of COVID-19 or the benefit of teleworking more than housing price.

3.4.2 Teleworking Index Data

We utilize people flow data called "Papilio" provided by Agoop, Inc.[30] This data contains hourly counts of people present in each municipality[31], recorded daily from January 1, 2019, to December 31, 2022. This data is generated by acquiring GPS location information from users of certain smartphone apps who have agreed to provide their GPS location information. Because this dataset provides information about detailed area and time, we can calculate the daytime-to-nighttime population ratio. Using this data, we

[30] https://agoop.co.jp/service/papilio/

[31] This is the estimated number of people who are considered to have stayed in a municipality during a certain period. This data is weighted depending on the samples' residence and converted to the scale of Japan's total population. This data covers only people residing in Japan.

develop a monthly teleworking index at the municipality level, and the index enables us to capture the widespread of teleworking. To generate the index, we first calculate the monthly ratio of daytime population to nighttime population in weekdays for each municipality. Then, we compare the ratio before and after COVID-19 to capture how teleworking has spread. The detailed process for creating this index involves the following two steps.

Table 3-2 Basic Statistics

Variable		Mean	Std.dev.	Min	Max
Housing rent per square meter	JPY	2675.908	862.2783	476.1905	14709.68
Distance to Tokyo Station	km	17.73525	11.61542	0.4404154	98.4846
Structure					
Wooden	-	0.2180415	0.412916	0	1
Block	-	0.0005119	0.0226188	0	1
Steel	-	0.1832815	0.3868974	0	1
Reinforced Concrete	-	0.4216476	0.4938231	0	1
Steel Reinforced Concrete	-	0.0627938	0.2425918	0	1
Prestressed Concrete	-	0.0024876	0.0498137	0	1
Hard Prestressed Concrete	-	0.0001909	0.0138167	0	1
Light Steel Frame	-	0.0929252	0.2903278	0	1
Other	-	0.01812	0.1333856	0	1
Building Age	year	2.801375	1.018064	0	7.612337
Distance to the nearest station	minute	8.15796	5.299363	1	99
Floor Area	㎡	32.20817	14.07537	12.49	81.3
Layout					
Studio	-	0.1568361	0.3636465	0	1
K	-	0.4291943	0.4949615	0	1
DK	-	0.1974339	0.3980627	0	1
LK	-	0.0004591	0.0214208	0	1
LDK	-	0.2064769	0.404777	0	1
SK	-	0.0020001	0.0446777	0	1
SDK	-	0.001667	0.0407945	0	1
SLK	-	0.0000393	0.0062665	0	1
SLDK	-	0.0058933	0.0765414	0	1
N			738,465		

In the first step, we calculate the ratio of daytime population to the nighttime population on weekdays for every month between January 2019 to December 2022. Following Watanabe and Yabu (2021), the average population between 0-5 am is defined as the night-time population, and the average population between 9 am to 5 pm is defined as the day-time population. Using these two variables, we define the ratio as that of daytime population to the nighttime population.

Second, we calculate the teleworking index by calculating the change of the ratio of the daytime population to nighttime population. For 2020 onwards, the percentage change from the ratio of daytime population to nighttime population in 2019 is determined as the teleworking index; for 2019 and earlier, this is set to zero. This is because we can use people flow data from 2019, and considering teleworking as not being widespread before 2019 is reasonable.

This teleworking index has two advantages. First, it allows us to use detailed monthly data. An alternative approach to create a teleworking index, such as a method by Brueckner et al. (2023), is to generate working from home potential based on the share of employees and teleworkability for each sector. Although this methodology could provide us the very precise number, the data is only available every 5 years in Japan. In contrast, our index comes from estimated people flow, offering more timely insights. Our teleworking index matches the work from home potential by Brueckner et al. (2023)[32]. Although scale is different because of the definition of two indices, these are correlated as shown in Figure 3-2.

[32] To generate this index, we use the industry-level population in each municipality from the 2020 census, and the proportion of teleworking for each industry in the year 2020 from the Telework Survey by the Ministry of Land, Infrastructure, Transport and Tourism.

Figure 3-2 Comparing our index with the existing index

Second, it allows us to observe the teleworking rate of people residing in the area, rather than those working in it. In the alternative methodology, we can only get the teleworking rate of those working in the area. However, those who work in the area are not necessarily the same as those who reside in the area. For example, Brueckner et al. (2023) used the employment share of industry in each area to create working from home potential, which is a teleworking index generated by them. Therefore, the alternative index might not accurately reflect the telework rate.

Although the data we use cannot identify whether those who stay within the same municipalities are teleworkers or not, the teleworking index can capture the change in the teleworking rate for those who work in different municipalities from where they live. As the teleworking index we have created reflects commuting pattern to the center of the Tokyo Metropolitan Area, the index can be interpreted as the change in the proportion of teleworking in each municipality. The ratio of daytime population to nighttime population is low in residential areas where many people commute to the city center, and high in the city center where many commuters come to work. If teleworking was widespread, people do not have to commute to the city center. Therefore, this index is considered positive and large in areas where teleworking has become widespread.

Additionally, we define the "daytime population outflow area" as one where the average ratio of daytime population to nighttime population in 2019 is less than 0.8, following the methodology outlined by Watanabe and Yabu (2021). Figure 3-2 shows both the defined daytime population outflow area and the average ratio of daytime population to nighttime population in 2019. The darker the color, the higher the ratio of daytime population to nighttime population. The lightest shade indicates residential areas. Figure 3-3 indicates that the daytime population outflow area is mainly situated in the vicinity of the city center, centered on Tokyo station. Furthermore, we use the commuting zones defined by Adachi et al. (2021). They use the Hierarchical agglomerate clustering method and generate commuting zones from the number of commuters and workers.

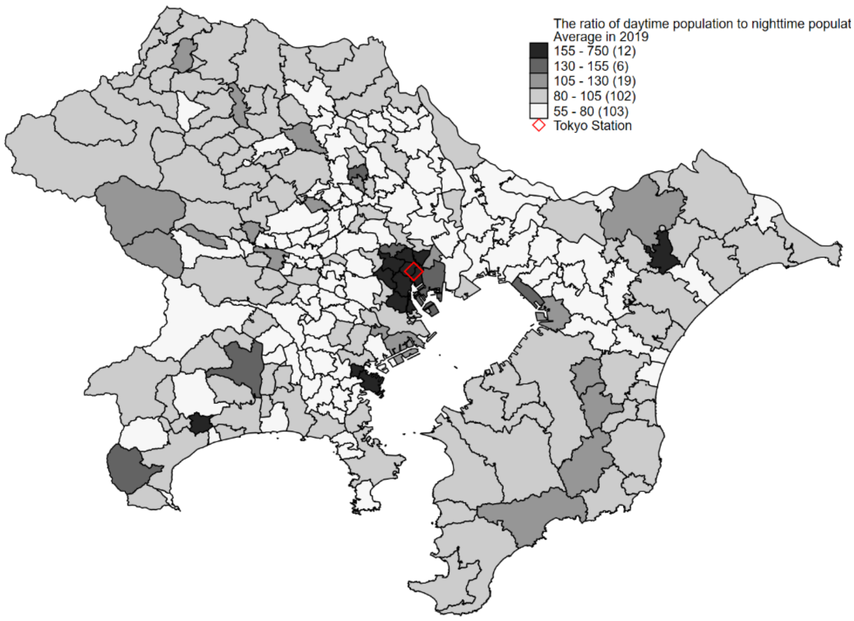

Figure 3-3 Map of the ratio of daytime population to nighttime population

Notes: This map shows the average ratio of daytime population to nighttime population at the municipality level in 2019. The lightest shaded area represents the daytime population outflow area.

3.5 Empirical Model

This study analyzed the impact of COVID-19 on the rent of apartments. The number of commuting days decreased significantly owing to the spread of teleworking because of the pandemic. Consequently, workers' evaluations of rental housing close to the city center, where the workplace is located, was likely to change. In other words, demand for smaller, higher-rent housing in the city center may have decreased, while demand for larger, lower-rent housing in the suburbs may have increased.

Therefore, this study estimates the rent function, as in Gupta et al. (2022), and analyzes how the rent gradient with respect to distance from the city center changed before and after COVID-19. Additionally, we assume that the demand for housing space changed with the encouragement of teleworking during COVID-19 and analyze the difference in the impact of exclusive areas on rent before and after COVID-19. To achieve these objectives, we implement four distinct analyses.

First, we calculate monthly rent gradients. By doing so, we can see the pre-COVID-19 trends in rent gradients. Additionally, it makes finding the change in trends after the COVID-19 pandemic easier. We divide the sample into each month from January 2018 to June 2022, and for each month, we conduct regressions using the following Equation (3.1):

$$\ln\left(P_{ij}\right) = \alpha_0 + \alpha_1 \times \ln(Distance_i) + \boldsymbol{\delta}'\boldsymbol{X_{ij}} + d_j + \nu_{ij}, \cdots (3.1)$$

where $\ln\left(P_{ij}\right)$ is the logarithm of the rent per square meter for property i located in municipality j and $\boldsymbol{X_{ij}}$ is the housing attributes (building structure, age, distance to the nearest station, exclusive area, and floor plan). $\ln(Distance_i)$ is the logarithm of the straight-line distance (km) from property i to Tokyo Station, d_j is municipality fixed effects, and ν_{ij} is the error term. The coefficient α_1 represents the rent gradients for each month, which is what we are interested in. This coefficient represents the extent to which housing rent decreases as one moves away from city center.

Second, to analyze the change in the rent gradient with the distance from the city center before and after COVID-19, we estimated Equation (3.2) using rental apartment data for individual property units.

$$\ln\left(P_{ijt}\right) = \alpha_0 + \alpha_1 \times \ln(Distance_i) + \alpha_2 \times After_t + \alpha_3 \times \ln(Distance_i) \times After_t$$
$$+\boldsymbol{\delta}'\boldsymbol{X_{ijt}} + d_j + YearMonth_t + \nu_{ijt} \cdots (3.2)$$

$\ln\left(P_{ijt}\right)$ is the logarithm of the rent per square meter for property i transacted in year-month t located in municipality j. $After_t$ is a dummy variable that takes the value of 1 if property i was transacted after COVID-19, and X_{ijt} is the housing attribute (building structure, age, distance to the nearest station, exclusive area, and floor plan). d_j and $YearMonth_t$ are municipality fixed effects and time fixed effects, respectively, and ν_{ijt} is the error term. The coefficient of interest here, α_3, represents the extent to which the impact of linear distance to Tokyo Station on rents changed after the COVID-19 pandemic.

Despite various arguments regarding when the COVID-19 pandemic started, we defined it as starting from the date the first state of emergency was declared (April 7, 2020). Therefore, $After_t$ is a dummy variable that equals 1 if the property was traded after April 7, 2020.

Then, we analyzed the changes in housing characteristic preferences due to COVID-19. We focus on the size of rental properties and estimate a model that allows the impact of property size on housing rent to vary before and after the pandemic. To do so, we estimate Equation (3.3).

$$\ln(P_{ijt}) = a_0 + a_1 \times \ln(Distance_i) + a_2 \times After_t + +a_3 \times \ln(Distance_i) \times After_t$$

$$+a_4 \times \ln(Area_i) + a_5 \times \ln(Area_i) \times After_t + \boldsymbol{\delta' X_{ijt}} + d_j + YearMonth_t + v_{ijt} \cdots (3.3)$$

$Area_t$ is the floor space, and Equation (3.3) adds to Equation (3.2) the log of the exclusive area and intersection term between the log of the exclusive area and post-COVID-19 dummy. The coefficient of interest, a_5, captures the change in willingness to pay relative to the exclusive area. The increase in teleworking owing to the COVID-19 pandemic is thought to have increased the demand for properties with larger square footage. Therefore, this coefficient is expected to be positive.

