Chapter

Supply Management of Rental Housing Facilities: Effect of Changes in the Quality of Housing Equipment in the Tokyo Housing Rental Market

Takeshi So and Chihiro Shimizu

Abstract

The Tokyo housing market is considered to be one of the fastest evolving markets in the world. In recent years, functions such as TV intercoms, bathroom dryers, system kitchens, and toilets with washlets, which are not often seen in European and US houses, have spread and become common in Japanese houses. Under such circumstances, the importance of various equipment ancillary to housing, together with the location and quality of the building, is increasingly a factor for determining the value of housing in Tokyo. This is because when a new product appears, the old product is ordered to be withdrawn from the market, or its commodity value is greatly depreciated. This study measured the economic value of improving the quality of housing with new equipment in the Tokyo rental housing market and clarified the extent of economic depreciation that is occurring due to obsolescence. According to the obtained results, new functions are being added sequentially to the Japanese rental housing according to the age of the building, and these functions are non-negligible in the determination of housing rent, even when compared with location and building structure. The effect of obsolescence due to the addition of new functions was roughly—5%.

Keywords: quality change, housing equipment, hedonic approach, depreciation, obsolescence, cohort effect

JEL classification: R31—housing supply and markets; R32—other spatial production and pricing analysis

1. Introduction

In the past, Japanese houses were ridiculed as being “rabbit hutches” as they were smaller in scale, lower in quality, and shorter in average service life than those of Western countries, and examples were often given illustrating Japan as having the worst residential environment among major advanced countries. However, after the period of high economic growth since the chaotic postwar period, this environment has already greatly improved. In recent years high-performance housing stock has accumulated, and housing with functions not found in other countries have become common.

Needless to say, when attempting an analysis of a housing market, it is necessary to fully understand the characteristics of the country. Below, we set out the reasons that have led to the false perception of Japanese housing still belonging to the era when they were ridiculed as rabbit hutches.

Although commonalities can be found in many parts of the Japanese housing market in comparison with the European and US housing markets, the following heterogeneity is conceivable as the postwar historical origin is different. It is possible that these are the cause of many misunderstandings.

In Japan, many houses were destroyed due to the large-scale air raids during the Second World War, not only in metropolitan areas but also in regional cities. In particular, a large number of houses were destroyed in the Tokyo metropolitan area,[1] and very-low-quality houses were built in a disorganized manner to satisfy the urgent housing demand in the chaotic postwar period. In the so-called high economic growth period that began in the mid-1950s, such houses were rapidly upgraded as large numbers of apartment buildings came up throughout Japan.[2] In addition, the drastic change in Japanese lifestyle through the rapid economic growth triggered the renewal of old housing stock by Westernizing the traditional housing style of Japan.

The private sector led construction to realize such a large-scale housing supply because the public sector was saddled with the large financial burden of postwar reconstruction. In particular, the government established a personal loan system to promote housing investment by households, and as a result, the ownership rate in postwar Japan significantly increased in comparison to before the war. Furthermore, as the supply of public housing was limited, a dedicated housing market for single-person renters formed in the rental housing market, which was rarely seen in Europe and the United States.

As a result of these short-term housing renewals, Japanese housing was brought into a state where their style, quality, and housing equipment were greatly different depending on the period of construction. In addition, due to natural disasters such as the Great Hanshin earthquake[3] and the Great East Japan earthquake,[4] housing earthquake resistance and other legal regulations have been successively

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[1] The Bombing of Tokyo was a series of firebombing air raids in Second World War. This was conducted on the night of 9–10 March 1945, 16 square miles (41 km^2) of central Tokyo were destroyed, leaving an estimated 100,000 civilians dead and over 1 million homeless.

[2] Although the improvement of low-quality stock developed during the postwar reconstruction period has been carried out in many areas, some areas remain in which stock has not improved, referred to as "high density wooden structure areas." Since these areas are vulnerable to earthquake disasters and so on, improvement is urgently required.

[3] The Great Hanshin earthquake, or Kobe earthquake, occurred on January 17, 1995 in the southern part of Hyōgo Prefecture, Japan, when combined with Osaka, known as Hanshin. Up to 6434 people lost their lives.

[4] The Great East Japan Earthquake occurred on March 11, 2011. The report from the Japanese National Police Agency report in 2018 confirms 15,896 deaths, 6157 injured, and 2537 people missing across twenty prefectures.

strengthened, thereby rapidly increasing the performance requirements of housing.[5]

This history is also closely related to the shortness of service life, which is a characteristic of the previously ridiculed Japanese houses. Several reasons can be envisaged to explain the short service life of Japanese houses, but the two most influential factors are considered to be the urgent task of promoting the renovation of low-quality housing stock that was built to temporarily compensate for the housing shortage after the war and the fact that the stock renewal was promoted by strengthening public regulations due to large-scale earthquakes and other disasters.

In addition, the high urban renewal rate can also be cited as a reason. In the rapid economic growth of postwar Japan, the main industrial structure shifted from primary to secondary industry in a single stroke, and urbanization was promoted throughout the country in the 1970s by developing highway and railway networks across the country, known as "Japanese archipelago remodeling." In the 1980s, a policy was developed to transform the industrial structure, which was centered on secondary industry to tertiary industry. The transformation of Tokyo into an international financial center was a symbolic policy, and against this background, redevelopment rapidly advanced in major cities. Under such circumstances, the conversion of building use of even physically usable housing into offices, commercial facilities, and so on was promoted through rebuilding, and the advancement of land use was promoted [1].

As a result, it can be said that the average service life of housing seen throughout the stock as a whole has been shortened over a long period.

In addition to these features, it should be noted that the speed of technological innovation in Japanese housing is fast. "Technological innovation" here refers not only to the improvement of productivity on the manufacturing side but also the significant improvement of household welfare levels through the release of new products developed by R&D. In recent years, smart houses utilizing IOT and so on have become symbolic of advancing technology, but functions such as TV intercoms, bathroom dryers, system kitchens, and toilets with washlets, which are not often seen in European and American houses, have become common functions in Japanese houses and have greatly improved household living standards.

However, in a market where products with such new features arrive so quickly, the speed of obsolescence also increases. In these markets, when a new product appears, the old product is ordered to be withdrawn from the market, or its commodity value is greatly depreciated, that is, the service life of products is shortened.

This study aims to measure the economic value of the functions of housing with new quality in the rental housing market in Tokyo, where technological advancement has been the greatest, and to clarify how much economic depreciation is occurring due to obsolescence. In Section 2, we present the model and the framework for empirical analysis together with the data, and in Section 3, we present the estimated results. According to the obtained results, new functions are being added sequentially to Japanese rental housing according to the age of the building, and these functions are non-negligible in the determination of housing rent, even when compared with location (LC) and the building structure (ST). The effect of obsolescence due to the addition of new functions was roughly—5%. In Section 4, we summarize the results by way of a conclusion.

