Vacant Houses, Duration for Search and Optimal Vacancy Rate in the Rental Housing Market in Tokyo 23 Wards: Based on Landlords’ Optimal Search Model

Jianping GU*, Yasushi ASAMI**

ABSTRACT:
A certain amount of vacant houses is indispensable for the well-functioning of the housing market. On the other hand, excessive vacant houses including surplus houses from rental or sale market, abandoned houses, etc., would gradually accumulate in amount and degrade in quality to impose significant externalities to form a vicious cycle to deteriorate the neighborhood. Until now, literatures for vacant houses are focus on the negative influences of the excessive vacant houses or some individual reutilization cases. However there is lacking a pre-condition for those literatures, which is what the proper amount of vacancies is and what extra is.

The paper provides a brand new angle to view the issue of vacant houses to support the management of the housing market and vacant houses by producing an ideal vacancy rate. The optimal vacancy rate in the housing rental market means the vacancy rate that required for the landlords to search for the tenants, and in the search process the landlord will maximize the present value of return with the optimal list rent strategy.

In Tokyo (23 wards), the optimal vacancy rate for the housing rental market is found to be 1.96%. Comparing to the actual vacancy rate in the housing rental market, large part of the vacant houses are structural vacancies which can barely be rented out. There is large social cost caused by the excessive vacancies in the housing rental market in Tokyo, which is against the sustainable development, and responding management policies are in need as well.

KEYWORDS: optimal list rent strategy, housing rental market, vacancy rate

1. Introduction
Vacant residential house means the residential house without households living in, including the houses for rent, houses for sale, second dwellings and the others like deserted houses. Without vacancies, if one wants to migrate, one would need to find someone who has the house that the one wants and wants the one’s house. Also new households can’t generate without vacancies. Thus a certain amount of vacant houses is indispensable for the well-functioning of the housing market.

However, excessive vacant houses including surplus houses from rental or sale market, abandoned houses, etc., would become a problem for sustainability. Vacant houses occupy the locations are a waste of the land lots, gas and electricity networks, and infrastructures for residence and livelihood in the neighborhood. The vacancy properties lacking management would gradually degrade in quality and outlook, which will cause potential dangers like fire, sudden collapse, etc., and degrade the environment and street view as well (Ishizaka and Tominaga, 2014). Deterioration in environment would degrade the life quality in the

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neighborhood, at the same time lower the market price of properties (Stephan and Thomas, 2012) which would reduce neighboring properties owners’ equality and thus, their wealth, and makes resale of their properties very difficult. As properties lose market value, the tax base for properties decreases so that tax revenue for local government decreases. As tax revenue declines, there will be fewer resources to devote to public improvement and maintenance in the neighborhood and business districts (John, 2002) which would further degrade the life quality and local economy in the area to lead to more vacancies in the area. Excessive vacant houses would gradually accumulate in amount and degrade in quality to impose significant externalities to form a vicious cycle to deteriorate the neighborhood economically by causing inefficiency in allocation of resources and disinvestment in the neighbor, socially by reducing the local life quality, and environmentally by causing potentially dangers, degrading the street view and causing poor maintenance in the neighborhood.

It is neither economically, socially, and environmentally sustainable to have too little vacancy, nor too much vacancy. There would be an optimal vacancy rate that satisfies the needs for housing market, at the same time not causing any negative chain-effects discussed above due to excessive vacant houses.

In Japan, the amount of the vacant residential houses as well as the vacancy rate has been increasing. As in Figure 1, the number of the vacant residential houses in Japan is 8.195 million in 2013, and the vacancy rate is 13.5%, which is the highest in the history. Comparing to 5 years ago, the number of vacant houses increased 0.628 million. Among the residential vacant houses, the majority is the house for rent, which occupies 52% of the total residential vacancies as shown in Figure 2. The amount of the vacant houses have generated a lot of problems in environment, the life quality and local vitality in Japan (Ishizaka and Tominaga, 2014). With the shrinking and aging population in Japan, the vacant houses will continue to accumulate. In the projection that in the near future in 2033, the number of vacant house will be over 21 million and the vacancy rate will exceed 30% (NRI, 2015).

![Figure 1: Residential vacant houses in Japan in 2013](image)

Source: housing and land survey 2013 and NRI report 2015
The issue of vacant houses which is challenging the sustainable development of Japan becomes a hotspot attracting researchers from various disciplines.