Third, to capture the impact of teleworking on housing rent, we use teleworking index generated in Section 3.4.

$$\ln(P_{ijt}) = a_0 + \alpha_1 \times \ln(Distance_i) + a_2 \times After_t + \lambda_3 \times \ln(Distance_i) \times After_t$$

$$+\beta \times WFH_{jt} + \boldsymbol{\delta' X_{ijt}} + d_j + YearMonth_t + v_{ijt}, \cdots (3.4)$$

where WFH_{jt} is the teleworking index in municipality j in year-month t. Since a higher teleworking index (WFH_{jt}) indicates greater penetration of teleworking, the coefficient β represents the extent of rent changes with the prevalence of teleworking.

Fourth, we estimate the impact of COVID-19 on property size. This analysis enables us to identify whether renters' preferences shifted to properties with larger rooms. Teleworking is the prime reason for the increased demand for larger rooms. This means that teleworking encourages people to move to suburban areas because teleworkers are not required to commute to the city center daily. Additionally, the need for a workspace, alongside a residential area, heightened the demand for larger rooms among teleworkers. Therefore, we analyze the following equation which includes floor space on the left-hand side, and log of distance to Tokyo station and teleworking index on the right-hand side:

$$\ln(Area_{ijt}) = \gamma_0 + \gamma_1 \times \ln(Distance_i) + \gamma_2 \times After_t$$
$$+ \gamma_3 \times \ln(Distance_i) \times After_t$$
$$+\gamma_4 \times WFH_{jt} + \boldsymbol{\delta'X_{ijt}} + d_j + YearMonth_t + \nu_{ijt}, \cdots (3.5)$$

Each variable in Equation (3.5) remains consistent with those previously introduced.

3.6 Estimation Results

3.6.1 Estimation results of monthly rent gradients

Figure 3-4 plots the monthly rent gradients α_1, estimated based on Equation (3.1), to confirm the change in the rent gradient over time. Because there are no pre-trend adjustments, we allow time-varying shock toward rent gradients before COVID-19.

Before the spread of COVID-19, a downward trend was observed as the dashed line (fitted value) indicates. This downward trend implies that rent gradients with respect to the distance from the city center had become steeper over time. Conversely, after the COVID-19 pandemic, Figure 3-4 shows an upward trend, marked by a dashed line, indicating that the rent gradient has been becoming less steep.

These changes are consistent with the effect of the decline in marginal commuting costs in the single-center-city model assuming a closed city and can be interpreted as the development of teleworking and reduced commuting congestion lowering commuting costs, resulting in a flattening of the rent gradient.

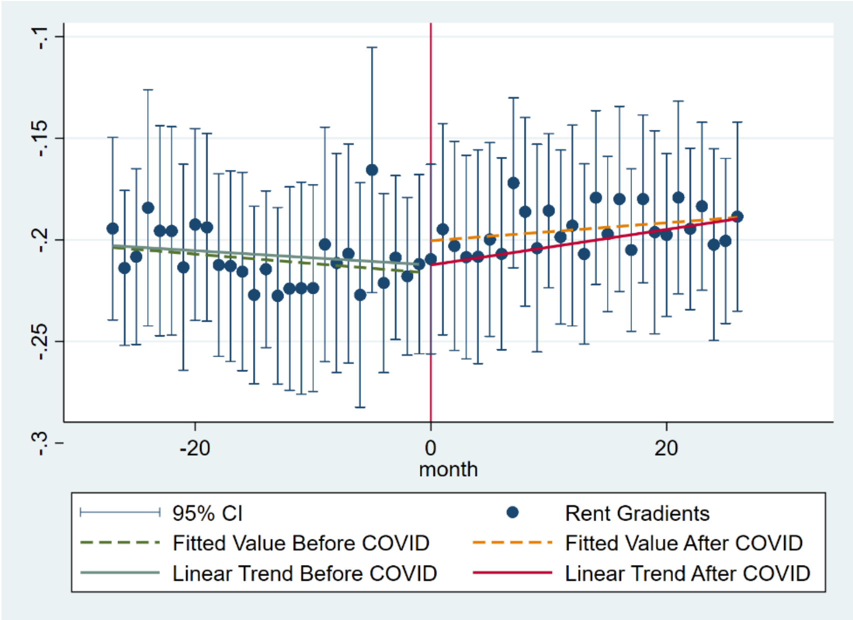

Figure 3-4 Monthly level rent gradients

Notes: Dots indicate rent gradients of each month, and bars indicate the 95% confidential interval. April, 2020 is 0 on the horizontal axis. Dashed lines are the fitted value of dots, and solid lines are the estimated rent gradients from Column (6) of Table 3-3.

3.6.2 Estimation results of rent gradients

Table 3-3 Estimation results for the slope of the rent curve presents the estimation results for Equation (3.2). The estimation results show that the rent per square meter declined with distance from Tokyo Station, but the effect was diminished after COVID-19. In all models, we add year-month fixed effect and municipality fixed effect to remove influences specific to time and location.

In Table 3-3 Estimation results for the slope of the rent curve, the regression result of housing rent on the logarithm of the distance to Tokyo Station is shown. In Column (1) of Table 3-3, which housing attributes are not included, the coefficients of the log of distance from Tokyo Station is found to be negative and significant. This means that the rent gradient is negative during the pre-pandemic period. This pattern suggests that housing rent is the highest in the city center and decreases as the distance to the city center increases. Because we do not include housing attributes in Column (1), the coefficients of the interaction term between the post-COVID-19 dummy and log of distance from Tokyo Station is not significant.

However, the coefficient turns out to be positive and significant after controlling housing attributes (Column (2) of Table 3-3). We add housing attributes to account for the effects of other variables that are not of interest. This result implies that COVID-19 makes the rent gradient flattened, suggesting that the dynamics of housing rent has changed because of COVID-19.

The regression result with the linear trend[33] is shown in Column (3) of Table 3-3 Estimation results for the slope of the rent curve. The predicted rent gradients are also shown as solid lines in Figure 3-4 Monthly level rent gradients. The regression result illustrates that rent gradient was inclined before COVID-19, and that it gradually became gentler after the pandemic.

In Columns (4) of Table 3-3 Estimation results for the slope of the rent curve, we omit transactions that occurred in the city center, namely, Chiyoda, Minato, and Chuo wards, because transactions in these areas are sparse. The result is consistent with our baseline model (Column (2) of Table 3-3 Estimation results for the slope of the rent curve), indicating the stability of our base model.

In Column (5) of Table 3-3 Estimation results for the slope of the rent curve, we conducted a placebo test following Huntington-Klein (2021). Specifically, we used only transaction properties prior to April 7, 2020, when the first state of emergency was declared, and analyzed the data assuming that the pandemic began on October 6, 2019. The estimation result indicates that the assumption of parallel trends is satisfied because the cross terms are not statistically significant.

These analyses reveal a negative rent gradient before the COVID-19 pandemic, and the gradient became less steep after the pandemic. Overall, we found that the rent gradient in the Tokyo Metropolitan Area flattened by 4.4%[34] after the COVID-19 pandemic.

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[33] We regress $\ln(P_{ijt}) = \beta_0 + \beta_1 \times After_t + \beta_2 \times \ln(Distance_i) + \beta_3 \times \ln(Distance_i) \times After_t + +\beta_4 \times \ln(Distance_i) \times Trend_t + \beta_5 \times \ln(Distance_i) \times Trend_t \times After_t + \boldsymbol{\delta' X_{ijt}} + d_j + YearMonth_t + v_{ijt}$, where $Trend_t$ represents a time trend where March 2020 is -1, April 2020 is 0, and so on.

[34] $\left(\frac{0.00920}{-0.207}\right) \times 100 \sim 4.4$

Table 3-3 Estimation results for the slope of the rent curve

			Linear Trend	Excluding the City Center	Placebo
	(1)	(2)	(3)	(4)	(5)
ln(Distance to Tokyo Station)	-0.292***	-0.207***	-0.212***	-0.228***	-0.209***
	(0.0340)	(0.0213)	(0.0212)	(0.0212)	(0.0220)
AFTER	-0.0188*	-0.0280***	-0.00979	-0.0260***	
	(0.0104)	(0.00657)	(0.00775)	(0.00710)	
ln(Distance to Tokyo Station) ×AFTER	-0.000125	0.00920***	0.00240	0.00855***	
	(0.00210)	(0.00138)	(0.00213)	(0.00158)	
ln(Distance to Tokyo Station) ×Linear Trend			-0.000352***		
			(0.0000789)		
ln(Distance to Tokyo Station) ×Linear Trend×AFTER			0.00123***		
			(0.000155)		
FAKE					0.00533
					(0.00526)
ln(Distance to Tokyo Station) ×FAKE					-0.000160
					(0.00159)
Housing Attributes	NO	YES	YES	YES	YES
N	773379	738459	738459	718168	403855
R-squared	0.611	0.857	0.857	0.854	0.857

Notes: Standard errors are clustered at the municipality level and shown in parentheses. ***, **, and * indicate that the estimated coefficient is significant at the 0.01, 0.05, and 0.1 levels, respectively. Year-Month fixed effects and Municipality fixed effects are included in all models.

Following this, we examine the shifts of preferences for housing characteristics arising from the COVID-19 pandemic. Using Equation (3.3), we analyze changes in residential area preferences. Results are shown in Table 3-4. In Column (1) of Table 3-4, we include Year-Month fixed effects and municipality fixed effects, but not include housing attributes. Although the cross term between the coefficient of the cross-term between distance and post-COVID-19 dummy remains insignificant, the coefficient of the cross term between log of floor space and post-COVID-19 dummy is positive and significant. This indicates that the willingness pay for larger floor space has increased after the COVID-19 pandemic.

After controlling housing attributes, Column (2) of Table 3-4 shows that the coefficient of the cross-term between distance and post-COVID-19 dummy is positive and significant. This result is consistent with Column (2) of Table 3-3.

Similarly, the coefficient of the cross-term between the exclusive area and post-COVID-19 dummy is also positive and significant. Thus, the demand for exclusive spaces for rental housing increased after the COVID-19 outbreak. A possible reason for this is the spread of teleworking owing to the pandemic. As work is performed from home, the demand for residential housing with a large exclusive area may have increased owing to the need for space for work in addition to the space for living.

In Column (3), we drop transactions in city center, as with Column (4) of Table 3-3. The result remains consistent with the result of Column (2). Additionally, we implement placebo test in Column (4), and the result indicates that the changing trend of the rent gradient comes from COVID-19 because the coefficient of the cross term between distance and fake event is insignificant.