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[5] In response to major disasters, the Japanese Building Standards Law was revised. The first major revision of the Building Standards Law was in 1991, and the revision strengthened the earthquake resistance standards. After that, following the two great earthquakes, the standards strengthened.

2. Empirical analysis: data and estimation model

2.1 Literature review

A technique known as the hedonic approach is effective to decompose prices of commodities corresponding to different qualities. Since the hedonic approach theoretically depicts the behavior of suppliers and consumers in a market with diverse quality and presents a framework for empirical analysis, it is possible to approximately measure the household limit shadow price for new functions and to identify economic deterioration accompanying obsolescence [2, 3].

Generally, the construction of household selection models in the residential market faces many difficulties compared to regular commodities and service markets. Not only is consumption expenditure high for housing, but consumers are also troubled by its highly nonuniform nature. Even when located in the same place, prices vary depending on the quality of housing, and even if the buildings are of the same quality, prices vary depending on the location. Furthermore, since housing has durability, depreciation has to be taken into consideration.

In such a market, the law of one price assumed by traditional pricing theory cannot be applied. Furthermore, the application of a model that deals with differentiated products as analyzed by Lancaster [4] is not effective both theoretically and in empirical analysis. Accordingly, Rosen [5] theoretically clarified the type of market mechanism that is generated when commodity price data are a bundle of such attributes. Specifically, the relationship between the offer function of the commodity supplier, the bid function of the commodity consumer, and the market price function established by the equilibrium of these is closely examined, and the market price is characterized from the behavior of consumers and producers [6].

However, when attempting to estimate the hedonic function, we face various difficulties. The first is the existence of unobservable variables, the so-called omitted variable bias problem [7]. In general, in the estimation of a hedonic function for the housing market, only the location and building attributes, which are easy to obtain, are taken into consideration. However, it is also easy to envisage that the actual market price of housing will change depending on the environment surrounding the house and the various kinds of performance of the building.

As for variable selection in the estimation of hedonic functions in Tokyo's rental housing market, Nishi et al. [8] have conducted an exhaustive survey of the previous research. Nishi et al. [8] pointed that the housing amenities used in hedonic analyses are categorized as "location or accessibility," "housing features," and "site advantages." This paper is focused on housing features, because they can be reflected in the rent due to the technological progress in the information systems and supply management.

Accessibility is defined as the "main accessibility related to commuting." Housing features are defined as "amenities that can be changed by landlords." Accessibility and housing features are the basic characteristics used as explanatory variables in hedonic models and are widely used in previous studies [2, 6, 9, 10].

Site advantages have also been researched recently using variables calculated using geographical information system or GIS [11, 12]. Shimizu [11] demonstrates that the environment surrounding housing is important in the case where house prices are determined by building use conditions and the *characteristics of neighboring residents* and suggests that in the case such variables are not taken into consideration and the estimated statistics of the hedonic function lack robustness. Nishi et al. [8] also show that there is a similar problem with estimated statistics when housing equipment is not taken into consideration. Fuerst and Shimizu [13] show that in the new condominium market in Tokyo, the offered value for highly novel functionality such as *environmental performance* differs greatly when taking the household's annual income into account.

As can be understood from these facts, attention must be given to the kind of variables that are used in estimating the hedonic function. According to Nelson [14], housing characteristics to be considered in function estimation are classified as follows.

Excluding characteristics related to traffic convenience, Nelson [14] considers it possible to categorize the positional characteristics of housing into *housing equipment* and *location*. Of these, "housing equipment" is variable and depends on the owner of the house, and "location" is an element that cannot be changed. Meanwhile, Chau and Chin [15] and Shimizu [11] add *neighborhood characteristics*.

In addition to location and building structure, this study classifies housing equipment into equipment ancillary to the room (room equipment (RE)) and to the building (building equipment (BE)) and also takes the conditions of the contract into account to estimate their marginal price effect by estimating the hedonic function and to estimate the extent of obsolescence caused by the appearance of products with new performance.

2.2 Data

Since the latter half of the 1990s, the use of the Internet for real estate advertising has expanded rapidly in Japan, and websites dealing with a large amount of rental advert data have been developed. This study uses the data on homes managed by LIFULL Co., Ltd. which is a major real estate portal site.[6]

Multiple real estate companies post concurrent advertisements for the same property on the real estate website, so we eliminated the duplicates from the data by grouping them by the criteria of address, property name, and room number.[7] Furthermore, we independently assigned daytime railway travel time from Tokyo station to the nearest station to the property (minutes), which was not included in the data posted on the portal.

Since the aim of this study is to identify the effect due to the addition of new functions over time, we hypothesize that the price structure will change according to the period of construction.[8] Data were segmented into the following three stocks:

- Old stock: built between 1968 and 1981
- Main stock: built between 1982 and 1999
- New stock: built between 2000 and 2018

[6] It should be noted that the data used are only for adverts appearing as of October 2018, and do not represent the situation of the entire housing stock.

[7] Analytical data were prepared using the following conditions. (a) The average and standard deviation of the rent was calculated, and data of a value that is the average plus twice the standard deviation (249,000 yen) were deleted. At the same time, data on rents of 30,000 yen or less that market participants recognize as the lower limit of market rent were deleted (this level is a value larger than the average minus twice the standard deviation). (b) Data on floor area less than 15 m^2 (rental housing of floor area less than this is generally considered unsuitable for habitation) or over 100 m^2 (generally housing of over 100 m^2 is for the very wealthy) were deleted. (c) Data on housing exceeding 50 years of age (built before 1967), which were exceedingly few, were deleted.

[8] When the market structure changes, it is necessary to construct a model to absorb the change [16, 17]. In addition, Karato et al. [18] propose an estimation method to discriminate between aging, period of construction, and time effects. In this research, we avoided these problems by using cross-sectional data and simply classified it into three period categories according to age.

Earthquake resistance standards were greatly revised in 1981 according to the *Building Standards Act*, which stipulates building quality in Japan, and the earthquake resistance of buildings differs greatly according to whether they were built in or before 1981 or in or after 1982; buildings were therefore categorized using 1981 as a basis. There was also a major change in earthquake resistance standards in 2000, so this was also used as the standard for a category. In addition, the data used are for the 23 wards of Tokyo where a large volume of housing stocks was supplied due to a large population inflow.

As a result of this process, 53,550 data points were acquired as data for analysis.[9]

2.3 Estimation model

A general hedonic model can be expressed as

$$y = \log p = \sum_i \beta_i x_i + \alpha \# \tag{1}$$

where y is the explanatory variable, p is the housing rent, x_i is the explanatory variable (housing characteristic), and β_i and α are the estimation parameters.