2. Literature review

Excessive vacant houses including surplus houses from renting or selling market, abandoned houses, etc. stand as a great challenge for sustainability. The amount of the vacant houses has generated a lot of problems in environment, the life quality, and local vitality in Japan (Ishizaka and Tominaga, 2014). It has been evidenced those vacant houses are not only a ‘symptom’, but also a ‘disease’ to form a vicious cycle to blight the region (Hirokawa and Gonzalez, 2010; Mikelbank, 2008; Stephan and Tomas, 2012). The determinants for the phenomena of vacant houses are studied by White (1985) and Amy et.al (2003). To deal with the vacant houses, some possibilities for the reutilization of the vacant house have been discussed based on individual cases in the literatures. In Great East Japan Earthquake, many vacant houses were used as emergency houses (Asami, 2014). There are also cases that vacant houses have been turned into factory warehouses, shops, and experiential houses for tourism (Toshikazu, 2014; Yamamoto et. al, 2012). On the other hand, in the face of the large amount of disserted vacant houses which can’t be reutilized now or in the expected future, the Clemens et.al (2010) predicted the demolish rate in eastern Germany based on population projection.

However, there is lacking a pre-condition before we discuss about how to deal with the vacant houses, which is how many vacant houses are appropriate for the market and what the extra amount of the vacant houses is. In Japan, as shown in Figure 1, most vacant houses are concentrated in the rental housing market. If there is the optimal vacancy rate for the rental housing market in Japan, it would be a critical index for the management of rental housing market and the issue of vacant houses in Japan.

Economists argue that there is the existence of the natural vacancy rate, at which the housing market is in equilibrium which means there is neither shortage supply nor excess supply in the market (Rosen and Smith, 1983). The natural vacancy rate should be more than zero due to the imperfect information, heterogeneities in the house units, etc. Empirical study evidencing the existence of the natural vacancy dates back to Smith (1974). Since then, the natural vacancy starts to attract the attention of researchers. The natural vacancy rate is commonly defined in the analogous to natural unemployment rate as the vacant houses that are needed to facilitate the tenants’ search for houses as well as the landlords’ search for tenants (Rosen and Smith, 1983).

Strategies in search process will influence the duration of search as well as the natural vacancy rate (Hagen and Hansen, 2010). In the rental housing market with imperfect information, the rental price listed on the market plays a fundamental role to exchange information between the landlords and tenants. There is still lacking the research discussing what the optimal vacancy rate with the optimal list rent strategy is, and what the possible implications of the optimal vacancy rate are for the rental housing market as well as the management for vacant houses in Japan.

The paper applies a search-theoretical model for the optimal vacancy rate with the optimal list rent strategy for maximum present value of return to rental housing market in Tokyo. Scenarios analyses will be made to see the dynamic changes in the optimal vacancy rate. The results and implications of the optimal vacancy rate for the management of the rental housing market as well as the issue of vacant houses are discussed in the paper.

3. Methodology

The methodology is a search-theoretical model to achieve the optimal vacancy rate that maximizes the landlord’s expected present value of return with the optimal list rent strategy as the search strategy. The paper will apply the theoretical model developed by Gu and Asami (2015) to the housing rental market, the model is summarized in this section.

The model describes the process that a landlord trying to rent his house with uncertainties of the potential tenants. In the process there are decisions for choosing initial rental price, information learning from the feedback of the potential tenants, and decisions for revising the rents.

Table 1: summary of parameters and variables

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\sigma$</td>
<td>Standard deviation of the distribution of tenants’ reservation prices</td>
</tr>
<tr>
<td>$m^*$</td>
<td>Mean of the distributions of tenants’ reservation prices for the rent</td>
</tr>
<tr>
<td>$r$</td>
<td>The landlord’ reservation price</td>
</tr>
<tr>
<td>$c$</td>
<td>Cost triggered by revising the rent</td>
</tr>
<tr>
<td>$N$</td>
<td>Maximum number of the potential tenants</td>
</tr>
<tr>
<td>$\delta$</td>
<td>Time discount ratio</td>
</tr>
<tr>
<td>$k$</td>
<td>Number of observations before the landlord lists the rent</td>
</tr>
<tr>
<td>$t_0$</td>
<td>Time for one potential tenant to visit</td>
</tr>
<tr>
<td>$\sum_{j=1}^{k} x_j / k$</td>
<td>Mean of the observations before the landlord lists the rent</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Variables</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>$m$</td>
<td>The landlord’s estimated mean values for the distribution of tenants</td>
</tr>
<tr>
<td>$p$</td>
<td>List rents</td>
</tr>
</tbody>
</table>