Table 3-4 Estimation results for floor space and the slope of the rent curve

			Excluding the City Center	Placebo
	(1)	(2)	(3)	(4)
ln(Distance to Tokyo Station)	-0.257***	-0.206***	-0.227***	-0.210***
	(0.0246)	(0.0212)	(0.0212)	(0.0220)
AFTER	-0.0857***	-0.115***	-0.109***	
	(0.0152)	(0.0107)	(0.0105)	
ln(Distance to Tokyo Station) ×AFTER	0.00199	0.00723***	0.00621***	
	(0.00240)	(0.00135)	(0.00148)	
ln(Area)	-0.348***	-0.400***	-0.402***	-0.392***
	(0.0122)	(0.00863)	(0.00870)	(0.00885)
ln(Area)×AFTER	0.0192***	0.0273***	0.0262***	
	(0.00288)	(0.00213)	(0.00202)	
FAKE				0.0238**
				(0.00991)
ln(Distance to Tokyo Station) ×FAKE				0.000227
				(0.00165)
ln(Distance to Tokyo Station) ×FAKE				-0.00572**
				(0.00254)
Housing Attributes	NO	YES	YES	YES
N	773379	738459	718168	403855
R-squared	0.754	0.857	0.854	0.857

Notes: Standard errors are clustered at the municipality level and shown in parentheses. ***, **, and * indicate that the estimated coefficient is significant at the 0.01, 0.05, and 0.1 levels, respectively. Year-Month fixed effects and Municipality fixed effects are included in all models. Standard errors are clustered at the municipality level.

3.6.3 Results of the impact of teleworking on housing rents

Similar to Brueckner *et al.* (2023) and Gupta *et al.* (2022), our results indicate that teleworking has flattened the rent gradient. In this subsection, using Equation (3.4), we try to capture the impact of the proportion of teleworking on housing rent. The areas with a higher proportion of teleworkers indicate the increase of housing demand. Teleworkers demand more room or space to work because teleworkers work at home instead of commuting to their office. Therefore, to capture the impact of teleworking, we calculate the change of the ratio of daytime population to nighttime population and use it as teleworking index. Table 3-5 shows that teleworking has a positive effect on housing rent (Column (1) of Table 3-5). Furthermore, when we restrict the sample to the daytime population outflow area, where residents in the area are highly likely to commute to other municipalities in daytime, the impact of teleworking on housing rent becomes more pronounced (Column (2) of Table 3-5). These results indicate that the spread of teleworking increases housing rent. Additionally, Column (3) of Table 3-5 shows the results when the sample is restricted to the commuting zone of Tokyo in 2015 defined by Adachi *et al.* (2021). This is the area where residents in the area are highly likely to commute to central Tokyo. The result indicates the positive impact of the teleworking index on housing rent.

Table 3-5 Estimation results of the impact of teleworking on housing rents

		Low-Teleworking index	Commuting Zone
	(1)	(2)	(3)
ln(Distance to Tokyo Station)	-0.206***	-0.241***	-0.203***
	(0.0214)	(0.0270)	(0.0219)
After	-0.0203***	-0.0198	-0.0116
	(0.00694)	(0.0121)	(0.00770)
ln(Distance to Tokyo Station)	0.00636***	0.00762**	0.00506**
×After	(0.00157)	(0.00308)	(0.00199)
Teleworking index	0.0247***	0.0518**	0.0273***
	(0.00558)	(0.0206)	(0.00570)
N	738459	371870	587877
R-squared	0.857	0.840	0.818

Notes: Standard errors are clustered at the city level and shown in parentheses. ***, **, and * indicate that the estimated coefficient is significant at the 0.01, 0.05, and 0.1 levels, respectively. Housing attributes, Year-Month fixed effects, and Municipality fixed effects are included in all models.

3.6.4 Subsample analysis on floor space

In this subsection, we focus on the size of apartments. This is because we want to analyze the heterogeneous attitude toward CODID-19 by household type. Families are less likely to move compared to single households because of family members. When a family moves, considering the spouse's and children's will is necessary in addition to the individual's situation. In contrast, single household can move easily because there are no barrier once he/she decides to move.

In Table 3-6, we divide the sample based on floor space following Mikawa, Yasuda, and Yukutame (2023). The objective of this sub-sample analysis is to see the impact of COVID-19 separately for single-type apartments and family-type apartments. In Columns (1) and (2), we restrict samples to transactions where the floor space is 25 square meters, as it is the housing area standard for single-person household defined by the Statistics Bureau of Japan. In Columns (3) and (4), we restrict samples to transactions where floor space is less than 40 square meters, as it is the target housing area for single-person household defined by the Statistics Bureau of Japan. These subsamples are regarded as those of single-person household. In contrast, we restrict the samples where the floor space is 40 square meters or more as a proxy for family-type apartments in Columns (5) and (6). We regard these larger apartments as family-type apartments.

We implement the same model as Column (2) of Table 3-3 and Column (1) of Table 3-5. The results indicate that single-type apartments are consistent with our baseline model, and family-type apartments do not show any significant effect. These results support the statement that families are less likely to move compared to single households.

Table 3-6 Estimation results of subsample analyses

	Less than 25m2		Less than 40m2		40m2 or more	
	(1)	(2)	(3)	(4)	(5)	(6)
ln(Distance to Tokyo Station)	-0.190***	-0.189***	-0.194***	-0.193***	-0.260***	-0.259***
	(0.0242)	(0.0244)	(0.0235)	(0.0236)	(0.0284)	(0.0284)
After	-0.0447***	-0.0386***	-0.0297***	-0.0244***	0.00222	0.00630
	(0.00852)	(0.00937)	(0.00831)	(0.00902)	(0.0100)	(0.0102)
ln(Distance to Tokyo Station) ×After	0.0125***	0.0102***	0.00838***	0.00636***	-0.00112	-0.00253
	(0.00140)	(0.00173)	(0.00160)	(0.00187)	(0.00193)	(0.00202)
Teleworking index		0.0184***		0.0166**		0.0141
		(0.00658)		(0.00712)		(0.00898)
N	296688	296688	531681	531681	206774	206774
R-squared	0.717	0.717	0.741	0.741	0.848	0.848

Notes: Standard errors are clustered at the municipality level and shown in parentheses. ***, **, and * indicate that the estimated coefficient is significant at the 0.01, 0.05, and 0.1 levels, respectively. Housing attributes, Year-Month fixed effects, and Municipality fixed effects are included in all models.

3.6.5 Impact of COVID-19 on floor space

In Equation (3.5), we have focused on the impact of the COVID-19 and the advancement of teleworking on housing rent. Moreover, we have evaluated the changes in the willingness to pay for floor space as a consequence of COVID-19. In this subsection, we analyze the impact of the COVID-19 pandemic and progression of teleworking on housing floor space.

To examinate the shift of renters' preference toward larger floor space, we estimate Equation (3.5). Table 3-7 shows the impact of the distance to city center to floor space. Columns (1) and (2) show that the distance to the city center positively affects floor space after the COVID-19 pandemic, with and without housing attributes. Moreover, The result remains consistent after controlling the teleworking index (Column (3) of Table 3-7).

In Columns (4) to (5) of Table 3-7, we divide the sample according to the teleworking index. These results indicate that the further away from the city center, the larger the floor space becomes.

Furthermore, we observed that the degree to which floor space increases has intensified after the COVID-19 outbreak. However, from Columns (3), (4), and (5), no significant impacts of COVID-19 are observed in the daytime population outflow area. This might indicate that the supply of rental housing does not change dramatically in the area. Even if many people look for large apartments, the supply of large apartments cannot increase immediately. Therefore, housing rent for larger floor space has increased after the COVID-19 pandemic.

Table 3-7 **Estimation results of the impact of COVID-19 on floor space**

				Daytime population outflow area	Not daytime population outflow area
	(1)	(2)	(3)	(4)	(5)
ln(Distance to Tokyo Station)	0.0993**	0.0258	0.0260	0.0950***	-0.0228
	(0.0492)	(0.0190)	(0.0191)	(0.00931)	(0.0200)
AFTER	-0.0173	-0.00959	-0.00861	0.0114	-0.0177*
	(0.0140)	(0.00688)	(0.00730)	(0.0124)	(0.00958)
ln(Distance to Tokyo Station)	0.0109***	0.00522***	0.00485***	-0.00113	0.00733***
×AFTER	(0.00360)	(0.00165)	(0.00163)	(0.00297)	(0.00188)
Teleworking index			0.00313	-0.0374	-0.00300
			(0.00967)	(0.0262)	(0.0176)
Housing Attributes	NO	YES	YES	YES	YES
N	773379	738459	738459	371870	366589
R-squared	0.0740	0.707	0.707	0.726	0.688

Notes: Standard errors are clustered at the city level and shown in parentheses. ***, **, and * indicate that the estimated coefficient is significant at the 0.01, 0.05, and 0.1 levels, respectively. Year-Month fixed effects, and Municipality fixed effects are included in all models.

3.7 Conclusion

This study focuses on the rental housing market and analyzes how the rent gradient with distance from the city center changed after the COVID-19 pandemic. The results show that the rent gradient became smaller after the COVID-19 pandemic, with the trend lasting at least two years. These results are thought to be due to the shift to teleworking that occurred because of the COVID-19 pandemic, and a shift in demand from housing with good access to the city center and high rents to inexpensive housing in the suburbs. It was also clear that rents were higher for properties with larger private floor space after the COVID-19 pandemic compared to before. This increased the demand for larger residences, possibly because teleworking increases the number of people requiring a workspace in addition to a living space in their rental houses. In relation to this, we find that municipalities with a high proportion of teleworkers experience a rise in housing rent. Additionally, we show the expansion of teleworking has no impact for family-type apartments.

While this paper has prevailed in the impact of teleworking on rental housing market, further research is required to refine empirical data. Although we used the straight-line distance to Tokyo Station as an indicator of access to the city center, using the train commuting time from the nearest station to Tokyo Station is more accurate. Whether rapid trains stop at the nearest station may be important for choosing a place to live; however, this is an issue to be addressed in the future.

Moreover, the current analysis of changes in housing preferences focuses on residential floor spaces; however, changes in housing needs due to the COVID-19 pandemic may occur in various aspects other than housing size. For example, longer self-restraint may have increased the importance of urban amenities in residential areas, whereas amenities in places of employment may have decreased in relative importance. These possibilities should be explored when additional information becomes available.

4. Impact of the 2011 earthquake on the real estate market in Tokyo

4.1 Introduction

Globally, natural disasters are increasing steadily. Japan experiences approximately 2,000 earthquakes per year. Figure 4-1 shows the annual frequency of earthquakes in Tokyo. It indicates that the average frequency of earthquakes drastically increased in 2011 after the Great East Japan Earthquake, and this trend has persisted.

