Examination of Imputed Rent Estimation Method for Considering the Quality of Housing in Subregions: A Case Study Using Data from the Housing and Land Survey [Translated version*]

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The purpose of this study is to present an alternative method to estimate imputed rent by taking into accounts of quality of houses. It is important to understand and rectify the difference in quality between owned and rental houses because the imputed rent of homeownership is estimated from the rent price. Therefore, we used a hedonic model to identify the factors that influence rent and compared it with the current estimation method. Based on the results of the hedonic analysis, we verified the need to incorporate the subdivision of the analysis area and quality of city planning and housing. Drawing from the new estimations of the imputed rent of homeownership, we verified that the current estimation method underestimates the results. The imputed rent of homeownership would increase if the estimation method changed from the prefectural unit to the small area unit. Moreover, based on the quality of housing, the imputed rent can be estimated using the results of the hedonic analysis and would increase by 10.8% in this case. The novelty of this study is that it is possible to reflect regional characteristics and quality of housing by slightly changing the current method of estimating imputed rent.

Keywords: Imputed Rent, Estimation Method, Subregion, Housing Quality, Hedonic Price Model

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https://www.stat.go.jp/training/2kenkyu/2-2-old.html

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1. Introduction

Imputed rent is an estimate of what owners would have to pay if they rented the properties they occupy. The total value of this imputed rent is incorporated into the Statement of National Accounts (SNA) and is a component of gross domestic product (GDP). The estimation of this value does not use market prices per se; instead, imputed rent is valued by using the market prices of rental housing. The methodologies used to make such estimates are determined by each country's statistics bureau, following the recommendations of the United Nations (1977). There is no internationally standardized method for these estimates; instead, countries develop their own methods consistent with their unique situations. After adoption, countries will update their methods as their situations change.

The Japanese SNA, which includes imputed rent, is estimated according to the Cabinet Office's "Explanatory Notes on the Methodology for Calculating the Statement of National Accounts[1]" (Cabinet Office, 2011). The methodologies used in other countries' estimates are outlined in Eurostat-OECD (2012), Eurostat (2010), and Frick and Grabka (2002). In the United Kingdom, statisticians have also worked on improving methods for estimating imputed rent (Yu and Ive, 2008) and the hedonic models used to adjust for housing quality (Richardson and Dolling, 2005).

The importance of imputed rent in Japan has been widely discussed among Japanese statisticians, who state that it neither reflects market prices nor considers regional characteristics or housing quality. In light of these issues and in line with the 2008 United Nations recommendation (08SNA; United Nations, 2008), an accurate estimation method for imputed rent is required.

The most important problem with the current estimation method's failure to reflect market prices in imputed rent is the issue of continuous rent. Shimizu et al. (2010) and Shimizu and Watanabe (2011) highlighted that the current estimate uses continuous rent data from the "Housing and Land Survey[2]" of the Ministry of Internal Affairs and Communications (MIC), which differ from market rental contract data. Examining the question of continuous rent, Shimizu (2013) created estimates using private-sector rental housing data and pointed out that the trends in these indicators differ from the trends in imputed rents.

The previous studies pointed out regional characteristics and housing quality are not accounted for and imputed rents are estimated uniformly nationwide because of data limitations. To estimate imputed rents by prefecture, Arai (2005, 2006) used rent data for each prefecture, which is an improvement from prior estimates. At the prefecture-level, however, Moriizumi (1996) has argued that it is not possible to ascertain the effects of various market characteristics (such as the ratio of leased houses to owner-occupied houses, completion period and structure, population density, and housing supply) on rent. Sato (2013) noted that the effect of differences

[1] An edition of the Explanatory Notes on the Methodology for Calculating the Statement of National Accounts is published for each base year in Japan; the most recent being the 2011 base year edition. In addition, annual estimates, and quarterly preliminary GDP estimates (QE) differ, and editions are also published for annual and QE estimates. (Accessed: October 22, 2020) https://www.esri.cao.go.jp/jp/sna/data/reference1/sakusei_top.html.

[2] Statistics Bureau, Ministry of Internal Affairs and Communications (Accessed: October 22, 2020) URL:https://www.stat.go.jp/data/jyutaku/index.html

in quality between rental and owner-occupied housing on current imputed rent estimations is not considered. These criticisms relay a need for a method for estimating imputed rents that is more in line with reality and reflects both regional characteristics and housing quality.

This study focuses on one of the problems with the current imputed rent estimation method in Japan, which does not take regional characteristics and housing quality into account. Using data from the Housing and Land Statistics Survey used in current estimates, we will verify that it is possible to make estimates that take regional characteristics and housing quality into account as much as possible.