In order to describe the landlord’ search process, we need to make several assumptions. The vacancy rate is constructed from the perspective of durations as the following equation:
First of all, there are some assumptions on the distribution of the potential tenants’ reservation rents. We assume that for a house unit for rent with the quality \( m^* \), the distribution of the tenants’ reservation prices is a log-normal distribution with \( m^* \) as the mean and \( \sigma^2 \) as the variance. Due to the imperfect information of the housing rental market, the landlord doesn’t know the exact distribution of the tenants’ distribution, so we assume that the landlord knows the variance \( \sigma^2 \) for the distribution of tenants’ reservation prices, but the landlord doesn’t know the mean \( m^* \) for the distribution. The landlord will try to estimate the mean of the distribution of the tenants’ reservation price during the whole process for rent.

Different landlords have different prior knowledge on the rental housing market, which will influence the information learning process afterwards since the landlord considering himself knows the market well will be more reluctant to change his belief and vice versa. So we assume that before the landlord lists the rental price, he will observe some samples of tenants’ reservation prices for the rent. Assume that he has observed \( k \) reservation prices \( \{x_1, x_2, \ldots, x_k\} \), and he estimates the initial mean value \( m(1) \) for the distribution of the tenants’ reservation price by maximizing log-likelihood.

\[
\text{MAX. } \log \prod_{j=1}^{k} \phi(\ln(x_j); m, \sigma^2)
\]

where \( \phi() \) is the probability density function for standard normal distribution.

Since in Japan, the final deal price almost equals to the final list price (Shimuzi et al., 2004). So the bargaining process is ignored in the model, and the tenant will rent the house only when the tenant’s reservation rent is higher the list rent. The landlord’s expected probability to rent at price \( p \) is:

\[
\int_{\ln(p)}^{\infty} \phi(z; m, \sigma^2)dz = 1 - \Phi(\ln(p); m, \sigma^2)
\]

where \( \Phi() \) is the cumulative probability function for normal distribution.

The model focuses on the landlord’s search. For the simplicity, we assume that the landlord will encounter \( N \) potential tenants at most and each potential tenant visits the landlord at the constant interval, denoted as \( t_0 \). For a landlord who wants to maximize the expected present value of return during the search process, we have the expression as the follow:

\[
\text{MAX. } (1 - \Phi(\ln(p(1)); m(1), \sigma^2))(p(1) - r)t_0 + \Phi(\ln(p(1)); m(1), \sigma^2)\delta f(2)
\]

where \( \delta \) is the future discount ratio, \( f() \) is the future return, \( r \) is the reservation price of the landlord, and \( p(1) \) is the initial list rent.

When each potential tenant arrives, there will be two outcomes. If the potential tenant rent the house, the process ends. If the potential tenant doesn’t rent the house, the landlord will receive the fact that the tenant doesn’t rent the house is because the list rent is higher than the tenant’s reservation rent, so the landlord will adjust his brief on the distribution of tenants’ reservation rents by re-estimating the mean value for the tenants’ distribution. The likelihood for the situation that \( n \)-th potential tenant comes is as the Expression (5)
Take natural logarithm of Expression (5), and the first order condition on \( m \) for the log-likelihood is as the following expression:

\[
\sum_{j=1}^{k} \frac{\ln(x_j) - m}{\sigma^2} + \sum_{i=1}^{n-1} \int_{-\infty}^{\ln(p(i))} \frac{y - m}{2\sigma^2} e^{-\frac{(y-m)^2}{2\sigma^2}} dy = 0
\]

Moreover, if the potential tenant doesn’t rent the house, we assume that the landlord receives a chance to revise the rent for the next potential tenant. The decision for the list rent for the \( n \)-th potential tenant is made by the maximizing the following utility function.

\[
\text{MAX. } U_n(U_{n1}, U_{n2})
\]

\[
U_{n1} = \left( 1 - \Phi(\ln(p(n)); m(n), \sigma^2) \right) (p(n) - r) t_0 + \Phi(\ln(p(n)); m(n), \sigma^2) \delta f(n+1), \quad p(n) = p(n-1)
\]

\[
U_{n2} = \left( 1 - \Phi(\ln(p(n)); m(n), \sigma^2) \right) (p(n) - r) t_0 + \Phi(\ln(p(n)); m(n), \sigma^2) \delta f(n+1) - c, \quad p(n) \neq p(n-1)
\]

When the \((n+1)\)-th tenant comes, there is a similar utility expression denoted as \( U_{n+1} \). The future return from the last stage equals to the maximum utility value from the current stage. We have the equation as the follow:

\[
f(n+1) = \max(U_{n+1})
\]

The landlord will repeat the decision making process on rent and estimating the mean value after each visit of the potential tenants until the visits from the potential tenants reaches the maximum number \( N \).