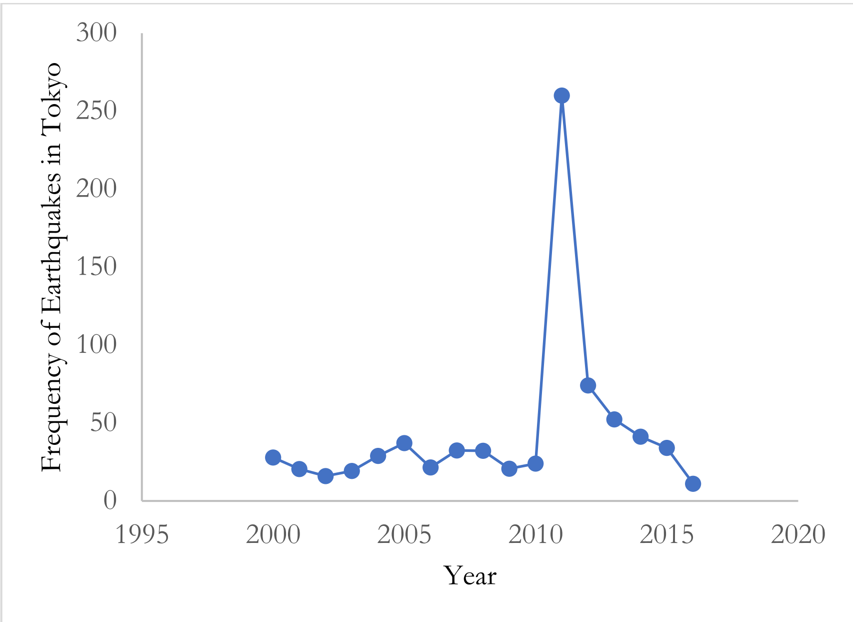

Figure 4-1 Annual frequency of earthquakes in Tokyo

Source: Japan Meteorological Agency

Toda et al. (2011) report that seismic activity in Japan increased rapidly after the 2011 Great East Japan earthquake. Furthermore, the Cabinet Office (2012) confirms that the occurrence of the earthquake is unexpected even for seismology experts, stating that

> "There is a possibility that the source region includes six zones for long-term risk assessment conducted by the Earthquake Research Committee of the Headquarters for Earthquake Research Promotion. … However, an earthquake that interlocks all of those zones simultaneously has not been predicted to occur."

On March 11, 2011, the Great East Japan Earthquake struck the Tohoku region causing over 15,000 casualties. The residents usually receive information regarding the disaster through the regular news broadcasts (Gallagher, 2014). Therefore, after the Great East Japan Earthquake, it is likely that people in Tokyo realized the risk of disasters through broadcast, although they did not suffer severe damage.

This study explores how people heterogeneously react to a big disaster depending on their perception of disaster risk before the disaster. It uses the nature of the ground on which a building stands as a source of people's assessment of disaster risk. This is because earthquake damage is greater when the ground is soft, as observed in Japan (Osaki, 1983). Milne (1886) mentions that heterogeneity in the magnitude of damage due to the ground is also recorded in the great Jamaica earthquake of 1692 and other earthquakes of the early modern period.

This study uses land prices to see how people's perceptions of disaster risk change. This is because people's risk perception after a catastrophe is commonly determined by both their prior and updated risk perceptions (Fink and Stratmann, 2015; Tanaka and Zabel, 2018). Prior risk perception is based on expected earthquake risk. Updated risk perception is based on new information reported after a disaster, such as information obtained from broadcasts about the damages caused by the disaster. In the hedonic model, changes in risk perception can be captured by changes in real estate price; a price drop shows that people perceived a higher earthquake risk.

Therefore, this study investigates the impact of ground conditions (topography) on real estate prices in areas that have not been hit by disasters recently. It reveals that land prices in lowland areas decreased by approximately 3% in the undamaged area after the 2011 Great East Japan Earthquake. This result indicates that risk perception in lowland areas, where people's risk perception before the earthquake is higher, is updated after the earthquake, and the degree of renewal of risk perception is higher in lowland areas.

The study also reveals that land prices in high-risk areas increased after the Great East Japan Earthquake, validating Yasuda et al. (2018) who find that housing rents and prices increased in high-risk areas after the Great East Japan Earthquake. They assert that the increase is because of the overestimated seismic risk before the Great East Japan Earthquake.

This chapter contributes to the existing literature as follows. First, it uses a restricted version of transaction data from Tokyo, which was not adversely affected by the 2011 Great East Japan earthquake. These data include the exact date and address of the transaction, although the web version contains community-level transaction points and quarter-year-level transaction dates to maintain anonymity. The detailed data enables us to control seasonality with greater precision. Second, a novel finding of this study is that people change their risk perception by ground classification. Previous studies which focus on Tokyo mainly use the community earthquake risk, which is published every five years. This index is calculated by many factors. In contrast, this study captures the impact of ground solely.

This chapter is structured as follows. Section 4.2 reviews the previous research. Section 4.3 shows the data and basic model used in this study. Section 4.4 presents the main results, and Section 4.5 provides a robustness check. Lastly, Section 4.6 concludes the chapter.

4.2 Literature Review

Previous studies have investigated the impact of natural disasters on economic activity. Natural disasters reduce GDP per capita (Barone and Mocetti, 2014) and night light intensity (Elliott et al., 2015; Kocornik-Mina et al., 2020) in the short run. Moreover, some studies have focused on the relationship between natural disasters and firm activity (Cole et al., 2019; Okazaki et al., 2019; Okubo and Strobl, 2021), as well as natural disasters and income (Groen et al., 2020; Noy et al., 2021).

Various studies on how natural disasters affect an individual's behavior also exist. Gallagher (2014) suggests an increase in insurance buying rates after disasters. Boustan et al. (2020) find the increase in population outflow rate after a big disaster. Another major way to assess risk perception is to focus on the real estate market. Several studies, such as Brown et al. (2018) and Kousky (2010), have demonstrated how risk perception can affect real estate prices in damaged areas.

This study relates to the literature on risk perception in the real estate market. Gayer et al. (2000) and Fink and Stratmann (2015) theoretically show that increasing risk perception leads to a decrease in real estate prices.

Many studies show that people's risk perception can change even if they do not suffer direct damage. Fekrazad (2019) finds that the impact of large foreign earthquakes on housing prices is greater in high-risk areas of California because people avoid high-risk areas after receiving updated information. The reduction is caused by an affective reaction, which means that people tend to avoid taking risks. Moreover, Naoi et al. (2009) observe that higher the predicted probability of a large earthquake, lower the housing rent and owner-provided house value after major earthquakes in other municipalities. Timar et al. (2018) assert that liquefaction risk reduced housing prices in earthquake-prone areas after a huge earthquake in other areas.

Even when a huge earthquake has not occurred, real estate prices decrease when earthquake risk has changed. Nakagawa et al. (2007, 2009) and Singh (2019) show that the changes in hazard levels due to the release or updating of hazard maps change real estate prices.

Several studies have explored the impact of the Great East Japan Earthquake and the following Fukushima Daiichi nuclear power plant accident on the Japanese real estate market. Tanaka and Managi (2016), Kawaguchi and Yukutake (2017), and Munro (2018) use real estate price data to analyze the impact of radiodensity, indicating a fall in the real estate prices for land in the periphery of nuclear power plants or in areas with increased radiodensity after the earthquake. These studies focus on heavily affected areas in Japan.

In addition, some studies investigated whether the Great East Japan Earthquake and the following Fukushima Daiichi Nuclear Power Plant accident affected real estate prices outside Japan. Numerous studies have been conducted in several countries to observe whether real estate prices in proximity to nuclear power plants decreased after the accident in Switzerland (Boes et al., 2015), Germany (Bauer et al., 2017), and the United States (Fink and Stratmann, 2015; Tanaka and Zabel, 2018). These studies find that real estate prices in the periphery of nuclear power plants decreased in multiple countries because of expectations of a change in risk perception except for Fink and Stratmann (2015).

This chapter also contributes to the literature on the spillover effects of severe disasters. Hornbeck and Keniston (2017) reveal that land price and building value increased in the areas affected by the Great Boston Fire of 1872 and the surrounding areas owing to the reconstruction of the buildings. In contrast, some studies find negative spillover effects from natural disasters.

4.3 Data and Methods

4.3.1 Data

This study uses five datasets to estimate the heterogeneous impact of the Great East Japan Earthquake on land prices. The first dataset used in this study was obtained from the Land General Information System provided by the Ministry of Land, Infrastructure, Transport and Tourism (MLIT). It contained daily-level real estate transaction data, such as transaction dates, addresses, and land attributes. Land attributes contain front road information (direction, width, and kind), building-coverage ratio, floor-area ratio, and zoning information. This study used data from transactions in the Tokyo Special Zone from April 2008 to July 2018 and land prices to measure risk perception. As it is difficult to estimate the information and damage effect separately (Cohen et al., 2021), this study focuses on the nondamaged area.

There are other potential datasets that can be used to analyze the real estate market. One common real estate dataset used in Japan is the appraisal land price (*koji-chika*). The data are the evaluated value determined by licensed real estate appraisers, effective as of January 1, and announced annually. Although using panel data is advantageous, it is not the actual transaction price but the evaluated value. Therefore, *koji-chika* is unlikely to properly capture catastrophes that have never experienced, as the evaluation by professional appraisers of the impact of unforeseen event is often not accurate in the immediately aftermath. (Kawaguchi and Yukutake, 2017). Moreover, Shimizu and Nishimura (2006) compare appraisal and transaction prices and find a significant difference. These studies suggest the use of the transaction price as the most appropriate method.

Furthermore, housing prices can be used to analyze the real estate market. However, this study uses land prices because people do not prefer pre-owned housing in Japan. Munro (2018) mentions that it is common for Japanese homeowners who purchase a pre-owned house to demolish an existing structure and construct a new one. Hence, this study uses land prices instead of housing prices and focuses on land and pre-owned housing transactions in residential areas. The dataset of pre-owned housing includes information on housing and land values. This enables the distinction between the land value and total transaction value.

Housing rent is another metric to analyze the real estate market. However, this study does not use it because housing rent can be rigid, and those who live in rental housing may not be concerned about the future. Unlike homeowners, they are less likely to consider disasters with a low probability of occurrence.

The second dataset used in this study was obtained from the community earthquake risk provided by the Tokyo Metropolitan Government. It contained the risk of earthquakes in each community. The study used the combined risk in 2008 and 2013, before and after the Great East Japan Earthquake. Combined risk is determined by considering the chance of building collapse, fire risk, and emergency response difficulties. The risk index was categorized from 1 to 5, where 1 denoted the lowest risk area and 5 denoted the highest risk area. This risk index was calculated under the assumption that tremors of the same intensity had occurred in each community.[35] This dataset also contained community-level ground classification.

The third dataset used in this study was the ground condition. This dataset was obtained from Japan Seismic Hazard Information Station (J-SHIS). It contained mesh data with an amplification rate of 250 m × 250 m. This rate indicates the amplification frequency of the underground seismic waves. A large number indicates that the area experienced more intense tremors. In the sample area, this rate falls between 0.52 m/s and 2.88 m/s, and the value exceeding 1.6 m/s is classified as a high-risk area.[36] While the second dataset contained information about lowland area, the lowland ground classification used at the community level was only divided into 12 categories. To supplement this limited information, we utilized a more detailed dataset. This dataset was matched to real estate prices using the Geography Information System (GIS) software.

The fourth dataset was obtained from the National Land Information Division by MLIT. It included the locations of railroad stations and routes. This information was also matched to each transaction plot using GIS software. The fifth dataset included the seismic scale of the Great East Japan Earthquake and was obtained from tenki.jp. The seismic scale was divided into 10 scales from 0 to 7,[37] with 7 being the strongest. The

[35] See Tokyo Metropolitan Government (2022).
[36] See website of J-SHIS (https://www.j-shis.bosai.go.jp/labs/wm2020/).
[37] Seismic intensity in order of weakest to strongest: 0, 1, 2, 3, 4, 5-, 5+, 6-, 6+, 7.