Our empirical objective is to introduce an estimation method that reflects housing market characteristics consistent with the current estimation methods [3] using information from the Cabinet Office (2011). Specifically, we estimate imputed rents that incorporate regional characteristics and housing quality and identify their differences with respect to the current imputed rent estimates. We conduct this study to propose directions for improvement. We also assess the possibility of an estimation method that adjusts for housing quality.

2. Existing issues and proposed improvement plan

The estimates of current imputed rents differ in methodology depending on whether they are calculated in base or non-base years of the Housing and Land Survey. Estimates in the base year (base year estimates) are developed using Housing and Land Survey data on (1) prefecture, (2) house structure, (3) attributes of the period from housing completion (completion period classifications), and (4) total floor space of owner-occupied housing. Since the Housing and Land Survey only presents data in five-year intervals, estimations for non-base years need to be developed from other data sources. To create adjusted estimates that capture changes from base year estimates, sources such as the “Statistics of Housing Construction Starts” by the Ministry of Land, Transport and Tourism are used for the period between base years.

In this study, we examine the process of adjustment for regional characteristics and housing quality in base year estimates, which serve as the basis for the five-year estimates. If base year estimates can be made more accurately, the accuracy of the estimates for non-base years will consequently improve. Moreover, we address the issues in base year estimates calculated using the Housing and Land Survey, presenting potential improvements in the imputed rent estimation methodologies using the data.

2.1 Issues with regional characteristics

Current base year estimates take regional characteristics into account to an extent, as rental housing data in the Housing and Land Survey are identified by prefecture. However, the method of calculating average rent per square meter—by dividing the rent by floor space in each prefecture and multiplying this by the total floor space of owner-occupied houses—neither distinguishes between commercial and residential areas nor adjusts for the quality of regional characteristics. In other words, it does not reflect the “geographical neighborhood” or “regional

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[3] National Accounts Estimation Methodology Manual (Annual Estimates Edition) 2011 Base Version (Accessed: October 22, 2020)
URL:https://www.esri.cao.go.jp/jp/sna/data/reference1/h23/kaisetsu.html

characteristics," as pointed out by Ptacek and Baskin (1996). As addressed in the analysis by Arévalo and Ruiz-Castillo (2006), geographical variables representing regional characteristics should be considered.

2.1.1 Limitations by prefectures

As regional attributes in a single prefecture cannot be expressed using a single term, it is necessary to make estimates in line with each regional attribute for each sub-area. According to the theory of urban additive functions developed by Ricardo (1817), Mills (1972), and others, the rent values decline as one moves farther away from city centers. Yamada (1991) used data from Tokyo metropolitan area to reveal land price gradients in which the distance from the city center is negatively correlated with land prices. Those must also be factored into the estimates.

Using data from the Housing and Land Survey can solve this problem without having to acquire new data; that is, these data make it possible to distinguish between municipalities and zones as well as divide prefectures into three or four smaller areas, creating scope for improvement in rent estimates.

2.1.2 Incorporating housing environments

Regional characteristics include neighborhood environments (housing environment factors). For example, Naoi (2019) recommended considering the impact of landscape, disaster prevention, and education services on land prices by surveying previous empirical studies. The effect of omitted variable bias concerning the effect of housing environment factors on land prices is known to be not small. Kutsuzawa (2014) found a positive correlation between education services and land prices. As such, a method for estimating imputed rent, while considering these factors, is also required.

The Housing and Land Survey data include zoning, distances to nearby facilities, floor–area ratios (FAR), etc. It is possible to incorporate these variables as housing environment factors and analyze the effects on the rent price. This study analyzes housing environment factors using the hedonic model.

2.2 Housing quality issue

The imputed rent of houses in the current estimation is determined by considering the structural attributes of individual houses and the completion period classifications. According to Arévalo and Ruiz-Castillo (2006), indicators of housing quality are important, but the current estimate raises doubts about this point. The question here is whether these two variables can be used to capture housing quality and whether other variables could also be used to measure housing quality. In the current estimation, the possibility that completion period classification variables compensate for everything related to housing quality except housing structure cannot be dismissed. It is necessary to examine what variables representing housing quality should be incorporated into estimates, subject to the limitations of the Housing and Land Survey data.

2.2.1 Problems with the two structure types

Although the current estimates consider housing structure, the method is simplistic and consists of only two categories: wooden and non-wooden structures. There are five structural categories in the Housing and Land Survey: wooden framed, fireproof wooden framed, steel-framed reinforced concrete (SRC), steel-framed (S), and others. The wooden structure includes wooden-frame, fireproofed wooden-framed structures, and others, whereas the non-wooden structure includes SRC and S structures.

The Construction Research Institute[4] categorizes structures as reinforced concrete (RC), SRC, and S structures, and points out that the prices and trends differ for each. By using these survey data, it is impossible to separate non-wooden structures into the three categories of RC, SRC, and S structures, but it is possible to group them into SRC and S structures at least.