In this study, in addition to the commonly used *location* and *building structure*, housing equipment was added to the estimation of the hedonic function for the housing market. Specifically, we classified housing equipment into equipment ancillary to the room (*room equipment*) and equipment ancillary to the building (*building equipment*) and took the *conditions of contract* (CC) into account to construct a hedonic function.

Eq. (1) can be rewritten as follows:

$$\log p = \alpha + \sum_j \beta_j^{LC} LC_j + \sum_k \beta_k^{ST} ST_k + \sum_l \beta_l^{RE} RE + \sum_m \beta_m^{BE} BE_m + \sum_n \beta_n^{CC} CC_n \# \tag{2}$$

Here, the actual estimation formula can be expressed as follows:

$$\begin{aligned} \# \log p_{it} = {} & \beta_0 + \beta_1 \cdot Age_{it} + \sum_{j=1}^{3} \beta_{2j} \cdot ST_{jit} + \beta_3 \cdot S_{it} + \beta_4 \cdot TS_{it} + \beta_5 \cdot DT_{it} \\ & + \sum_{k=1}^{5} \beta_{6k} \cdot Str_{kit} + \sum_{l=1}^{23} \beta_{7l} \cdot W_{lit} + \sum_{m=1}^{2} \beta_{8m} \cdot TR_{mit} \\ & + \sum_{n=1}^{20} \beta_{9n} \cdot RE_{mit} + \sum_{p=1}^{15} \beta_{10p} \cdot BE_{pit} + \sum_{q=1}^{9} \beta_{11q} \cdot CC_{qit} + \varepsilon_{it} \end{aligned} \tag{3}$$

In Eq. (1), $ln\ p_{it}$ represents the log rent for i property at time t (October 2018). Age_{it} is the years since construction, ST_{jit} is the period of construction dummy (old/main/new), S_{it} is the floor area, TS_{it} is the number of minutes on foot from the nearest station, DT_{it} is the number of minutes by train from Tokyo station, Str_{jit} is the structure dummy, W_{mit} is the ward dummy, TR_{hit} is the high-rise condominium and ground floor room position dummy, RE_{kit} is the room equipment dummy, BE_{kit} is the building equipment dummy, CC_{kit} is the contract condition (CC) dummy, β_0 is a constant term, and ε_{it} is an error term.

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[9] The number of old stock data for 1968–1981 was relatively small at 4868, the number of properties built between 1992 and 1999 was 19,982, and the number of properties built between 2000 and 2018 was 28,700.

3. Verification analysis

3.1 Descriptive statistics for analysis data

Before analysis, we calculated the descriptive statistics of the data to be analyzed (**Table 1**). From the descriptive statistics, there are several features as follows, depending on the period of construction:

Variable	Type	Mean	Std. dev.	Min.	Max.
Monthly rent	All	94,779	34,873	30,000	249,000
(JYE)	Old stock	84,968	30,631	30,000	240,000
	Main stock	85,305	32,566	30,000	249,000
	New stock	103,040	34,994	45,000	249,000
	New/old	121.3%	114.2%	150.0%	103.8%
Floor space	All	31.3	13.4	15.0	100.0
(m^2)	Old stock	32.5	12.4	15.0	91.4
	Main stock	32.0	15.3	15.0	100.0
	New stock	30.6	12.1	15.0	99.5
	New/old	94.3%	97.7%	100.0%	108.9%
Monthly rent/m^3	All	3192	806	988	8134
(JYE)	Old stock	2717	668	1076	6528
	Main stock	2864	701	988	7535
	New stock	3501	766	1165	8134
	New/old	128.9%	114.8%	108.3%	124.6%
Age of unit	All	18.5	12.7	0.0	50.0
(year)	Old stock	42.3	3.8	37.0	50.0
	Main stock	27.4	4.4	19.0	36.0
	New stock	8.3	5.5	0.0	18.0
	New/old	19.7%	144.0%	0.0%	36.0%
Time to the nearest station	All	7.7	4.6	0.6	41.0
(minutes)	Old stock	7.4	4.4	1.0	41.0
	Main stock	8.1	4.8	1.0	40.0
	New stock	7.4	4.4	0.6	38.0
	New/old	99.4%	98.8%	62.5%	92.7%
Time to Tokyo station	All	27.2	8.6	1.0	48.0
(minutes)	Old stock	26.5	8.3	4.0	48.0
	Main stock	28.8	8.1	4.0	48.0
	New stock	26.2	8.8	1.0	48.0
	New/old	99.1%	105.4%	25.0%	100.0%
Number of observations (all) = 53,550					

Table 1.
Descriptive statistics.

- There is little difference between old and main stocks in average rent, but it is about 20% higher for new stock than the old stock.
- There is no significant difference in the average floor area, the number of minutes by foot from the nearest station, and the number of minutes by train from Tokyo station.
- Concerning the years since construction, the average of the total is 18.5 years and the standard deviation is 12.7 years, and the average value and standard deviation by construction date are consistent with the classification.

Based on these features, there is found to be little difference between the physical space distribution due to the period of construction and only the building quality changes.

3.2 Distribution of analysis data by ward

Next, we examined the distribution of old/main/new stock for each of the 23 wards (**Table 2**). The ratio of new stock ratio exceeds 70% in Chiyoda, Chuo, and Minato wards, which make up the center of Tokyo. As previously mentioned, the probability of large-scale redevelopment and so on being carried out increases for more urban areas, which may have caused this result due to active stock renewal.[10]

Outside the three wards of the city center, the ratio of new stock is over 70% in Taito and Sumida wards and over 60% in Koto and Shinagawa wards, but this may be due to the supply of large-scale high-rise condominiums due to the relaxation of regulations in the 1990s. The ratio of new stock in other wards is around 50% (**Table 3**).

3.3 Ancillary equipment rate by period of construction

Table 4 shows the ancillary equipment rate by period of construction. Equipment was classified into that ancillary to the room, ancillary to the building, and conditions of contract.[11]

Housing equipment items are arranged in descending order of ancillary rate in all samples, and a comparison is made between old, main, and new stocks.

In terms of room equipment, the five items (i) air conditioning, (ii) hot water supply, (iii) indoor washing machine area, (iv) separate bath and toilet, and (v) flooring have a high ancillary rate of over 80%. The equipments for which there is a large difference in ancillary rate between old and new stocks (ancillary rate increased) are bathroom dryer (+62.6%), system kitchen (+50.7%), toilet with washlet (+43.4%), indoor washing machine area (+38.0%), and separate washroom (+36.0%).

In terms of building equipment, the ancillary rate is over 50% for the bicycle parking lot and fiber optic Internet. The equipment for which there is a large difference in ancillary rate between old and new stocks (ancillary rate increased) is automatic entrance door (+65.0%), TV intercom (+55.4%), delivery locker

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[10] This result is consistent with the results of Shimizu et al. [1].