Great East Japan Earthquake recorded a score of 7 in the Miyagi prefecture. Tokyo recorded a score of 5+ and 5−. The last dataset was the area of liquefaction. It was obtained from the MLIT (Tokyo Metropolitan Government, 2022) and showed the communities affected by liquefaction in the Great East Japan Earthquake. Seismic scale data were matched at the city level, and earthquake risk and liquefaction data were matched at the community level. The sample area was restricted to 23 wards in Tokyo. Table 4-1 presents the basic statistics.

Table 4-1 Basic statistics

Variable	Obs	Mean	S.D.	Min	Max
log of land price per square meter	101,852	12.8756	0.7373548	2.639057	18.16579
After	101,852	0.743736	0.4365714	0	1
Kumamoto	101,852	0.2051997	0.4038495	0	1
Lowland	101,852	0.4839473	0.4997447	0	1
Amplification rate (Amp)	101,852	1.725655	0.3674842	1.0832	2.8763
Distance to the nearest railway station (m)	101,852	562.1066	380.3919	2.60352	3055.151
Building coverage ratio	101,849	61.78868	10.51485	30	100
Floor-area ratio	101,843	236.6616	128.4772	50	1300
Width of the front road	99,299	6.029633	4.208111	0.5	30
Liquefaction area	101,852	0.0100047	0.0995224	0	1
Seismic scale of the Great East Japan Earthquake					
5-	101,852	0.6213722	0.4850475	0	1
5+	101,852	0.3786278	0.4850475	0	1
Community earthquake risk in 2008					
1 (lowest)	101,847	0.1065127	0.3084942	0	1
2	101,847	0.4293401	0.4949844	0	1
3	101,847	0.3087671	0.4619871	0	1
4	101,847	0.1164983	0.3208231	0	1
5 (highest)	101,847	0.0388819	0.1933143	0	1
Change of community earthquake risk between 2008 and 2013					
Decreased	101,852	0.1319562	0.3384448	0	1
Increased	101,847	0.1145345	0.318461	0	1

Notes: Sample includes transactions in Tokyo Special Zone. The sample period covers 2008–2018. Top 1% and bottom 1% of road width are excluded.

4.3.2 Empirical Model

This study estimates how the Great East Japan Earthquake changed peoples' earthquake risk perceptions. As stated by Fink and Stratmann (2015), people's risk perceptions change after obtaining new information about disasters. This study endeavors to find heterogeneity depending on the ground condition in which people live. It focuses on areas that were not affected by the earthquake significantly. Those who live in vulnerable areas might be sensitive to disasters because of information updates.

To estimate this, we used the difference-in-differences (DID) framework, as shown in Equation (4.1).

$$\ln(y_{icd}) = \beta_0 + \beta_1 AFTER_d + \beta_2 Lowland_i + \beta_3 AFTER_d \times Lowland_i + \boldsymbol{\gamma}'\boldsymbol{X_{icd}} + D_c + YEARMONTH_d + \varepsilon_{icd}, \quad (4.1)$$

where $\ln(y_{ict})$ is the log of land price per square meter of transaction i in community c at time t. $AFTER_t$ is a dummy variable, which is 1 if the transaction occurred after the Great East Japan Earthquake. $Lowland_i$ is the dummy variable of lowland, which is 1, if point i is located on the valley bottom lowland or alluvial lowland. $\boldsymbol{X_{icd}}$ is a vector of land attributes, D_c is a community-fixed effect, $YEARMONTH_d$ is a year-month fixed effect, and ε_{ijd} is an error term.

β_2 reflects the evaluation of lowlands before the Great East Japan Earthquake, and β_3 captures the impact of the Great East Japan Earthquake. The interest of this study is β_3, which shows how people living in lowland areas changed their risk perception after the disaster.

The study also estimates the impact of amplification rate instead of the impact of lowland. The equation is as follows:

$$\ln(y_{icd}) = \beta_0 + \beta_1 AFTER_d + \beta_2 Amp_i + \beta_3 AFTER_d \times Amp_i + \boldsymbol{\gamma}'\boldsymbol{X_{icd}} + D_c + YEARMONTH_d + \varepsilon_{ict}, \quad (4.2)$$

where Amp_i is the amplification rate of transaction point i. The amplification rate is 250m x 250m mesh data.

4.4. Results

This section shows the results of the estimation model mentioned in the previous section. Equations (4.1) and (4.2) estimated whether the Great East Japan Earthquake decreased land prices in soft ground areas. To identify soft ground areas, I used two measurements: lowland dummy and amplification rate. Table 4-2 shows the estimated impact of the Great East Japan Earthquake on land prices in the soft ground area of Tokyo.

Columns (1) and (2) of Table 4-2 show the results of the simple DID estimates, which do not include land attributes or fixed effects. Column (1) indicates that land prices in lowland areas decreased by approximately 2.9% after the Great East Japan Earthquake. Column (2) indicates that land prices in soft ground areas also decreased after the earthquake, although they are nonsignificant. In Columns (3) and (4), I added land attributes, a year-by-month fixed effect and community fixed effect. These results show that the 2011 Great East Japan Earthquake significantly decreased land prices in soft ground areas. Column (3) indicates that land prices in lowland areas reduced by approximately 3.4% due to the Great East Japan Earthquake.

Table 4-2 Basic difference-in-differences (DID) framework results

Dependent variable: ln (land price per square meter)				
	(1)	(2)	(3)	(4)
Lowland×After	-0.0293**		-0.0338***	
	(-2.17)		(-3.24)	
Amp×After		-0.0194		-0.0299**
		(-1.12)		(-2.05)
Land attributes	NO	NO	YES	YES
Year × Month FE	NO	NO	YES	YES
Community FE	NO	NO	YES	YES
N	101852	101852	98697	98697
R-squared	0.0473	0.104	0.471	0.471

Notes: ***, **, and * indicate that the estimated coefficient is significant at the 0.01, 0.05, and 0.10, levels, respectively.

These results indicate that because of updated risk perception, the Great East Japan Earthquake led to a decrease in land price in areas with soft ground conditions. Specifically, hearing about earthquakes in other areas updates information and raises people's perception of earthquake risk, leading to a decrease in land prices in vulnerable areas.

4.5. Robustness check

The results of this study show that, in 23 wards in Tokyo, land prices in areas with the soft ground decreased significantly after the Great East Japan Earthquake. The possible reasons that explain the change in land prices after the earthquake are as follows. First, damage from the Great East Japan Earthquake led to a decrease in land prices in Tokyo. This study implicitly assumed that there was no damage to the sample area. However, the maximum seismic intensity of the Great East Japan Earthquake in Tokyo was 5+[38]. In addition, some areas were affected by liquefaction.

Second, another huge earthquake must be considered during our sample period, namely the Kumamoto Earthquake of April 14, 2016. This earthquake also recorded a score of 7 on the seismic scale similar to the Great East Japan Earthquake during the sample period, causing 273 casualties. Third, some people consider earthquake risk when buying land or housing (Nakagawa et al., 2007, 2009). Therefore, this study needs to consider earthquake risk. Fourth, unobservable factors, such as reconstruction, affect land prices. This study adds a risk index for several periods to address this problem. This is because the earthquake risk index has challenges considering the risk of building collapse, building fire, and emergency response difficulties. This means that reconstruction can reduce the earthquake risk index. Therefore, this section uses the risk index for 2008 (before the Great East Japan Earthquake) and 2013 (after the Great East Japan Earthquake). Lastly, checking parallel trends was necessary to implement the DID framework. Therefore, to assess the parallel trend and estimate the duration of land price reduction, I replaced the dummy variable for the Great East Japan Earthquake in Equation (4.1) with year dummies.

In the subsequent subsections, I present evidence that the decreases in land prices after the Great East Japan Earthquake are caused by ground conditions, even after considering

[38] This intensity is defined as https://www.jma.go.jp/jma/en/Activities/inttable.html.

other possible factors. Damages of the Great East Japan Earthquake are analyzed (Section 4.5.1), and the impact of the Kumamoto Earthquake is discussed (Section 4.5.2). The earthquake risk index is also analyzed (Section 4.5.3), and the control for unobservable community-fixed effects such as reconstruction is discussed (Section 4.5.4). Lastly, parallel trends are assessed (Section 4.5.5).

4.5.1. Impact of the Great East Japan Earthquake

The Great East Japan Earthquake caused minor damage to Tokyo, with 7 casualties and damage to 16 buildings. Liquefaction caused the most severe damage, concentrating in the coastal area. After considering these damages, the heterogeneous impact on land prices was re-estimated. Table 4-3 presents the results.

In Columns (1) and (2), dummy variables of the seismic scale of the Great East Japan Earthquake have been added to Equations (4.1) and (4.2) for each transaction point i. Further, the interaction terms between the seismic scale dummies and dummy variable for the 2011 Great East Japan earthquake are added to identify the impact of the damage. In Columns (3) and (4), I added the liquefaction damage dummy, which is 1 if damage occurred in the community where transaction point i is located, along with the interaction term between liquefaction damage dummy and the dummy variable for the 2011 earthquake, in Equations (4.1) and (4.2).

Columns (1) to (4) show that the impact of the earthquake and liquefaction is nonsignificant. However, the interaction term between soft ground variables and after-the-earthquake dummy is still negative and significant, except for Column (2).

The results indicate that people did not react to direct damage from the Great East Japan Earthquake. These results justify the assumption that Tokyo did not experience significant damage from the Great East Japan Earthquake. There are two possibilities why people did not react to the liquefaction. First, they understood the impact of liquefaction. Landowners or house owners are already aware of the implications of liquefaction when buying real estate. Second, the damage caused by liquefaction was nonsignificant. If liquefaction occurred within the community and did not cause any direct damage to housing, then land prices would not change. Furthermore, it is possible that people did not react to the magnitude of the earthquake because there was little damage despite the high score on the seismic scale.

Although Kawaguchi and Yukutake (2017) assert that the impact from the Fukushima Daiichi Nuclear Power Plant accident, which occurred following the Great East Japan Earthquake, exists in the periphery of the Fukushima Daiichi Nuclear Power Plant, this impact does not affect this study's results. This is because the study's sample area is restricted to Tokyo Special Zone, where radiation level is low enough, indicating no potential impact of the Fukushima Daiichi Nuclear Power Plant accident in the results. In summary, damages from the Great East Japan Earthquake did not affect land prices in the Tokyo Metropolitan Area.

Table 4-3 Controlling damage and the Kumamoto Earthquake

Dependent variable: ln (land price per square meter)						
	(1)	(2)	(3)	(4)	(5)	(6)
Lowland×After	-0.0309***		-0.0344***		-0.0388***	
	(-2.89)		(-3.28)		(-3.63)	
Amp×After		-0.0233		-0.0310**		-0.0295**
		(-1.52)		(-2.11)		(-1.98)
Scale 5+ × After	-0.0172	-0.0176				
	(-1.58)	(-1.56)				
Liquefaction ×After			0.0303	0.0287		
			(0.58)	(0.54)		
Lowland×Kumamoto					0.0219*	
					(1.93)	
Amp×Kumamoto						-0.00185
						(-0.12)
Land attributes	YES	YES	YES	YES	YES	YES
Year×Month FE	YES	YES	YES	YES	YES	YES
Community FE	YES	YES	YES	YES	YES	YES
N	98697	98697	98697	98697	98697	98697
R-squared	0.471	0.471	0.471	0.471	0.471	0.471

Notes: Scale 5+ is the dummy variable that is equal to 1 if the seismic scale of the Great East Japan Earthquake in the transaction is 5+. Kumamoto is the dummy variable that is equal to 1 if a transaction occurred after the Kumamoto Earthquake. Standard errors are clustered at the community level. T-values are shown in parentheses, and ***, **, and * indicate that the estimated coefficient is significant at the 0.01, 0.05, and 0.10 levels, respectively.