2.2.2 Validity of housing age classifications

Respondents of the Housing and Land Survey form select a completion period classification. Thus, building age cannot be obtained from the survey, but information on completion period classifications can be obtained. Based on the assumption that housing values do not fall at a linear rate but decline with age following a convex curve, this classification is based on houses' age. The following ranges are considered: from the year of housing completion to four years earlier than the completion; every three years, from five to seven years earlier; every five years, from eight to 20 years earlier; and every ten years thereafter. All houses aged 65 years or older are grouped under one classification. In current estimates, these completion period classifications, which have more ambiguity than real building ages, are used to measure not only the aging of houses but also housing quality. Because building practices respond to revisions to laws and regulations, such as the Building Standards Law, there is a high correlation between the age and quality of housing; thus, it is assumed that the age of the building indicates the quality of the house. However, unlike previous periods when housing quality improved due to revisions to the Building Standards Law and other factors, housing quality has not necessarily been correlated with building age in recent years. This makes completion period classifications a poor proxy variable for housing quality.

Under the constraint of unknown real building ages, it is very important to substitute these completion period classifications with building ages, and then use housing quality data drawn from the Housing and Land Survey to clearly distinguish between age-related deterioration and house quality and to clarify the relationships between these two factors and rent.

2.2.3 Adjustments made for housing types

The detached housing types are separated into dedicated housing and housing combined with businesses (combined-use housing), although both categories are treated in the same manner in current estimation. As shown in Table 1, combined-use housing accounts for only 3.8% of all housing. However, due to the characteristics of this type of housing, it is often located in high-rent areas; thus, the impact of this housing type on rent estimates is likely to be significant.

The Housing and Land Survey data include dedicated and combined-use houses in each construction type. Therefore, it is possible to distinguish between dedicated and combined-use housing, and then create an estimation method that incorporates these differences.

2.2.4 Adjustments made for construction types

In the Housing and Land Survey, housing is classified into four construction types: detached houses, rowhouses, apartments, and others. However, the current estimates do not account for construction types.

It is necessary to control for construction type in an estimation of the imputed rent because building costs and housing attributes differ by construction type. For example, in Tokyo, detached houses and combined-use housing account for 62.4% (6,204,776 m^2) and apartments

[4] Construction Cost Index by the Construction Research Institute (Accessed: October 22, 2020) URL:https://www.kensetu-bukka.or.jp/business/so-ken/shisu/shisu_kentiku/

34.2% (3,424,682 m^2) of the total floor space and 96.7% (9,993,036 m^2) of housing (Table 1), respectively. Therefore, a method of estimating imputed rent should at least distinguish between detached and apartments.

Table 1. Total floor area of owner-occupied housing in Tokyo by housing type, construction method, and structure

Housing types	Construction types	Structures					Total Composition ratio
		Wooden-frame	Fireproofed Wooden-frame	SRC	S	Other	
Dedicated houses	Detached houses	1,130,958	4,168,841	303,421	311,105	11,967	5,926,292 59.3%
	Rowhouses	21,526	132,927	38,257	24,873	1,462	219,045 2.2%
	Apartments	19,237	90,535	3,143,777	158,709	340	3,412,598 34.1%
	Other	3,117	3,808	38,068	14,328	365	59,686 0.6%
	Subtotal	1,174,838	4,396,111	3,523,523	509,015	14,134	9,617,621 96.2%
Combined-use houses	Detached houses	48,812	132,640	65,526	57,697	1,197	305,872 3.1%
	Rowhouses	559	4,059	1,144	1,401	-	7,163 0.1%
	Apartments	465	498	6,010	5,111	-	12,084 0.1%
	Other	4,988	13,562	20,502	11,217	27	50,296 0.5%
	Subtotal	54,824	150,759	93,182	75,426	1,224	375,415 3.8%
Total Composition ratio		1,229,662 12.3%	4,546,870 45.5%	3,616,705 36.2%	584,441 5.8%	15,358 0.2%	9,993,036 100.0%

Source: Processed and aggregated data from the MIC "Housing and Land Statistical Survey"

3. Method of analysis and data

Given the issues with the existing methods of estimating the imputed rent, there is a need to conduct an analysis using a hedonic model that can adjust for regional characteristics as well as housing quality before estimating the imputed rent. We also employ new a approaches that incorporate structure type. Specifically, we consider the distinction between SRC and S construction, as well as the differences in construction types (detached and apartment houses), in order to create an intersection term with detached houses, which can differentiate the structural differences between each construction method. We used values rather than completion period classifications for building ages and employed variables that can be used to judge housing quality beyond age-related deterioration. After presenting a description of the data names from the Housing and Land Statistics Survey used in the imputed rent analysis and variable processing methods, we present the model used in the analysis.