[11] Although it seems that the housing equipment ancillary to the room and building fluctuates somewhat due to renewal and so on, the equipment seems to be influenced by the construction date. Attention must be given to the fact that contract conditions may be changed regardless of the construction date because physical investment is unnecessary.

	Number of observations				Ratio				
Item	**Total**	**Old stock**	**Main stock**	**New stock**	**Total**	**Old stock**	**Main stock**	**New stock**	**New-old**
Room equipment									
Air conditioning	49.088	4029	17.883	27.176	91.7%	82.8%	89.5%	94.7%	11.9%
Hot water supply	44.841	3879	16.961	24.001	83.7%	79.7%	84.9%	83.6%	3.9%
Indoor WM area	43.954	2663	14.696	26.595	82.1%	54.7%	73.5%	92.7%	38.0%
Separate bath and toilet	43.943	3447	12.851	27.645	82.1%	70.8%	64.3%	96.3%	25.5%
Flooring	43.269	3364	14.915	24.990	80.8%	69.1%	74.6%	87.1%	18.0%
Balcony	40.851	3204	15.276	22.371	76.3%	65.8%	76.4%	77.9%	12.1%
System kitchen	27.758	1093	5666	20.999	51.8%	22.5%	28.4%	73.2%	50.7%
Separate washroom	26.292	1412	6221	18.659	49.1%	29.0%	31.1%	65.0%	36.0%
1 gas stove	25.300	1416	6396	17.488	47.2%	29.1%	32.0%	60.9%	31.8%
Washlet	23.221	1089	3265	18.867	43.4%	22.4%	16.3%	65.7%	43.4%
Bathroom dryer	20.322	186	1077	19.059	37.9%	3.8%	5.4%	66.4%	62.6%
2 gas stoves	18.632	1081	3304	14.247	34.8%	22.2%	16.5%	49.6%	27.4%
Reheating bath	15.127	1268	3459	10.400	28.2%	26.0%	17.3%	36.2%	10.2%
Washroom with shower	12.678	364	1764	10.550	23.7%	7.5%	8.8%	36.8%	29.3%
Own house rental	7187	497	1588	5102	13.4%	10.2%	7.9%	17.8%	7.6%
IH stovetop	6623	215	2653	3755	12.4%	4.4%	13.3%	13.1%	8.7%
Walk-in closet	3694	88	235	3371	6.9%	1.8%	1.2%	11.7%	9.9%
Counter kitchen	3409	70	516	2823	6.4%	1.4%	2.6%	9.8%	8.4%
With loft	2110	19	754	1337	3.9%	0.4%	3.8%	4.7%	4.3%
Underfloor heating	1147	8	87	1052	2.1%	0.2%	0.4%	3.7%	3.5%
Building equipment									
Bicycle parking lot	33.795	2096	11.385	20.314	63.1%	43.1%	57.0%	70.8%	27.7%
Fiber optic Internet	27.307	2085	10.056	15.166	51.0%	42.8%	50.3%	52.8%	10.0%
TV intercom	26.689	953	4232	21.504	49.8%	19.6%	21.2%	74.9%	55.4%
Automatic entrance door	26.042	337	5062	20.643	48.6%	6.9%	25.3%	71.9%	65.0%
Cable TV	23.211	1316	8314	13.581	43.3%	27.0%	41.6%	47.3%	20.3%
BS antenna	20.013	472	4430	15.111	37.4%	9.7%	22.2%	52.7%	43.0%
Elevator	19.587	1189	5387	13.011	36.6%	24.4%	27.0%	45.3%	20.9%
Tiling wall	15.751	561	5265	9925	29.4%	11.5%	26.3%	34.6%	23.1%
Delivery locker	15.163	119	1550	13.494	28.3%	2.4%	7.8%	47.0%	44.6%
Security camera	12.694	302	1849	10.543	23.7%	6.2%	9.3%	36.7%	30.5%
CS antenna	11.888	304	1837	9747	22.2%	6.2%	9.2%	34.0%	27.7%
Garbage 24H available	6670	130	728	5812	12.5%	2.7%	3.6%	20.3%	17.6%
Bike parking lot	6335	354	1875	4106	11.8%	7.3%	9.4%	14.3%	7.0%

	Number of observations				Ratio				
Item	**Total**	**Old stock**	**Main stock**	**New stock**	**Total**	**Old stock**	**Main stock**	**New stock**	**New-old**
Design by artist	4068	29	286	3753	7.6%	0.6%	1.4%	13.1%	12.5%
Seismic structure	3827	37	702	3088	7.1%	0.8%	3.5%	10.8%	10.0%
Contract conditions									
with NO guarantor	20.257	1214	6274	12.769	37.8%	24.9%	31.4%	44.5%	19.6%
No pets	8417	733	3540	4144	15.7%	15.1%	17.7%	14.4%	-0.6%
NO musical instrument	6704	605	2702	3397	12.5%	12.4%	13.5%	11.8%	-0.6%
NO office use	5253	297	1731	3225	9.8%	6.1%	8.7%	11.2%	5.1%
FREE Internet	4682	100	616	3966	8.7%	2.1%	3.1%	13.8%	11.8%
Pet consultation	3906	210	801	2895	7.3%	4.3%	4.0%	10.1%	5.8%
Pets allowed	2189	150	437	1602	4.1%	3.1%	2.2%	5.6%	2.5%
Contract with limited term	1673	311	511	851	3.1%	6.4%	2.6%	3.0%	-3.4%
Office use allowed	1319	362	508	449	2.5%	7.4%	2.5%	1.6%	-5.9%
Building structure									
Wooden	10.851	1285	4273	5293	20.3%	26.4%	21.4%	18.4%	-8.0%
Steel frame	13.796	891	6044	6861	25.8%	18.3%	30.2%	23.9%	5.6%
RC	23.654	2074	7635	13.945	44.2%	42.6%	38.2%	48.6%	6.0%
SRC	3644	599	1626	1419	6.8%	12.3%	8.1%	4.9%	-7.4%
Others	1605	19	404	1182	3.0%	0.4%	2.0%	4.1%	3.7%
Others									
High-rise block (16F over)	387	3	54	330	0.7%	0.1%	0.3%	1.1%	1.1%
Room on the first floor	13.265	894	5217	7154	24.8%	18.4%	26.1%	24.9%	6.6%

Table 2.
Distribution of equipment in old stock, main stock, and new stock.