4.5.2. Impact of the Kumamoto Earthquake

From 2008 to 2018, Japan was struck by another massive earthquake, scoring a 7 on the seismic scale. On April 14, 2016, the M 7.0 earthquake hit Kumamoto. The main difference between this earthquake and the Great East Japan Earthquake was public interest. A key reason for the difference in press coverage might be the difference in damage. Figure 4-2 shows how the public's interest differed between the two earthquakes. It clearly indicates that public interest in the Great East Japan Earthquake lasted longer than the Kumamoto Earthquake.

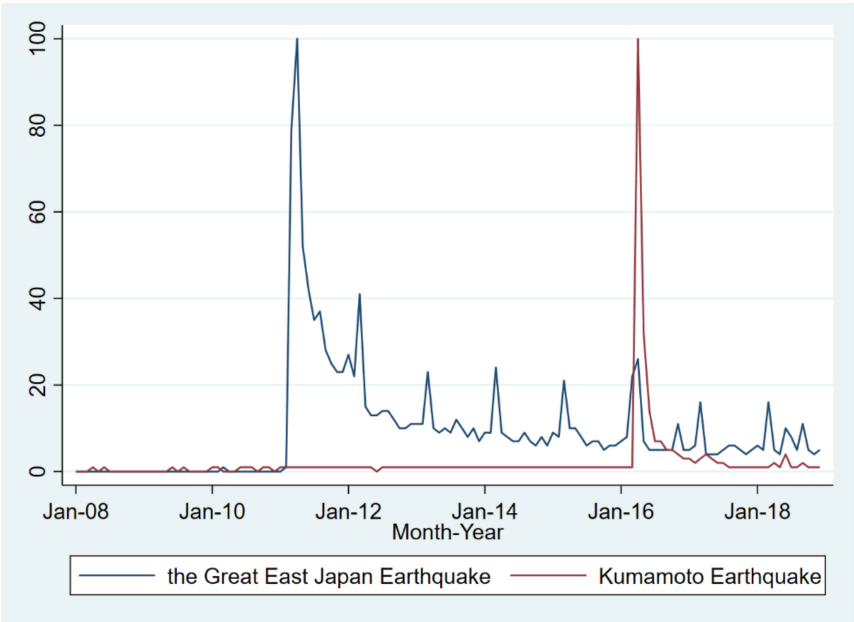

Figure 4-2 People's interest in the Great East Japan Earthquake and Kumamoto Earthquake

Notes: This graph is derived from Google Trends by searching "The Great East Japan Earthquake" and "Kumamoto Earthquake" in Japanese. The sample period is from January 2008 to December 2018. This graph indicates how people are interested in the words. The value 100 indicates the most interested, and other values are relative values. Values less than 1 are replaced by 1.

To capture the effect of the Kumamoto Earthquake, a dummy variable, ("Kumamoto" in Table 4-3) which is equal to 1 if a transaction occurred after the Kumamoto earthquake, was added, along with the interaction between the Kumamoto dummy and lowland indices. Columns (5) and (6) in Table 4-3 show the results. In Column (5), the coefficients of the lowland dummy and Kumamoto dummy are positive and significant, indicating that land prices in the lowlands recovered owing to the Great East Japan Earthquake. In Column (6), the cross-term of the amplification rate and Kumamoto dummy is nonsignificant. The coefficients of the interaction term between the soft ground and after the Great East Japan Earthquake in Columns (5) and (6) do not change much compared to the basic results in Table 4-2. These results show that the Kumamoto Earthquake did not result in a decrease in land prices in Tokyo.

4.5.3. Impact of earthquake risk measures

The Tokyo Metropolitan Government releases community earthquake risk measures every 5 years. This risk measure assumes that "the same intensity has occurred directly under each community" (Tokyo Metropolitan Government, 2022). Earthquake risk data contain three risk measures: building collapse, fire, and combined risks. These three measures were rated on a five-point scale from 1 (low) to 5 (high). The building collapse risk was assessed by ground characteristics, building density, and building characteristics. Fire risk was measured by the chance of fire outbreak and spread. Combined risk consists of the risk of collapse, risk of fire, and emergency response difficulties.

In this study, the combined risk measure was used. This community earthquake risk affects land prices and housing rents (Nakagawa et al., 2007, 2009). Moreover, this measure led to heterogeneous effects on land prices after the Great East Japan Earthquake (Yasuda et al., 2018). To consider the impact of community earthquake risk, dummy variables for earthquake risk in 2008 were added, along with cross-terms for these and after in Equations (4.1) and (4.2). Table 4-4 presents the results.

In Columns (1) and (2), community risk dummies and interaction terms are added. After adding these variables, the coefficients of soft ground indices and after dummies are slightly higher than the results in Table 4-2. Moreover, these results indicate that land prices in areas with high community risk increased after the earthquake. This result aligns with Yasuda et al. (2018), who mention that housing rent decreased after the Great East Japan Earthquake but increased in high-risk areas.

Table 4-4 Controlling community earthquake risk

Dependent variable: log (land price per square meter)				
	(1)	(2)	(3)	(4)
Lowland×After	-0.0531***		-0.0515***	
	(-4.78)		(-4.17)	
ARV×After		-0.0431***		-0.0383**
		(-2.93)		(-2.35)
Risk 2×After	0.0176	0.0156	0.0180	0.0157
	(1.16)	(1.03)	(1.18)	(1.04)
Risk 3×After	0.0576***	0.0505***	0.0588***	0.0511***
	(3.35)	(2.97)	(3.31)	(2.91)
Risk 4×After	0.0712***	0.0520**	0.0724***	0.0517**
	(3.36)	(2.51)	(3.21)	(2.37)
Risk 5×After	0.107***	0.0886***	0.106***	0.0843**
	(3.27)	(2.74)	(3.16)	(2.55)
Rank Down×After			-0.00983	-0.0104
			(-0.63)	(-0.64)
Rank Up×After			-0.0102	-0.0267
			(-0.58)	(-1.55)
Land attributes	Yes	Yes	Yes	Yes
Year × Month FE	Yes	Yes	Yes	Yes
Community FE	Yes	Yes	Yes	Yes
N	98693	98693	98693	98693
R-squared	0.471	0.471	0.471	0.471

Notes: Rank Down is the dummy variable that is equal to 1 if the community earthquake risk in 2013 is lower than that in 2008. Rank Up is the dummy variable that is equal to 1 if the community earthquake risk in 2013 is higher than that in 2008. Standard errors are clustered at the community level. T-values are shown in parentheses, and ***, **, and * indicate that the estimated coefficient is significant at the 0.01, 0.05, and 0.10 levels, respectively.

4.5.4. Controlling reconstruction

In this subsection, there is an attempt to control unobservable community-fixed effects such as reconstruction. To capture this, a good proxy is the community earthquake risk used in the previous subsection, which incorporates the factors related to reconstruction, such as the width of roads, parks, building density, and building characteristics. Therefore, considering the change in community risk can capture unobservable community-level effects. Dummy variables of the increase and decrease of the community risk from 2008 to 2013 were added along with their cross terms and after dummies.

Columns (3) and (4) in Table 4-4 present the results. The coefficients of the earthquake impact did not change significantly. Therefore, the Great East Japan Earthquake lowered land prices in lowland areas.

4.5.5. Assessing parallel trends

This study determines how long land price reductions last and assesses whether the parallel trend assumption holds. Therefore, I replaced the dummy in Equation (4.1) with the year dummies in Equation (4.3).

$$\begin{aligned}\ln(y_{icd}) = {} & \beta_0 + \beta_1 AFTER_d + \beta_2 Lowland_i \\ & + \sum_{j \neq 2010} \beta_{3\_j} Yeaer_d \times Lowland_i + \boldsymbol{\gamma}' \boldsymbol{X_{icd}} + D_c + D_d \\ & + \varepsilon_{icd}.\end{aligned} \tag{4.3}$$

All variables, except for the year dummies, are similar to Equation (1). The interest is β_{3_j} because these coefficients indicate how much the land price in lowland areas decreased in comparison to 2010, one year before the Great East Japan Earthquake.

Figure 4-3 plots the coefficients of the interaction terms of year dummies and lowland dummy of Equation (4.3). This result indicates that after the Great East Japan Earthquake, land prices in soft ground areas decreased for 5 years before increasing again. The coefficients show how much land prices decreased compared to 2010. The coefficients of 2008 and 2009 are nonsignificant, indicating that the parallel trend is satisfied. The reasons for this effect to last only 5 years could be that people might have forgotten about the disaster risk (Fekrazad, 2019) and might have overreacted to the disaster (Deng et al., 2015).

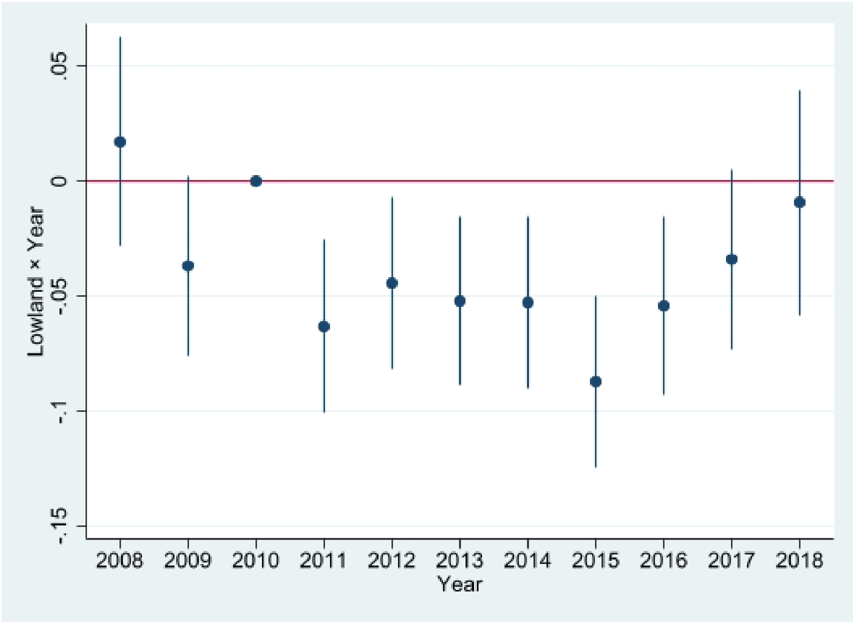

Figure 4-3 Long-term effect of the Great East Japan Earthquake in the lowlands of Tokyo

Notes: This figure shows the result of Equation (4.3). All variables used in Table 4-3 and Table 4-4 are used. The coefficients of interaction terms between year and lowland dummies are plotted. The dots indicate coefficients and bars with 95% confidence intervals.

4.6. Conclusion

This study analyzes the impact of the Great East Japan Earthquake on people's updating of information. For this purpose, it uses land prices. In addition, it targeted Tokyo Special Zone, which was not directly damaged by the Great East Japan Earthquake.

It reveals that, following the 2011 Great East Japan Earthquake, land prices in the lowland areas of the Tokyo Special Zone decreased by 3% than that in other areas. This impact lasted 5 years before returning to the pre-disaster level, suggesting that a large disaster affects land prices in areas unaffected by the disaster.