When the \( N \)-th tenant comes, the future return is 0 because he is the last potential tenant. The utility of the \( N \)-th tenant is as Expression (9)

\[
U_{N1} = \left( 1 - \Phi(\ln(p(N)); m(N), \sigma^2) \right) (p(N) - r) t_0 \quad p(N) = p(N-1)
\]

\[
U_{N2} = \left( 1 - \Phi(\ln(p(N)); m(N), \sigma^2) \right) (p(N) - r) t_0 - c \quad p(N) \neq p(N-1)
\]

Assume that the landlord lists \( S \) different rents, \( S \in [1, N] \), and changes the rents at the timings \( n_s \), \( n_s \) is an array with \( (S-1) \) elements, and \( n_s(i) \) means the \( i \)-th element in \( n_s \). For \( i \in [1, N-1] \), and \( n_s(i) \in [2, N] \), we have Expression (10).

\[
\left( 1 - \Phi(\ln(p(1)); m(1), v^2) \right) (p(1) - r) t_0
\]

\[
+ \sum_{i=2}^{N} \prod_{j=1}^{i-1} \Phi(\ln(p(j)); m(j), v^2) \left( 1 - \Phi(\ln(p(i)); m(j), v^2) \right) (p(i)
\]

\[
- r) t_0 \sigma^{i-1} - \sum_{i=2}^{S} \prod_{j=1}^{n_s(i-1)-1} \Phi(\ln(p(j)); m(j), v^2) \sigma^{n_s(i-1)-1} c
\]

The optimization problem can be solved by numerical simulation using integer-mixed genetic
algorithm, or by other widely used numerical simulation methods with the enumeration of all possible $S$ and $n_s$.

4. Housing rental market in Tokyo (23 wards)

4.1 Vacant rate and duration for search

As shown in Figure 3, in Tokyo, most of the vacant houses are in housing rental market. Number of the vacant houses for rent is 425,300 houses. The number of tenants-occupied houses is 2,283,600 in housing and land survey 2013. The vacant rate for the housing rental market is 15.70%.

![Figure 3 Composition of vacant houses in Tokyo 23 wards in 2013](source: Housing and land survey in 2013)

The expectation for the survival time on the market for rental in Figure 4 is 50.78 days (about 1.69 months). According to Figure 6, the expectation of the duration residence in a tenant occupied house is 5.7823 years. The average rental price is 99,044 JPY.

![Figure 4 Survival time for rental in Tokyo](source: 126,293 samples for rent in Tokyo (23 wards) from At Home Co. Ltd. 2012)

For the tenants’ side, according to the results for the survey of the user of real estate websites (RSC, 2014) shown in Figure 5, before a tenant decides to rent a house, he will averagely visit 4.7 houses, and spend 1.31975 months for the search. So for a potential tenant, the interval for visiting one house is averagely 8.4 days.
4.2 Reservation prices of landlords and tenants

Following Aigner et al.’s (1977) production function for stochastic frontier analysis and Huang et al.’ (2001) idea using the inefficiency term in stochastic frontier analysis to represent the difference between the market price and the reservation price, with the consideration that reservation rent of the tenant is higher than the market rent while the reservation rent of the landlord is lower than the market rent, the market rent can be constructed as follows:

\[ p_i = f(Z_i, \beta) \exp(v_{i\text{tenant}}) \exp(-u_{i\text{tenant}}) \]  \hspace{1cm} (11)

\[ p_i = f(Z_i, \beta) \exp(v_{i\text{landlord}}) \exp(u_{i\text{landlord}}) \]  \hspace{1cm} (12)