(+44.6%), BS antenna (+43.0%), and security camera (+30.5%). In the conditions of contract, there are no items of note except for guarantor unnecessary, which is high at 37.8%, and only guarantor unnecessary (+19.6%) has a large difference in ancillary rate between old and new stocks (ancillary rate increased), but free Internet is also +11.8%.[12]

Overall, the rise in security equipment is significant in building equipment, and the rise in the equipment that improves the living convenience is significant in room equipment. In addition, the ratio of building structures also shows changes,

[12] Traditionally, when renting out a house in the Japanese rental housing market, it is necessary to have a guarantor to hedge the risk of nonpayment of rent. Since the guarantor is liable in the case of unpaid rent, relatives often become the guarantor, but as the size of families decreases, it is becoming difficult to find a guarantor. Under such circumstances, rent-guarantee companies have appeared, and systems that eliminate the need for a guarantor by paying a set insurance premium have been introduced.

Ward	Old stock	Main stock	New stock	Total	Old stock	Main stock	New stock
Chiyoda	39	65	342	446	8.7%	14.6%	76.7%
Chuo	57	117	740	914	6.2%	12.8%	81.0%
Minato	137	182	927	1246	11.0%	14.6%	74.4%
Shinjuku	284	574	1264	2122	13.4%	27.0%	59.6%
Bunkyo	144	379	706	1229	11.7%	30.8%	57.4%
Taito	86	210	796	1092	7.9%	19.2%	72.9%
Sumida	103	348	1077	1528	6.7%	22.8%	70.5%
Kouto	134	454	1056	1644	8.2%	27.6%	64.2%
Shinagawa	190	650	1463	2303	8.3%	28.2%	63.5%
Meguro	134	537	789	1460	9.2%	36.8%	54.0%
Ota	458	2022	3054	5534	8.3%	36.5%	55.2%
Setagaya	494	2605	2450	5549	8.9%	46.9%	44.2%
Shibuya	188	425	908	1521	12.4%	27.9%	59.7%
Nakano	292	996	1367	2655	11.0%	37.5%	51.5%
Suginami	421	1915	1778	4114	10.2%	46.5%	43.2%
Toshima	189	687	1019	1895	10.0%	36.3%	53.8%
Kita	300	797	1061	2158	13.9%	36.9%	49.2%
Arakawa	100	339	582	1021	9.8%	33.2%	57.0%
Itabashi	291	1254	1441	2986	9.7%	42.0%	48.3%
Nerima	243	1639	1796	3678	6.6%	44.6%	48.8%
Adachi	182	1020	1518	2720	6.7%	37.5%	55.8%
Katsushika	177	926	1074	2177	8.1%	42.5%	49.3%
Edogawa	225	1841	1492	3558	6.3%	51.7%	41.9%
Total	4868	19,982	28,700	53,550	9.1%	37.3%	53.6%

Table 3.
Spatial distribution of rental housing.

such as wooden buildings decreasing by 8.0% and SRC by 7.4%, while steel frames increase by 5.6% and RC by 6.0%.[13]

3.4 Estimated results

Table 5 shows the estimated results of the model. In addition, **Figure 1** illustrates the dummy partial regression coefficients for the equipment.

Looking at the estimated results, as floor area increases, rent goes up, and as the number of minutes on foot from the station increases or the railway travel time from Tokyo station increases, the rent goes down. When taking a wooden structure as the baseline of the building structure, the rent will increase in the order of steel frame, RC, and SRC. The rent varies greatly depending on the ward in which the property is located; a high-rise condominium is a positive driver, and a 1F

[13] In addition, although the ratio of high-rise condominiums is rising, it is at about 1%, and even the number of 1F room positions is increasing.

Dependent variable			**ln (monthly rent) JPY**								
Estimation method			OLS								
Number of observations			53,520		4867		19,975		28,678		
Adj R-squared			0.894		0.853		0.897		0.892		
Independent variables		**Mark**	**All**		**Old stock**		**Main stock**		**New stock**		New-old
			Coef.	**P>t**	**Coef.**	**P>t**	**Coef.**	**P>t**	**Coef.**	**P>t**	Coef.
Age of unit (year)			−0.53%	0.00	−0.13%	0.01	−0.43%	0.00	−0.63%	0.00	−0.50%
Old stock dummy			1.53%	0.00	(Omitted)		(Omitted)		(Omitted)		–
Main stock dummy			−0.54%	0.01	(Omitted)		(Omitted)		(Omitted)		–
New stock dummy			Baseline		(Omitted)		(Omitted)		(Omitted)		–
Floor space (m^2)			1.69%	0.00	1.60%	0.00	1.61%	0.00	1.73%	0.00	0.13%
Time to Tokyo station (minutes)			−0.70%	0.00	−0.67%	0.00	−0.77%	0.00	−0.64%	0.00	0.03%
Time to the nearest station (minutes)			−0.62%	0.00	−0.53%	0.00	−0.61%	0.00	−0.64%	0.00	−0.11%
Building	Wooden		Baseline		Baseline		Baseline		Baseline		–
Structure	Steel frame		4.28%	0.00	7.22%	0.00	3.67%	0.00	3.51%	0.00	−3.71%
	RC		9.26%	0.00	13.04%	0.00	8.41%	0.00	8.17%	0.00	−4.87%
	SRC		10.75%	0.00	13.10%	0.00	9.72%	0.00	8.99%	0.00	−4.11%
	Others		4.01%	0.00	6.83%	0.11	4.20%	0.00	3.25%	0.00	−3.58%
Wards	Chiyoda		−1.44%	0.01	8.72%	0.00	3.21%	0.03	−3.03%	0.00	−11.75%
	Chuo		−3.77%	0.00	0.14%	0.94	−2.84%	0.01	−4.29%	0.00	−4.43%
	Minato		12.01%	0.00	17.08%	0.00	11.20%	0.00	10.75%	0.00	−6.34%
	Shinjuku		0.54%	0.07	3.46%	0.00	0.15%	0.77	−0.54%	0.14	−4.00%
	Bunkyo		−5.38%	0.00	−4.39%	0.00	−5.82%	0.00	−5.52%	0.00	−1.13%