The decrease in land prices after the earthquake can be explained by differences of prior risk perception. When people update their risk perception after the Great East Japan Earthquake, those who live in vulnerable areas may experience greater shifts in their risk perception compared with those living in other regions. This can occur even when people in both vulnerable and nonvulnerable areas have access to the same information after the earthquake. This is because prior risk perception of the people in vulnerable area is higher.

In other words, people residing in lowland area may have had a higher pre-existing risk perception because they have experienced more intense earthquakes, making them more vulnerable to change in their perceived risk level after the earthquake. The differences in prior risk perception can lead the heterogeneous risk updates, and such updates are reflected in the decrease in land prices in the lowland areas after the earthquake.

However, land prices reverted to the previous trend after 5 years. There are two possible reasons for this. First, people may have forgotten the severity of the disaster (Fekrazad, 2019). Second, people may have overreacted to the disaster (Deng et al., 2015). As this study does not confirm which reason is correct, future research should determine the reason for the land price reduction.

Another finding was that the Kumamoto Earthquake, which occurred during the sample period, did not affect the land prices in Tokyo Special Zone. It is highly likely that the Kumamoto Earthquake did not arouse as much interest as the Great East Japan Earthquake. The lower interest may be due to the lesser extent of damage caused by the earthquake and scale of broadcasting. In contrast, Fekrazad (2019) shows that earthquakes in different countries decreased land prices. Future studies should investigate the heterogeneous effect of a disaster depending on its scale or media coverage.

This study makes two significant contributions. First, it examines how people perceive earthquake risk and update their earthquake risk assessment even when they do not experience severe damage. There are about 2,000 earthquakes in Japan every year; therefore, people are accustomed to them. However, they unaccustomed to major earthquakes and the information about them can change their risk perception. Second, this study finds new factors that people consider when evaluating earthquake risks. Previous studies mainly used community earthquake risk provided by the Tokyo Metropolitan Government; however, this study explicates ground classification, which is an index of tremor.

Although this study provides new insight to the literature on how disasters affect real estate markets, it has some limitations that require focus in future research. First, the mechanism of the land price reduction should be identified. As mentioned above, there are some possible reasons for the land price reduction. However, this study cannot identify the specific reason. Second, the difference in the reaction between land price, rent, and housing price is obscure.

5. Conclusion

In this dissertation, I investigate the effect of exogenous shocks on the real estate market. Using Japanese real estate price data, I find that these shocks significantly affect Japanese real estate market. Especially, I found spillover effect from the shock.

In Chapter 2, I investigated the impact of the inheritance taxation reform on housing rent. I find that the 2015 taxation reform increased the construction of low-construction-cost apartments. This leads to a decrease in housing rent for those housing structures. In Chapter 3, I investigate the impact of COVID-19 outbreak. I found that the rent gradient became smaller after the COVID-19 pandemic. Also, I found the increase for the willingness to pay for spacious room, positive impact of the proportion of teleworking on housing rent, and the heterogeneous impact depending on the property intended for single-person household or families. In Chapter 4, I investigate the impact of a distant earthquake. I found that land process on soft ground decreased after a big earthquake, even if the earthquake occurred in a distant area.

Overall, this dissertation contributes to comprehensive understanding of how large-scale exogenous shocks affect real estate market in Japan. The results provide insights for policymakers. Future research should be dedicated to considering the characteristics of housing buyers and renters. Although the data used in this dissertation is detailed, information on housing buyers and renters is not included in the dataset. This limitation prevents a deeper understanding of how individual characteristics, such as age and income, influence the way people respond to exogenous shocks.

Bibliography

Adachi, D., Fukai, T., Kawaguchi, D., Saito, Y. U., 2021. Commuting zones in Japan. RIETI Discussion Paper Series 20-E-021.

Ahlfeldt, G. M., Redding, S. J., Sturm, D. M., and Wolf, N., 2015. The Economics of Density: Evidence from the Berlin Wall. Econometrica, 83(6), 2127-2189.

Americans for Tax Fairness, 2012. Responsible Estate Tax Proposal. Retrieved from. http://d3n8a8pro7vhmx.cloudfront.net/ufe/legacy_url/393/2012_20Estate_2_0Tax_20Sign_20On_20Statement_202_0.pdf?1448056400 (accessed December 11, 2022).

Asada, Y., Yamazaki, F., 2010. Effects of bequest tax on land price variations in Japan. The Japanese Journal of Real Estate Sciences 23(4), 80-89.

Autor, D.H., Palmer, C.J., Pathak, P.A., 2014. Housing market spillovers: Evidence from the end of rent control in Cambridge, Massachusetts. Journal of Political Economy 122(3), 661-717.

Banzhaf, H. S., 2021. Difference-in-differences hedonics. Journal of Political Economy, 129(8), 2385-2414.

Barone, G., Mocetti, S., 2014. Natural disasters, growth and institutions: A tale of two earthquakes. Journal of Urban Economics 84, 52-66.

Batalha, M., Gonçalves, D., Peralta, S., Dos Santos, J. P., 2022. The virus that devastated tourism: The impact of covid-19 on the housing market. Regional Science and Urban Economics, 95, 103774.

Bauer, T.K., Braun, S.T., Kvasnicka, M., 2017. Nuclear power plant closures and local housing values: Evidence from Fukushima and the German housing market. Journal of Urban Economics 99, 94-106.

Baum-Snow, N., 2007. Did Highways Cause Suburbanization?. Quarterly Journal of Economics, 122(2), 775-805.

Bellemare, M. F., Wichman, C. J., 2020. Elasticities and the inverse hyperbolic sine transformation. Oxford Bulletin of Economics and Statistics 82(1), 50-61.

Best, M. C., Kleven, H. J., 2018. Housing market responses to transaction taxes: Evidence from notches and stimulus in the UK. The Review of Economic Studies, 85(1), 157-193.

Bloom, N., Liang, J., Roberts, J., Ying, Z. J., 2015. Does working from home work? Evidence from a Chinese experiment. Quarterly Journal of Economics, 130(1), 165-218.

Boes, S., Nüesch, S., Wüthrich, K., 2015. Hedonic valuation of the perceived risks of

nuclear power plants. Economics Letters 133, 109-111.
Boustan, L.P., Kahn, M.E., Rhode, P.W., Yanguas, M.L., 2020. The effect of natural disasters on economic activity in US counties: A century of data. Journal of Urban Economics 118, 103257.
Brown, P., Daigneault, A.J., Tjernström, E., Zou, W., 2018. Natural disasters, social protection, and risk perceptions. World Development 104, 310-325.
Brueckner, J. K., Kahn, M. E., Lin, G. C., 2023. A new spatial hedonic equilibrium in the emerging work-from-home economy? American Economic Journal: Applied Economics, 15(2), 285-319.
Brynjolfsson, E., Horton, J. J., Makridis, C., Mas, A., Ozimek, A., Rock, D., TuYe, H. Y., 2023. How many Americans work remotely? A survey of surveys and their measurement issues. NBER Working Paper, w31193.
Cabinet Office, 2012. White papers on Disaster Management 2011 Executive Summary.
Chapman, K., Hariharan, G., Southwick Jr., L., 1996. Estate Taxes and Asset Accumulation. Family Business Review 9.3 , 253-268.
Cohen, J.P., Barr, J., Kim, E., 2021. Storm surges, informational shocks, and the price of urban real estate: An application to the case of Hurricane Sandy. Regional Science and Urban Economics 90, 103694.
Cole, M.A., Elliott, R.J.R., Okubo, T., Strobl, E., 2019. Natural disasters and spatial heterogeneity in damages: The birth, life and death of manufacturing plants. Journal of Economic Geography 19, 373-408.
D'Lima, W., Lopez, L. A., Pradhan, A. (2022). COVID-19 and housing market effects: Evidence from US shutdown orders. Real Estate Economics, 50(2), 303-339.
Delventhal, M. J., Kwon, E., Parkhomenko, A. (2022). JUE Insight: How do cities change when we work from home? Journal of Urban Economics, 127, 103331.
Deng, G., Gan, L., Hernandez, M.A., 2015. Do natural disasters cause an excessive fear of heights? Evidence from the Wenchuan earthquake. Journal of Urban Economics 90, 79-89.
Diamond, R., McQuade, T., Qian, F., 2019. The effects of rent control expansion on tenants, landlords, and inequality: Evidence from San Francisco. American Economic Review, 109(9), 3365-3394.
Dingel, J. I., Neiman, B., 2020. How many jobs can be done at home? Journal of Public Economics, 189, 104235.
Duff, D.G., 2005. The abolition of wealth transfer tax: lessons from Canada, Australia, and New Zealad. Pittsburgh Tax Rev. 3 (1), 71–120.
Duranton, G. and Turner, M. A., 2011. The Fundamental Law of Road Congestion:

Evidence from US Cities. American Economic Review, 101(6), 2616-2652.
Duranton, G., Handbury, J., 2023. Covid and cities, thus far. NBER Working Paper, w31158.
Elliott, R.J.R., Strobl, E., Sun, P., 2015. The local impact of typhoons on economic activity in China: A view from outer space. Journal of Urban Economics 88, 50-66.
Escobar, S., 2017. Inheritance tax evasion: Spousal bequests and under-reporting of inheritances in Sweden. Working paper.
Fekrazad, A., 2019. Earthquake-risk salience and housing prices: Evidence from California. Journal of Behavioral and Experimental Economics 78, 104-113.
Fink, A., Stratmann, T., 2015. US housing prices and the Fukushima nuclear accident. Journal of Economic Behavior and Organization 117, 309-326.
Gallagher, J., 2014. Learning about an infrequent event: Evidence from flood insurance take-up in the United States, American Economic Journal: Applied Economics 6, 206-233.
Gayer, T., Hamilton, J.T., Viscusi, W.K., 2000. Private values of risk tradeoffs at Superfund sites: Housing market evidence on learning about risk. The Review of Economics and Statistics 82, 439-451.
Gibbons, S. and Machin, S., 2005. Valuing Rail Access Using Transport Innovations, Journal of Urban Economics, 57(1), 148-169.
Gilding, M., Glezos, L., 2014. Inheritance taxes in Australia: a matter of indifference, not taboo. Australian Journal of Social Issues, 49(1), 23-43.
Groen, J.A., Kutzbach, M.J., Polivka, A.E., 2020. Storms and jobs: The effect of hurricanes on individuals' employment and earnings over the long term, Journal of Labor Economics 38, 653-685.
Grossman, P. J., 1990. Fiscal Competition among States in Australia: The Demise of Death Duties. Publius, 20(4), 145–159.
Gupta, A., Mittal, V., Peeters, J., Van Nieuwerburgh, S., 2022. Flattening the curve: Pandemic-induced revaluation of urban real estate. Journal of Financial Economics, 146(2), 594-636.
Horn, K., Merante, M., 2017. Is home sharing driving up rents? Evidence from Airbnb in Boston. Journal of Housing Economics 38, 14-24.
Hornbeck, R., Keniston, D., 2017. Creative destruction: Barriers to urban growth and the great boston fire of 1872, American Economic Review 107(6), 1365-1398.
Huang, N., Pang, J.,Yang, Y., 2023. JUE Insight: COVID-19 and household preference for urban density in China. Journal of Urban Economics, 133, 103487.
Huntington-Klein, N., 2021. The effect: An introduction to research design and causality.