3.1 Data and processing methods

We used individual survey data for Tokyo from the 2013 Housing and Land Survey in our analysis. We separate the survey data into two types: data showing regional characteristics and data showing housing quality. These are confirmed using the questionnaire (survey form) from the 2013 Housing and Land Survey[5] (MIC, 2013a) and its glossary of terms[6] (MIC, 2013b).

The data on regional characteristics include distance from the city center, *Distance from public transportation*, *Distance to the park*, *Residential use zone*, *Outside sewage treatment areas*, *FAR*, and *Road width* in front of the house. As the distance from the city center cannot be understood in terms of the real values from the data of the Housing and Land Survey, we divide the regions into smaller areas using municipal codes to capture differences between three areas: central (23 wards), *Suburban* (17 cities, including Tachikawa), and *Exurban* (three towns and a village, excluding islands, and nine cities including Hachioji) (Table 2). Next, we use the existing categories in the survey to establish ordinal scales for distance from public transport, including the walking distance to a rail station or bus stop. Similarly, for distance to the park, the distance category from the park in Housing and Land Survey is used as ordinal scale data. In order to understand the difference between residential use zone and industrial land and commercial land, we differentiate residential use zone using the residential use zone dummy variable, which is set to 1 if it falls under the residential use zone according to the classification in city planning. We then use a dummy variable to identify whether an area lies outside any sewage treatment areas, and use real data on FAR from the Housing and Land Survey. Similarly, we develop an ordinal scale for front-of-house road width using data from the same survey.

Table 2. Subregions

Subregions	Target municipalities
Central	23 wards
Suburban	Tachkawa, Musasino, Mitaka, Fuchu, Tyoufu, Koganei, Kodaira, Higasimurayama Kokubunje, Kunitach, Komae, Higashiyamato, Kiyose, Higasikurume, Musasimurayama, Inagi, Nisitoukyou City
Exurban	Hachouji, Oume, Akishima, Machida, Hino, Futusa, Tama, Hamura, Akiruno City Mizuho, Hinode, Okutama Town, Hinohara Village

The data of housing quality include the *Detached housing*, *Construction types*, *Combined-use houses*, *Building age*, *SRC/S structure*, *Floor space*, *Number of floors*, *Damage status*, *Handrails*, and *Energy-saving houses*. These data represent the quality of each housing (individual housing factors). To distinguish between detached houses and apartments, detached housing is used a dummy variable, which is set to 1. Similarly, we use a combined-use houses dummy to distinguish such houses from dedicated residential houses.

For the structure, we create the SRC and S structure dummies based on wooden and fireproof wooden structures. However, they are not statistically significant in the process of analysis. Thus, the S/SRC structure dummy, which is the sum of SRC construction and S construction, is used as a variable. Moreover, an intersection term [Detached house dummy x S/SRC construction

[5] Survey form of from the 2013 Housing and Land Survey (Accessed: June 22, 2020)
・Survey form A URL:https://www.stat.go.jp/data/jyutaku/2013/pdf/h25kou.pdf
・Survey form B URL: https://www.stat.go.jp/data/jyutaku/2013/pdf/h25otu.pdf

[6] Explanation of terms of the 2013 Housing and Land Survey (Accessed: June 22, 2020)
URL:http://www.stat.go.jp/data/jyutaku/2013/1.html

dummy] is used to incorporate the difference in cost between detached houses and apartments. The building age is calculated by replacing the construction period classification with the number of years. If the construction period classification has a range of years, the median value is used. For the floor space and number of floors, the actual values from the Housing and Land Survey are used. Damage dummy refers to the state of damage, and it is set to 1 if house had been damaged in the survey form. For handrail, we use the total value of the corresponding handrail installation locations in the survey. For energy-saving houses, the installation status of double-glazed glass windows in the questionnaire (0: Not supported (None), 1: Partially double-glazed, 2: All windows are double-glazed) is used as weight scale data. Table 3 lists all the data and descriptive statistics.