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Dependent variable	ln (monthly rent) JPY								
Taito	−14.43%	0.00	−12.95%	0.00	−14.68%	0.00	−14.73%	0.00	−1.78%
Sumida	−15.60%	0.00	−15.02%	0.00	−14.04%	0.00	−16.21%	0.00	−1.19%
Koto	−13.38%	0.00	−12.53%	0.00	−12.56%	0.00	−13.80%	0.00	−1.27%
Shinagawa	−6.09%	0.00	−2.83%	0.02	−6.83%	0.00	−6.62%	0.00	−3.79%
Meguro	8.18%	0.00	10.71%	0.00	6.95%	0.00	7.76%	0.00	−2.95%
Ota	−11.59%	0.00	−9.71%	0.00	−10.11%	0.00	−13.14%	0.00	−3.42%
Setagaya	Baseline		Baseline		Baseline		Baseline		–
Shibuya	10.74%	0.00	12.23%	0.00	7.93%	0.00	11.20%	0.00	−1.03%
Nakano	−4.79%	0.00	−3.33%	0.00	−3.76%	0.00	−6.01%	0.00	−2.68%
Suginami	−5.20%	0.00	−4.42%	0.00	−4.99%	0.00	−5.64%	0.00	−1.22%
Toshima	−7.34%	0.00	−4.23%	0.00	−6.35%	0.00	−9.01%	0.00	−4.79%
Kita	−16.82%	0.00	−14.43%	0.00	−16.10%	0.00	−17.69%	0.00	−3.25%
Arakawa	−19.82%	0.00	−17.14%	0.00	−18.83%	0.00	−20.71%	0.00	−3.57%
Itabashi	−15.50%	0.00	−15.73%	0.00	−15.13%	0.00	−15.86%	0.00	−0.12%
Nerima	−12.61%	0.00	−10.86%	0.00	−12.29%	0.00	−12.95%	0.00	−2.09%
Adachi	−27.31%	0.00	−24.71%	0.00	−27.17%	0.00	−27.90%	0.00	−3.19%
Katsushika	−26.27%	0.00	−24.68%	0.00	−26.83%	0.00	−25.97%	0.00	−1.29%
Edogawa	−21.84%	0.00	−19.56%	0.00	−21.90%	0.00	−21.92%	0.00	−2.35%
Difference between max. and min.	39.32%		41.79%		38.37%		39.10%		−2.69%

Table 4.
Results of hedonic equations: main estimated results.

Independent variables			All		Old stock		Main stock		New stock		New-old
			Coef.	**P>t**	**Coef.**	**P>t**	**Coef.**	**P>t**	**Coef.**	**P>t**	**Coef.**
High-rise block (16F over)			8.74%	0.00	14.12%	0.08	4.35%	0.01	9.22%	0.00	−4.89%
Room on the first floor			−2.76%	0.00	−0.55%	0.28	−2.94%	0.00	−3.00%	0.00	−2.44%
RE	Air conditioning		0.82%	0.00	1.87%	0.00	0.18%	0.48	0.02%	0.96	−1.86%
	Hot water supply		−1.77%	0.00	0.58%	0.24	−1.03%	0.00	−2.42%	0.00	−3.01%
	Indoor WM area		1.27%	0.00	2.73%	0.00	1.73%	0.00	−0.77%	0.00	−3.50%
	Flooring	**A**	0.16%	0.22	3.35%	0.00	0.50%	0.01	−1.81%	0.00	−5.17%
	Separate bath and toilet	**A**	5.07%	0.00	5.58%	0.00	6.46%	0.00	1.55%	0.00	−4.03%
	balcony	**A**	0.84%	0.00	3.28%	0.00	1.82%	0.00	0.01%	0.95	−3.27%
	System kitchen		1.85%	0.00	4.62%	0.00	2.40%	0.00	0.79%	0.00	−3.83%
	Separate washroom		2.11%	0.00	2.18%	0.00	2.35%	0.00	2.16%	0.00	−0.03%
	1 gas stove		−0.52%	0.00	−1.09%	0.04	0.13%	0.52	−1.13%	0.00	−0.05%
	Washlet	**A**	2.20%	0.00	3.17%	0.00	2.75%	0.00	1.16%	0.00	−2.01%
	Bathroom dryer	**A**	1.35%	0.00	4.90%	0.00	3.07%	0.00	1.29%	0.00	−3.61%
	2 gas stoves		−0.34%	0.01	−0.03%	0.95	1.17%	0.00	−0.09%	0.55	−0.05%
	Reheating bath	**C**	2.22%	0.00	0.26%	0.56	0.06%	0.82	3.45%	0.00	3.18%
	Washroom with shower		−1.16%	0.00	0.64%	0.41	−0.18%	0.55	−1.33%	0.00	−1.97%
	Own house rental	**D**	−2.92%	0.00	−0.54%	0.45	−1.87%	0.00	−3.42%	0.00	−2.88%
	IH stovetop	**D**	−1.03%	0.00	−0.65%	0.49	−1.68%	0.00	−1.62%	0.00	−0.97%
	Walk-in closet	**B**	1.22%	0.00	4.33%	0.00	0.77%	0.29	0.88%	0.00	−3.45%
	Counter kitchen		1.10%	0.00	2.83%	0.08	0.03%	0.95	0.72%	0.00	−2.11%
	With loft		4.72%	0.00	5.59%	0.07	4.08%	0.00	4.19%	0.00	−1.40%
	Underfloor heating	**C**	5.19%	0.00	−1.55%	0.73	−1.09%	0.36	4.97%	0.00	6.52%
BE	Bicycle parking lot		−0.94%	0.00	−0.71%	0.09	−0.70%	0.00	−0.96%	0.00	−0.25%
	Fiber optic Internet		−1.04%	0.00	−1.83%	0.00	−0.93%	0.00	−0.91%	0.00	0.92%
	TV intercom	**A**	1.08%	0.00	3.99%	0.00	1.71%	0.00	−0.15%	0.34	−4.14%
	Automatic entrance door	**A**	1.74%	0.00	4.47%	0.00	2.72%	0.00	1.63%	0.00	−2.84%
	Cable TV		−0.63%	0.00	−1.61%	0.00	−0.26%	0.13	−0.51%	0.00	1.10%

Independent variables			All		Old stock		Main stock		New stock		New-old
			Coef.	P>t	Coef.	P>t	Coef.	P>t	Coef.	P>t	Coef.
	BS antenna		−1.25%	0.00	−2.58%	0.01	−0.05%	0.83	−1.45%	0.00	1.13%
	Elevator		2.52%	0.00	2.89%	0.00	2.10%	0.00	2.63%	0.00	−0.26%
	Tiling wall		−1.44%	0.00	−1.91%	0.00	−1.21%	0.00	−0.97%	0.00	0.93%
	Delivery locker	**A**	2.03%	0.00	4.55%	0.00	1.42%	0.00	2.68%	0.00	−1.87%
	Security camera	**C**	1.33%	0.00	0.62%	0.45	1.06%	0.00	1.61%	0.00	0.99%
	CS antenna		0.60%	0.00	1.76%	0.15	−0.69%	0.04	1.25%	0.00	−0.51%
	Garbage 24H available	**C**	−0.13%	0.49	−1.58%	0.18	−0.84%	0.06	0.98%	0.00	2.56%
	Bike parking lot	**C**	0.75%	0.00	−0.38%	0.61	0.29%	0.28	0.94%	0.00	1.32%
	Design by artist		0.45%	0.02	0.62%	0.80	1.78%	0.01	0.52%	0.01	−0.09%
	Seismic structure		−2.25%	0.00	−4.11%	0.05	−1.95%	0.00	−1.82%	0.00	2.29%
CC	with NO guarantor	**D**	−0.82%	0.00	−1.47%	0.00	−1.07%	0.00	−0.23%	0.08	1.24%
	No pets		0.06%	0.77	−1.46%	0.12	0.37%	0.25	0.47%	0.07	1.93%
	Pet consultation		3.24%	0.00	2.85%	0.00	4.13%	0.00	3.10%	0.00	0.25%
	Pets allowed		2.57%	0.00	2.17%	0.05	3.40%	0.00	2.35%	0.00	0.18%
	No musical instrument		−0.32%	0.15	1.61%	0.11	0.22%	0.54	−0.83%	0.00	−2.44%
	No office use		0.81%	0.00	−1.18%	0.18	0.01%	0.97	1.13%	0.00	2.31%
	Office use allowed	**C**	5.04%	0.00	2.34%	0.00	4.01%	0.00	6.11%	0.00	3.77%
	Free Internet	**B**	0.82%	0.00	3.01%	0.02	0.58%	0.19	0.68%	0.00	−2.33%
	Contract with limited term	**B**	−0.82%	0.00	−2.80%	0.00	−0.86%	0.08	−0.30%	0.39	2.50%
_cons			0.00%	0.00	0.00%	0.00	0.00%	0.00	0.00%	0.00	–