CRC Press.
Joulfaian, D., 2006. The behavioral response of wealth accumulation to estate taxation: Time series evidence. National Tax Journal, 59 (2), 253–268.
Kanemoto, Y., 1989. An economic analysis of asset taxation [Shisan Kazei No Keizai Bunseki]. Japan Economic Research Institute Foundation [Nihon Keizai Kenkyu],18, 94-114.
Kanemoto, Y., 1997. The housing question in Japan. Regional Science and Urban Economics, 27(6), 613-641.
Kawaguchi, D., Yukutake, N., 2017. Estimating the residential land damage of the Fukushima nuclear accident. Journal of Urban Economics 99, 148-160.
Kocornik-Mina, A., McDermott, T.K.J., Michaels, G., Rauch, F., 2020. Flooded cities. American Economic Journal: Applied Economics 12, 35-66.
Kopczuk, W. Munroe, D., 2015. Mansion tax: The effect of transfer taxes on the residential real estate market. American Economic Journal: Economic Policy, 7(2), 214-257.
Kousky, C., 2010. Learning from extreme events: Risk perceptions after the flood. Land Economics 86(3), 395–422.
Kutsuzawa R., Akai, N., Takemoto, T., 2021. Empirical Analysis of the Effect of the Infection and Damage of COVID-19 on Land Prices. OSIPP Discussion Paper, DP-2021-J-009.
Lee, D., 2016. How Airbnb Short-Term Rentals Exacerbate Los Angeles's Affordable Housing Crisis: Analysis and Policy Recommendations. Harvard Law & Policy Review, 10(1), 229–254.
Liu, S., Su, Y., 2021. The impact of the COVID-19 pandemic on the demand for density: Evidence from the US housing market. Economics letters, 207, 110010.
Liu, Y., Tang, Y., 2021. Epidemic shocks and housing price responses: Evidence from China's urban residential communities. Regional Science and Urban Economics, 89, 103695.
Mikawa, N., Yasuda, S., Yukutake, N., 2023. Does inheritance taxation reform promote to build inexpensive rental housing? Journal of the Japanese and International Economies, 68, 101255.
Milne, J., 1886. Earthquakes and Other Earth Movements (Vol. 56), D. Appleton and Company: New York.
Ministry of Land, Infrastructure, Transport and Tourism, 2021a. Building Construction Work Started [Kenchiku Tyakkou Toukei] [Data file] Retrieved from https://www.mlit.go.jp/toukeijouhou/chojou/kakodata.html

(accessed August 31, 2021)
Ministry of Land, Infrastructure, Transport and Tourism, 2021b. Housing Construction Work Started [Jyutaku Tyakkou Toukei] [Data file]. Retrieved from http://www.mlit.go.jp/statistics/details/jutaku_list.html (accessed December 7, 2020)
Morikawa, M., 2021. Productivity of firms using relief policies during the COVID-19 crisis. Economics Letters, 203, 109869.
Morikawa, M., 2022. Work-from-home productivity during the COVID-19 pandemic: Evidence from Japan. Economic Inquiry, 60(2), 508-527.
Morikawa, M., 2023. Productivity dynamics of remote work during the COVID-19 pandemic. Industrial Relations, 62(3), 317-331.
Munro, A., 2018. Economic valuation of a rise in ambient radiation risks: Hedonic pricing evidence from the accident in Fukushima. Journal of Regional Science 58, 635-658.
Nakagawa, M., Asada, Y., Yukutake, N., Yasuda, S., Ishii, K., 2020. The Impact of COVID-19 and the Introduction of ICT Technologies into Work Processes on National and Urban Structures [COVID-19 Oyobi ICT Gijyutu No Gyomu Process Heno Donyu Ga Kokudokouzou Oyobi Toshi Kouzou Ni Oyobosu Eikyo]. NUPRI Working Paper 2020-1
Nakagawa, M., Saito, M., Yamaga, H., 2007. Earthquake risk and housing rents: Evidence from the Tokyo Metropolitan Area. Regional Science and Urban Economics 37, 87-99.
Nakagawa, M., Saito, M., Yamaga, H., 2009. Earthquake risks and land prices: Evidence from the Tokyo metropolitan area. Japanese Economic Review 60, 208-222.
Naoi, M., Seko, M., Sumita, K., 2009. Earthquake risk and housing prices in Japan: Evidence before and after massive earthquakes. Regional Science and Urban Economics 39, 658-669.
National Tax Agency, 2021. Long-term Data [Cho-ki Jikeiretsu De-ta] [Data file]. Retrieved from https://www.nta.go.jp/publication/statistics/kokuzeicho/jikeiretsu/01.htm (accessed May 10, 2021)
Niimi, Y., 2019. The effect of the recent inheritance tax reform on bequest behaviour in Japan. *Fiscal Studies*, *40*(1), 45-70.
Noy, I., Nguyen, C., Patel, P., 2021. Floods and spillovers: Households after the 2011 great flood in Thailand, Economic Development and Cultural Change 69, 829-868.
Okazaki, T., Okubo, T., Strobl, E., 2019. Creative destruction of industries: Yokohama city in the Great Kanto Earthquake, 1923, The Journal of Economic History 79, 1–

31.
Okubo, T., 2020. Spread of COVID-19 and telework: Evidence from Japan. Covid Economics, 32, 1-25.
Okubo, T., 2022. Telework in the spread of COVID-19. Information Economics and Policy, 60, 100987.
Okubo, T., Inoue, A., Sekijima, K. (2021). Teleworker performance in the COVID-19 era in Japan. Asian Economic Papers, 20(2), 175-192.
Okubo, T., NIRA, 2020. The 2nd Telework Survey Report on Employee Working Conditions [Dai Ni Kai Terewa-ku Ni Kannsuru Syugyosya Jittaityosa Houkokusyo]. NIRA Research Report.
Okubo, T., Strobl, E., 2021. Natural disasters, firm survival, and growth: Evidence from the Ise Bay Typhoon, Japan, Journal of Regional Science 61, 944-970.
Osaki, Y., 1983. Jishin to Kenciku [Earthquakes and Architecture]. Iwanami Syoten.
Peralta, S., dos Santos, J. P., Gonçalves, D., 2020. Do short-term rentals increase housing prices? Quasi-experimental evidence from Lisbon, GEE Papers 0155, Gabinete de Estratégia e Estudos, Ministério da Economia.
Piketty, T., 2014. Capital in the twenty-first century. Capital in the twenty-first century. Harvard University Press, 2014.
Poterba, J. M., 1984. Tax subsidies to owner-occupied housing: an asset-market approach. *The quarterly journal of economics, 99(4), 729-752.*
Rosenthal, S. S., Strange, W. C., Urrego, J. A. (2022). JUE Insight: Are city centers losing their appeal? Commercial real estate, urban spatial structure, and COVID-19. Journal of Urban Economics, 127, 103381.
Seshimo, H., 2019. Distortion of inheritance tax system and inefficiency of rental housing market [Souzokuzeisei No Yugami To Chintaijyutakusijyo No Hikouritsusei]. Tochi Sougou Kenkyu 27(3), 65-69.
Seshimo, H., Yamazaki, F., 2018. Inheritance tax assessment and the rental housing market [Souzokuzei No Kazei Hyouka To Chintai Jyutaku Shijyo]. Mimeo.
Shimizu, C., Nishimura, K., 2006. Biases in appraisal land price information: The case of Japan. Journal of Property Investment & Finance 24, 150-175.
Shimizu, C., Nishimura, K., Watanabe, T., 2012. Biases in commercial appraisal-based property price indexes in Tokyo -Lessons from Japanese experience in Bubble period-. RIPESS Working Paper, 48, 1-33.
Sims, D.P., 2007. Out of control: What can we learn from the end of Massachusetts rent control? Journal of Urban Economics 61(1), 129-151.
Singh, R., 2019. Seismic risk and house prices: Evidence from earthquake fault zoning.

Regional Science and Urban Economics 75, 187-209.
Statistics Bureau, 2020a. Statistical Handbook of Japan 2020. Retrieved from https://www.stat.go.jp/english/data/handbook/c0117.html (accessed October 16, 2021)
Statistics Bureau, 2020b. Housing and land survey of Japan. Retrieved from https://www.stat.go.jp/data/jyutaku/2018/tyousake.html (accessed November 15, 2022)
Sumaity, 2021. The reasons why running apartment is recommended as the inheritance tax measure [Souzokuzei Taisaku toshite Apa-to Keiei Ga Osusume Sareru Riyuu] Retrieved from https://sumaity.com/land_usage/press/259/ (accessed December 2, 2021)
Tanaka, K., Managi, S., 2016. Impact of a disaster on land price: Evidence from Fukushima nuclear power plant accident. The Singapore Economic Review 61, 1640003.
Tanaka, S., Zabel, J., 2018. Valuing nuclear energy risk: Evidence from the impact of the Fukushima crisis on US house prices. Journal of Environmental Economics and Management 88, 411-426.
The Government Tax Commission, 2000 "The Current State of and Challenges for Japan's Taxation System -People's Participation and Choices for the 21st Century" in Japanse[Wgakunizeisei no Genjo to Kadai -21 Seiki ni Muketa Kokumin no Sanka to Sentaku] Retrieved from https://www.cao.go.jp/zei-cho/history/1996-2009/etc/2000/zeichof.html (accessed November 1, 2022)
Thomson, N. J., 1972. The Dying Case for Death Duties. The Australian Quarterly, 44(1), 22–29.
Timar, L., Grimes, A., Fabling, R., 2018. That sinking feeling: The changing price of urban disaster risk following an earthquake. International Journal of Disaster Risk Reduction 31, 1326-1336.
Toda, S., Stein, R.S., Lin, J., 2011. Widespread seismicity excitation throughout central Japan following the 2011 M= 9.0 Tohoku earthquake and its interpretation by Coulomb stress transfer. Geophysical Research Letters 38(7).
Tokyo Metropolitan Government, 2022. Your community's earthquake, 2018. https://www.toshiseibi.metro.tokyo.lg.jp/bosai/chousa_6/download/earthquake_risk.pdf (accessed April 15, 2022).
Tomiura, E., Ito, B., 2024. Impacts of globalisation on the adoption of remote work: Evidence from a survey in Japan during the COVID-19 pandemic. World Economy, 47(3), 957-982.

Van Nieuwerburgh, S., 2023. The remote work revolution: Impact on real estate values and the urban environment. Real Estate Economics, 51(1), 7-48.

Van Vuuren, A., 2023. Is there a diminishing willingness to pay for consumption amenities as a result of the Covid-19 pandemic? Regional Science and Urban Economics, 98, 103858.

Watanabe, T., Yabu, T., 2021. Japan's voluntary lockdown. Plos one, 16(6), e0252468.

Yamazaki, F., 1999. The effect of bequest tax on land prices and land use. Japanese Economic Review, 50(2), 148-160.

Yamazaki, F., 2019. Souzokuzeisei ga tochi jyuutaku sijyou ni oyobosu eikyou ni tsuite [The impact of inheritance taxation system to land and housing market]. Kikan Kojinkinyuu, 2019, 46-55.

Yasuda, S., Yukutake, N., Naoi, M., 2018. The impact of earthquake risk on housing market before and after the great East Japan earthquake, Keio-IES Discussion Paper.