Table 3. Descriptive statistics

Variable name [Unit / Category]	Frequency	Min	Max	Average	Standard deviation
Logarithm of rent per square meter	78011	4.113	10.127	7.791	0.491
Suburban dummy [0:Not applicable, 1:Applicable area]	78011	0.000	1.000	0.231	0.422
Exurban dummy [0:Not applicable, 1:Applicable area]	78011	0.000	1.000	0.115	0.319
Distance from transportation [**Less than:** 1: 200m, 2:500m, 3:1km, **Less than 2km from the station and from the bus stop**: 4:Less than 100m, 5:200m, 6:500m, 7:500m or more, **2km or more from station and from the bus stop**: 8:Less than 100m, 9:200m, 10:500m, 11:1km, 12:1km or more from the bus stop]	78011	1.000	12.000	3.069	1.913
Distance to the park [**Less than**: 1:250m, 2:500m, 3:1km, 4:1km or more to the park]	78011	1.000	4.000	1.843	0.913
Residential use zone dummy [0: Non-residential, 1: Residential use zone]	78011	0.000	1.000	0.518	0.500
Outside sewerage treatment area [0:Inside treatment area, 1:Outside treatment area]	78011	0.000	1.000	0.013	0.115
FAR [%] [FAR=Gross floor area / Area of the plot]	78006	50.000	1000.000	283.356	143.989
Road width [1:Less than 2m, 2:4m, 3:6m, 4:10m, 5:10m or more]	76992	1.000	5.000	3.291	1.082
Detached house dummy [0: Apartment house, 1: Detached house]	78011	0.000	1.000	0.031	0.174
Store combination dummy [0:dedicated housing, 1:Combined-use housing]	78011	0.000	1.000	0.002	0.045
Building age [Year]	78011	0.000	67.500	22.231	13.639
S/SRC structure dummy [0: Wooden /fireproof wooden, 1: SRC /S]	78011	0.000	1.000	0.816	0.388
Cross term [Detached house dummy x S/SRC structure dummy]	78011	0.000	1.000	0.002	0.047
Floor space [㎡]	78011	5.000	1000.000	38.761	23.447
Number of floors [Story]	78011	1.000	58.000	5.603	5.533
Damage dummy [0: No decay/damage, 1: Yes]	78011	0.000	1.000	0.083	0.276
Handrail [location]	78011	0.000	8.000	0.356	0.920
Energy-saving house [0: None, 1: Partially double-glazed, 2: All windows are double-glazed]	78011	0.000	2.000	0.127	0.438

3.2 Analysis model

In our analysis, we incorporate regional characteristic and housing quality factors in the hedonic model using the ordinary least squares method to estimate the parameters of each variable.

$$lnY = \beta_0 + \sum_{i=1}^{n} \beta \ \ X_i + \varepsilon$$

$(i = 1,2,3\ldots,n)$ (1)

Here, lnY denotes the explained variable, log-transformed rent per m^2; β_0 and $\beta_i$represent the constant term and coefficient, respectively; and i denotes the number of explanatory variables. X is an explanatory variable. To discuss the effectiveness of the variables, we use the forced entry method.

4. Results of the analysis and estimation errors

In this section, we review the results of the analysis and the new estimation of imputed rents. We confirm the difference between the imputed rent derived herein and the current estimation. Based on these results, we discuss how to develop a new estimation method.

4.1 Results of analysis

Table 4 shows the results of our analysis. The degrees of freedom adjusted coefficient of determination is 0.495, whereas the variance inflation factor (VIF) for each variable is less than 10, indicating that multicollinearity is not an issue in our estimations. Excluding missing values, the sample size was 76,988. Although we use the limited data provided by the Housing and Land Survey, the degrees-of-freedom–adjusted coefficient of determination would be expected to increase if, for example, distances from the city center are accurately measured by the variables. However, to improve the estimation method in line with the current estimation method, we focus here on the results in Table 4 rather than the missing variables.

Table 4. Result of analysis

	Coefficient	Standard Error	t	VIF
Suburban dummy	-0.159 ***	0.003	-47.246	1.257
Exurban dummy	-0.306 ***	0.004	-69.450	1.247
Distance from transportation	-0.022 ***	0.001	-29.073	1.291
Distance to the park	0.000	0.001	-0.256	1.031
Residential use zone dummy	0.012 ***	0.003	3.693	1.732
Outside sewerage treatment area	-0.118 ***	0.011	-10.343	1.067
FAR	0.000 ***	0.000	18.881	2.305
Road width	-0.006 ***	0.001	-4.909	1.248
Detached house dummy	-0.019 **	0.009	-2.150	1.462
Store combination dummy	0.162 ***	0.029	5.670	1.059
Building age	-0.010 ***	0.000	-98.273	1.099
S/SRC stracture dummy	-0.003	0.004	-0.694	1.358
Cross term	0.137 ***	0.028	4.938	1.102
Floor space	-0.011 ***	0.000	-181.997	1.269
Number of floors	0.010 ***	0.000	35.453	1.595
Damage dummy	-0.021 ***	0.005	-4.425	1.050
Handrail	-0.023 ***	0.001	-16.262	1.094
Energy-saving house	0.029 ***	0.003	9.904	1.041
Constant term	8.466 ***	0.008	1079.087	

Freedom adjusted coefficient of determination＝0.495， N=76,988

Note: Superscripts ***, **, and * denote significance at the 1%, 5%, and 10% levels, respectively.