Table 5.
Estimated results of room equipment (RE), building equipment (BE), and contract conditions (CC).

apartment positions a negative driver for rent. These results are consistent with previous studies and the intuition of market participants.

The effect of the number of years since construction differs depending on the period of construction, and as a whole, there is a −0.53% reduction in rent per year after construction. However, looking at the old/main/new period of construction dummy, the speed of reduction is high for new stock and low for old stock. This shows that the effect of years since construction is nonlinear, indicating that the decline in rent will be considerably smaller after a certain number of years. Such nonlinearity is also consistent with a series of previous studies.

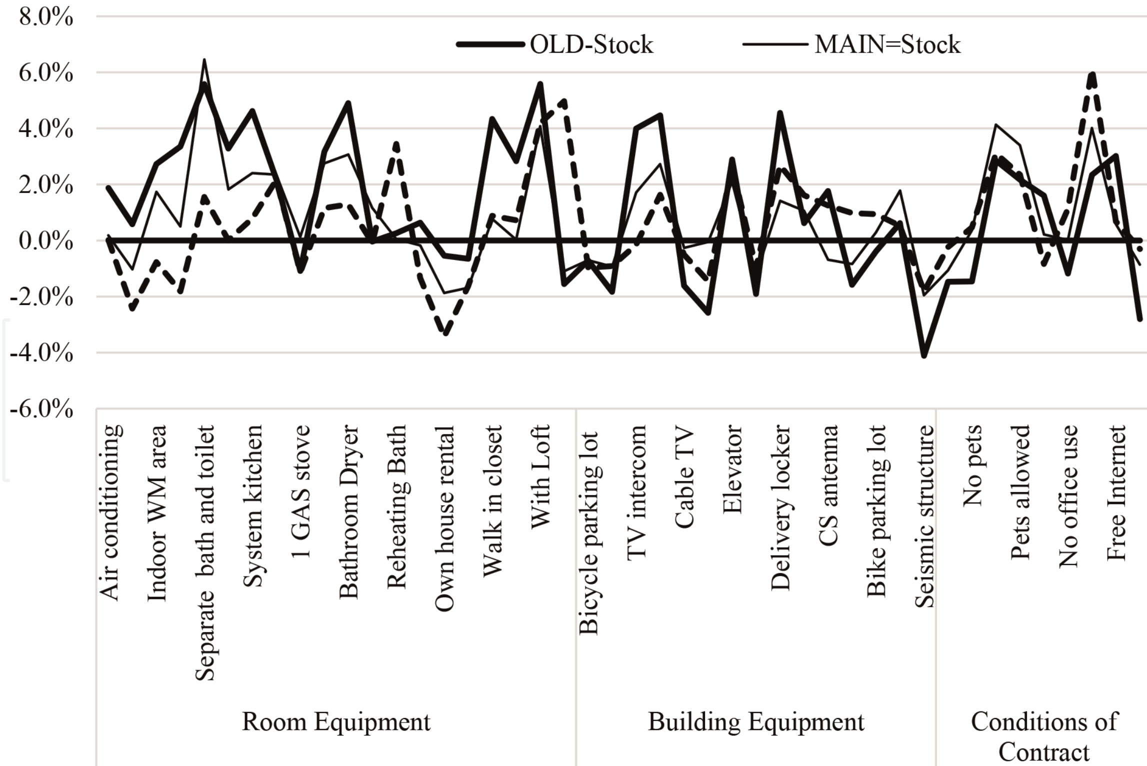

Figure 1.
Marginal price effect on RE, BE, and CC.

The influence of the ancillary equipment situation on the rent changes according to the period of construction (**Figure 1**). The change can be classified into the following four patterns.[14]

- Pattern A: Items considered to have lost value because of commonness

In Pattern A, it is assumed that the equipment premium that was once a differentiating factor for price was lost because of the advancing commonness of equipment. This corresponds to room equipment (RE) such as flooring, separate bath and toilet, balcony, toilet with washlet, and bathroom dryer and building equipment (BE) such as TV intercom, automatic entrance door, delivery locker, and so on. In all cases, the ancillary rate has increased, so the superiority of the ancillary equipment falls, the influence on rent differs between old and new stocks, and such influence is generally small in new stock. Flooring and TV intercoms have a negative impact on new stock. This indicates that flooring and TV intercoms are no longer special equipment and do not offer price advantages.

- Pattern B: Items considered to have lost value because they satisfied limited needs

[14] Shimizu et al. [19] and Diewert and Shimizu [20–22] estimate a depreciation structure for the detached house and apartment market and the office market in Tokyo. The estimated results in this study show roughly the same form. As Diewert and Shimizu [23] covers the office market, durability is longer than for rental housing. Therefore, it has been reported that this will become a positive driver for rent at a stage exceeding 40 years after construction. The same tendency is observed in research targeting commercial real estate markets in Europe, the United States, and so on. The reason for this could be the influence of large costs for large-scale repairs and survivorship bias caused by higher-quality buildings having longer service life and only such buildings remaining. In this study, such bias is not observed, as it is limited to a certain period of time.

In Pattern B, it is assumed that the price premium of the equipment was lost because the needs the equipment satisfied were limited in the first place and have been satisfied. The walk-in closet corresponds to this in room equipment (RE), nothing corresponds to this in building equipment (BE), and free Internet and contract with limited term correspond to this in contract conditions (CC). Contract with limited term has a negative impact on rent in new stock.

- Pattern C: Items for which demand is considered to be increasing but the ancillary rate is low, and value is increasing

Pattern C is such that although consumer demand is increasing over time, a price premium exists because of the low ancillary rate in the housing stock. Equipment such as a reheating bath and underfloor heating corresponds to this in room equipment (RE), and security cameras, garbage disposal available 24-hours a day, and bike parking correspond to this in building equipment (BE). Items such as use as an office correspond to this in contract conditions (CC). In particular, the reheating bath and use as an office have a significant influence of +3.45 and +3.77%, respectively.