The regional factor that positively affected rent includes being in a residential zone, having a high FAR, and individual housing factors such as being a residential building with a store, having a high number of floors, and being an energy-saving house. All these variables are statistically significant at the 1% level.

Conversely, the variables exerting a negative impact includes regional factor, such as being located in suburban or exurban area, outside sewerage treatment areas, at a large distance from public transportation, or FAR. Factors specific to individual houses that have a negative impact includes detached house, an old building age, and a large floor space. All variables, except detached house that is significant at the 5% level, are statistically significant at the 1% level.

From the above results, differences between regional characteristics over the three smaller areas are evident, and housing rent is lower in suburban areas. Land attributes, such as residential zone, FAR, distance from public transport, location outside a public sewerage treatment area, and the width of roads adjacent to the plot also affected rents. Proximity to public transport or higher FAR increases rent; in contrast, being located outside urban areas lowers rents. Additionally, having roads that are too wide lowers rents. This is presumed to be the result of noise from transportation vehicles in addition to private cars having a negative impact on rent. The results indicate that some kind of adjustment to account for these smaller areas is required in the current estimate. In addition, these variables related to urban planning should also be considered in any estimation.

The individual housing factor show that combined-use houses raised rents and that detached houses decreased rents, based on the owner house and apartment. Houses with more floors command higher rents. Larger floor space is a factor that decreased rents due to diminishing marginal utility. Although older construction dates reduce rents, they do not encompass all aspects of housing quality among the statistically significant housing variables. Moreover, we find a negative impact on rent for damaged buildings and a positive impact for energy-efficient buildings. Indeed, the coefficient for the building age or completion period classification variable is smaller than expected, as shown in Table 4, which suggests that using this variable as the only proxy for housing quality is inadvisable. Many numbers of handrails are also a factor in lowering rents, but this seems to be due to the difference in the needs of older adult versus younger households requiring handrails. Handrails may constrict living space and make rooms appear smaller; this factor requires further research that is beyond the scope of our objective.

Distance to the park, which is included as a factor in increasing rent, is not statistically significant. Since the residential use zone dummy had a positive impact at 1% statistical significance, a certain level of consumer evaluation of the living environment is reflected in the rent. Since the S/SRC structure dummy is not statistically significant, the difference in rent by structure is not large when considering apartments as the standard. However, there are differences between wooden and non-wooden houses in detached houses, with a statistically significant cross term.

4.2 Confirmation of differences in estimates

This study focuses on issues related to regional characteristics and housing quality and attempt to estimate imputed rent with a new approach in line with the current estimation method. Therefore, in subsequent imputed rent estimates, we include the building age and focus on the regional characteristics and quality of housing by type and structure. Based on the estimation incorporating regional characteristics and housing quality, we clarify the estimation error with the current estimation. The data used as the basis for the current estimates are the results of the 2013 Housing and Land Survey. The data were divided by survey district, multiplied by the product of the inverse of the extraction rate, summed, and further multiplied by a set ratio to match the population of the municipality as of October 1 of the relevant year[7]. However, we estimate and compare the results within that range based on the data used in the analysis. Therefore, the estimated amount is a reduced version that differs from the population ratio of analytical data only.

Figure 1 shows the degree of impact on rent per square meter, where the logarithmically transformed values are returned to their original values. Our model includes many variables that had an overall negative impact, given the analysis being based on the central area of the city and apartments, where the rent and construction costs are high, even in Tokyo. The degree of impact on rent per square meter value is used to estimate imputed rent.

As the results of our analysis demonstrate that older building ages had a negative impact on rents, the validity of using completion period classifications in the current estimates is confirmed. Further, we find that the factors specific to individual houses must be considered. Therefore, in subsequent imputed rent estimates, we focus on the regional characteristics and quality of housing by type and structure without building age, and compare these estimates with the current imputed rent estimates.

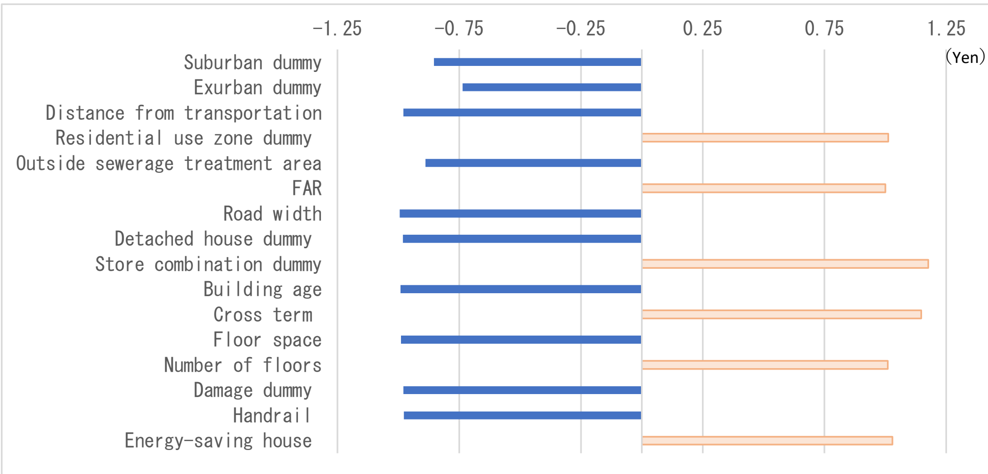

Figure 1. Influence on housing rent

Table 5 shows the total floor area of each small area in Tokyo, excluding islands from Table 1, which shows the total floor area of owner-occupied houses in Tokyo according to the 2013 Housing and Land Statistics Survey. Using the values of the variables in Figure 1, we correct the average value of rent per square meter (average rent per square meter) for suburban and exurban areas based on the central area, and then calculate the average rent per square meter for each area. This value is multiplied by the total floor area of each area to obtain an estimated value of imputed

[7] These came from "Sampling method and result estimation method" of the 2013 Housing and Land Statistics Survey. (Accessed: January 12, 2021)
URL:https://www.stat.go.jp/data/jyutaku/2013/pdf/sui_01.pdf

rent.

Table 5 also shows the imputed rent for each area and its total, which was estimated by multiplying the total floor area of each small area by the area's average square meter rent, which we adopt to resolve regional issues. The total amount of imputed rent is compared with the currently estimated value of imputed rent, and the difference between those amounts is confirmed. That is, our estimation now grasps the upward deviation or downward deviation of the current imputed rent estimate. However, this estimate is only a rough estimate, and we can only compare the approximate ratios.

Table 5. Imputed rent by subregions

Subregions	Total floor area (m^2)	Average rent per square meter (Yen)	Imputed rent (Yen)
Central	5,536,278	2,989.685	16,551,728,977
Suburban	2,639,755	2,988.832	7,889,784,291
Exurban	1,789,305	2,988.949	5,348,141,265
Total	9,965,338	-	29,789,654,533

Table 6. Estimation results of imputed rent considering individual housing factors

Subregions	Housing types	Construction types	Total floor area (m^2)	Average rent per square meter (Yen)	Imputed rent (Yen)
Central	Dedicated houses	Detached houses	2,266,724	2,988.704	6,774,567,568
		Detached houses S/SRC	443,883	2,989.852	1,327,144,286
		Apartments	2,373,027	2,989.685	7,094,603,949
		Other	188,234	2,989.685	562,760,424
	Combined-use houses	Detached houses	110,901	2,989.880	331,580,735
		Detached houses S/SRC	97,923	2,991.223	292,909,531
		Apartments	9,787	2,990.862	29,271,562
		Other	45,799	2,990.862	136,978,469
Suburban	Dedicated houses	Detached houses	1,719,358	2,987.851	5,137,185,411
		Detached houses S/SRC	116,294	2,988.998	347,602,568
		Apartments	686,276	2,988.832	2,051,163,689
		Other	55,122	2,988.832	164,750,399
	Combined-use houses	Detached houses	39,033	2,989.027	116,670,699
		Detached houses S/SRC	15,829	2,990.175	47,331,473
		Apartments	1,881	2,990.008	5,624,206
		Other	5,962	2,990.008	17,826,429
Exurban	Dedicated houses	Detached houses	1,307,236	2,987.968	3,905,979,126
		Detached houses S/SRC	49,614	2,989.115	148,301,961
		Apartments	353,234	2,988.949	1,055,798,386
		Other	35,126	2,988.949	104,989,820
	Combined-use houses	Detached houses	29,993	2,989.144	89,653,399
		Detached houses S/SRC	7,988	2,990.291	23,886,448
		Apartments	416	2,990.125	1,243,892
		Other	5,698	2,990.125	17,037,733
Total			9,965,338	-	29,784,862,164

The imputed rent in the current estimate is calculated by multiplying the total floor area (9,965,338 m^2) by the average rent per m^2 in Tokyo (¥2,696.8), which yields an imputed rent of ¥26,874,489,756. A comparison of this value with the total imputed rent in Table 5 shows that the current estimates underestimate rent by 10.9% (¥2,915,164,777), likely due to the high ratio of gross floor space in the central area (23 wards areas), which has the highest rent per square meter. We thus find evidence of underestimation when the Tokyo prefectural area average is used. Therefore, it is important to estimate imputed rent for each subregion.