- Pattern D: Items considered to be due to other individual factors

Items for which a price premium exists due to other factors correspond to owner-owned condominium for lease in room equipment (RE) and guarantor unnecessary in contract conditions (CC). Regarding condominium for lease, the effect of the increase in supply is considered to be caused by the change in the social situation, where the tendency for relatives to avoid guaranteeing rent obligations has strengthened.

3.5 Influence of ancillary equipment situation on equipment depreciation rate

Figure 2 shows the depreciation rate of all rents (All) and for the case where the ancillary equipment situation is poor (Poor). The equipment being poor indicates there is no (i) washlet, (ii) bathroom dryer, (iii) reheating bath, (iv) TV intercom, (iv) automatic entrance door, (iv) delivery locker, or (vii) security camera. These

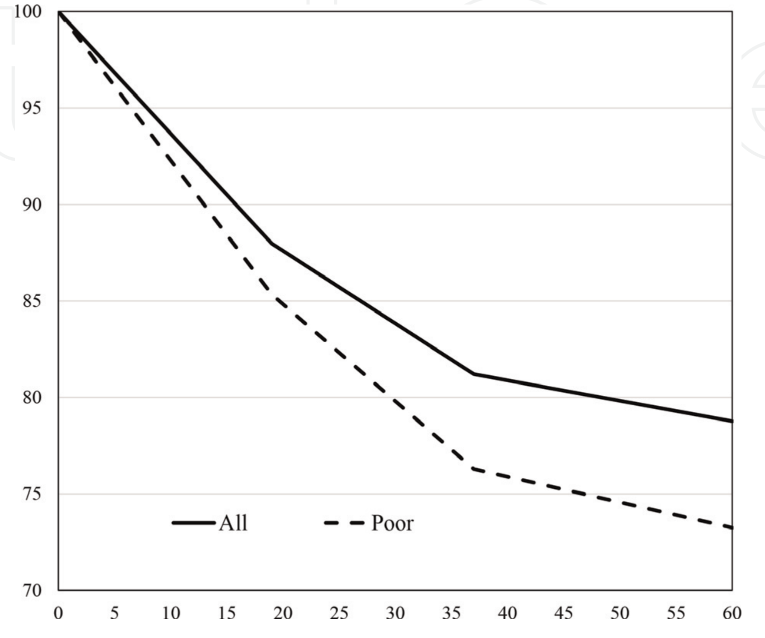

Figure 2.
Depreciation in rental housing.

types of equipment have become more common in recent years and can be installed in existing buildings.

There were 13,033 properties with poor equipment; a regression analysis similar to the previous one was carried out with the logarithm of the rent as a target variable, and the regression coefficient of the years since construction was obtained. That is, as of October 2018, data points without the aforementioned equipment exist regardless of whether they are new, main, or old stock. This means that low-quality rental housing that does not have equipment that has become popular in recent years is still supplied. By extracting such data and comparing the depreciation of rental housing with new functions that benefited from technological progress and the depreciation of low-quality rental housing with no new functions, it is possible to extract the depreciation that accompanies obsolescence.

In **Figure 2**, the depreciation rate for each period is calculated with the rent at the time of construction as 100 to demonstrate the theoretical effect of the increasing number of years since construction on rent. When comparing the depreciation rate of all rents with that of rents of properties with a poor ancillary equipment situation, the depreciation rate increases in all cases (new, main, and old stocks). Roughly 60 years after construction, the difference was found to be 5.5%.

In addition to the measurement of the magnitude of the age effect accompanying obsolescence, this result means that rent depreciation can be mitigated if appropriate ancillary equipment investment is made with respect to the demands for housing equipment that have increased with economic growth and changes in lifestyle. We believe that this will provide pointers for high-level policy with respect to Japan's rental housing market, where the aging of stock will advance in the future.

4. Conclusion and future tasks

Changes in prices over time are broken down into changes due to supply-demand relationships and those caused by quality changes. In particular, this means that in markets with rapid technological progress, the price rise accompanying quality change increases as new products are introduced successively, but at the same time, in markets where such new products are introduced, the speed of obsolescence is fast.

Compared with Western countries, new products are easy to create in the Japanese housing market. The background to this is there are many housing providers and a comparatively large number of companies that do business throughout Japan and overseas. Such companies possess, for example, think tanks to develop new products, and are developing integrated business from large-scale procurement of raw materials to design, construction, sales, and management.

In this study, we focused on the period in which the housing was supplied and clarified the types of functions and equipment supplied to the market in each period and the extent of the marginal price effect in 2018. In addition, we measured the magnitude of obsolescence that accompanies the addition of a new function.

The conclusion can be summarized as follows.

- Rent is strongly influenced by the floor area, years since construction, building structure, number of minutes on foot from the nearest station, railway travel time from Tokyo station, location, and so on. This confirms conclusions provided by previous studies.

- The ancillary conditions of housing equipment vary greatly depending on the construction year. This suggests that the Japanese rental housing market is strongly influenced by regulations such as the *Building Standards Act* and the improvement of living standards by economic growth.

- Some ancillary conditions have a large influence on rent, but if the ancillary rate increases, the influence becomes smaller due to commonness, and housing equipment responding to new needs have a positive influence on rent.

- Even if the number of years since construction is large, depreciation of the rent can be reduced if additional investment in appropriate housing equipment is carried out.

These evaluations are for the present time, and they are expected to change in the future as housing equipment ancillary rates change and social conditions, lifestyles, and resident demands evolve. The conclusion of this study shows the possibility of increasing profitability by responding to resident demands and raising rent through adding ancillary equipment, even in countries in Europe and in the United States, where housing building restrictions are strict.

However, several tasks remain. First, it is possible to add new functionality even to housing classified as old stock through large-scale renovation investment. In this sense, this study has not been able to measure the effect of investment in renovation. Moreover, in order to generalize the study result, it is necessary to identify appropriate housing equipment according to changes in lifestyle and social conditions, in addition to the influence of housing equipment on rent. Even if the scope is restricted to Japan, it is also necessary to consider points such as the type of differences that arise depending on the scale of the city and the standard of living and climate in different regions, as well as whether the necessary housing equipment differs according to the age, gender, family composition, income, and so on of the residents.

We would like to clarify these questions as future research tasks.

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Author details

Takeshi So[1,2] and Chihiro Shimizu[2]*

1 Institute of Future Design in Housing Market, Daito Trust Construction Co. Ltd., Tokyo, Japan

2 Center for Spatial Information Science, The University of Tokyo, Tokyo, Japan

*Address all correspondence to: cshimizu@csis.u-tokyo.ac.jp

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