Table 6 shows the estimation of imputed rent while incorporating subregions and individual housing factors such as combined-use houses and detached houses. The analytical model includes many variables of individual housing factors, but the estimations are made based on construction type, housing type, and structural type information. We use the S/SRC structure of detached houses because the dummy variable for detached houses had a negative sign, while the cross term was positive. Thus, we deem it necessary to add the S/SRC structure of detached houses, processed using a value of 0.1663, which is the difference between the detached house dummy variable and the cross term.

The resulting estimation reveals an underestimate rent of 10.8% (¥2,910,373,408) under the current estimation. By adopting the subregions and correcting for the housing and construction types, the estimate using the subregions classification in Table 5 is revised downward by 0.02% (¥4,792,370). This estimate is due to regional characteristics and is considered a more realistic estimate that reflects the quality of housing.

4.3 Discussion

Two issues need to be addressed regarding the imputed rent estimates herein. The first is the validity of the analytical model and the second is the validity of the estimation method.

4.3.1 Discussion of the analytical model

Concerning the analytical model, the degrees-of-freedom-adjusted coefficient of determination is 0.495; however, we cannot exclude the possibility of omitted variable bias. For example, important variables, such as the distance from the city center and location in the central business district rather than the nexus of the sub-areas, may be absent. As the Housing and Land Survey does not include this data, this is a limitation that also applies to the current estimates. However, the estimates in this survey, which employ sub-area classifications, also present a direction for improvement over the current estimation method. This can be regarded as Ricardian land rent, as proposed by Ricardo (1817). Tokyo can be viewed as a single-centered city (Mills, 1972), and this can be confirmed from simple tabulations of the Housing and Land Survey that show that rents decline with distance from the city center. As shown in Table 5, given that the total floor space within the 23 wards is overwhelmingly large, it is reasonable to conclude that the current estimates do not capture the full extent of the effect by multiplying simple averages by the total floor space. At least, the introduction of a method such as a weighted average should be considered.

The results of this analysis show that the building age classifications are not an appropriate proxy variable for housing quality, which confirms the need to incorporate factors specific to houses for accurate estimation. We conduct our analysis using the limited Housing and Land Survey data, and it is necessary to examine in more detail the variables related to individual housing factors that should be used in the model.

4.3.2 Discussion of the estimation method

In this study, taking into consideration regional characteristics, we estimated imputed rents by housing type, construction type, and structure. The results suggest that more detailed variables for factors specific to individual houses and regional characteristics should be incorporated. Subject to data availability, estimates should at least be created using housing type and construction type as proxy variables for housing quality. In the current estimates, for example, average rent per meter square is obtained excluding combined-use houses, and then multiplied by total floor space, which is totaled for both combined-use and dedicated housing. Excluding combined-use housing leads to the underestimation of rents; thus, it is necessary to account for combined-use housing while creating estimates.

Our estimations were made simply using the analysis results; although we point out the ratio of the difference in estimates, adjustments for regional characteristics and housing quality should be considered overall, including the construction period. We recommend continued discussion on new estimation methods.

The proposed estimation method provides a minimal response to the arguments advanced by Moriizumi (1986) and Sato (2013). However, changing the estimation method by adapting the hedonic model to a base year every five years also warrants consideration. In such a case, we need to consider incorporating the quality of housing and living environments in line with Kutsuzawa's (2014) findings. Moreover, the distance from the city center, which is essential to the analytical model, is not included in the questionnaire of the Housing and Land Survey. It is therefore necessary to redesign the questionnaire—a labor-intensive endeavor that will require ongoing research in the future.

5. Conclusions

Concerning estimating the imputed rent, this study followed the current "Explanatory Notes on the Methodology for Calculating the Statement of National Accounts" and examined whether data from the Housing and Land Survey, which is also used in current estimates, could reflect regional characteristics and housing quality. The 08SNA calls for a more accurate estimation method for imputed rents, which are a non-market good, that reflects the circumstances of each country.

We clarified the influence of regional characteristics and factors specific to individual houses through a hedonic model analysis. We used the theorical values from the coefficients obtained to estimate imputed rents that reflect regional characteristics and housing quality, comparing these values with the current imputed rent estimates.

Our results indicate that the new imputed rent estimates that reflect regional characteristics and housing quality are higher than the current imputed rent estimates. Since the difference in the ratio amounts to 10.8%, we suggest improvements to the estimation method—a novel contribution based on sound empirical evidence. The new estimation method presented is an improvement on the current method and represents a realistic proposal for implementation.

We also attempted an analysis using a hedonic model in the process of developing a new estimation. To consider a more rigorous estimation method, there is scope for future consideration of estimates that adapt the hedonic model. This has the additional advantage of being able to supplement data deficiencies in the model in regions where data collection is difficult. Going forward, the method by which statistical surveys are conducted should be reviewed. The adoption of a better and more rigorous hedonic model, including improvements to the current questionnaire, requires thorough consideration and careful research and discussion. These are issues to be addressed in the future.

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