where \( p_i \) is the market rent for \( i \)-th house; \( Z_i \) is a vector of quantities of tract characteristics for the \( i \)-th house; \( \beta \) is a vector of per unit prices for tract characteristics; \( \exp(v_{i\text{tenant}}) \) is a log-normally distributed term representing for tenants’ individual preferences, and \( \exp(v_{i\text{landlord}}) \) is a log-normally distributed term representing for individual difference in landlords’ evaluation on the house; \( \exp(-u_{i\text{tenant}}) \in (0,1] \) is the random value representing the difference between the market rental price and tenant’s reservation rent; \( u_{i\text{tenant}} \in [0, +\infty) \), and \( u_{i\text{tenant}} \) is assumed to be a single-sided exponential distribution; \( \exp(u_{i\text{landlord}}) \in [1, +\infty) \) is the random value representing the difference between the market rental price and landlord’s reservation rent. \( u_{i\text{landlord}} \in [0, +\infty) \), and \( u_{i\text{landlord}} \) is assumed to be a single-sided exponential distribution.
Take the natural logarithm of both sides of Equation (11) and Equation (12), and assume that there are k characteristics are considered as the composition of the reservation prices:

\[
\ln(p_i) = \beta_0 + \sum_{j=1}^{k} \beta_j \ln(z_{ij}) + v_i^{tenant} - u_i^{tenant}
\]

\[
\ln(p_i) = \beta_0 + \sum_{j=1}^{k} \beta_j \ln(z_{ij}) + v_i^{landlord} + u_i^{landlord}
\]

where \( v_i \sim N(0, \sigma_v^2) \), and \( u_i \sim \text{exponential distribution with the variance } \sigma_u^2 \).

The data used for the empirical analysis is the data of advertisements for rental houses in 2012 in Tokyo (23 wards) from At Home Co. Ltd. The variables are displayed in Table 2. The estimation result for Equation (13) is in Table 3, and the estimation result for Equation (14) is in Table 4.

For a house with attributives that are mean values in Table 2, the mean value of natural logarithm of the reservation rents of tenants is 11.4294, the standard deviation is 0.1884. The mean value of natural logarithm of the reservation rents of the landlord is 11.2851, the standard deviation is 0.1610. The house with attributives that are mean values in Table 2 will be the representative house for the numerical simulations for Tokyo in the following section.

Table 2: Descriptions for variables

<table>
<thead>
<tr>
<th>Variables</th>
<th>Description</th>
<th>Mean</th>
<th>Std. Dev.</th>
<th>Min</th>
<th>Max</th>
</tr>
</thead>
<tbody>
<tr>
<td>ln(dealprice)</td>
<td>natural log of the deal price</td>
<td>11.387</td>
<td>0.434</td>
<td>9.457</td>
<td>14.947</td>
</tr>
<tr>
<td>ln(areaofhouse)</td>
<td>natural log of the area of the house</td>
<td>3.398</td>
<td>0.483</td>
<td>0.693</td>
<td>6.571</td>
</tr>
<tr>
<td>ln(popinstation)</td>
<td>natural log of number of people take off at the nearest station in a day</td>
<td>9.795</td>
<td>0.890</td>
<td>6.565</td>
<td>13.054</td>
</tr>
<tr>
<td>ln(dist2nursery)</td>
<td>natural log of the distance to the nearest nursery</td>
<td>5.754</td>
<td>0.579</td>
<td>-0.100</td>
<td>7.238</td>
</tr>
<tr>
<td>ln(dist2station)</td>
<td>natural log of the distance to the nearest station</td>
<td>6.001</td>
<td>0.644</td>
<td>2.661</td>
<td>7.908</td>
</tr>
<tr>
<td>ln(dist2agedcare)</td>
<td>natural log of the distance to the nearest aged-care center</td>
<td>5.701</td>
<td>0.640</td>
<td>-0.455</td>
<td>7.961</td>
</tr>
<tr>
<td>ln(dist2mall)</td>
<td>natural log of the distance to the nearest shopping mall</td>
<td>7.515</td>
<td>0.780</td>
<td>2.347</td>
<td>8.970</td>
</tr>
<tr>
<td>ln(dist2tokyo)</td>
<td>natural log of the distance from the nearest station to Tokyo station</td>
<td>9.014</td>
<td>0.531</td>
<td>6.270</td>
<td>9.897</td>
</tr>
</tbody>
</table>

Table 3: Estimation for tenants’ reservation rent

<table>
<thead>
<tr>
<th>Stoc. frontier normal/exponential model</th>
<th>Number of obs=126293</th>
</tr>
</thead>
<tbody>
<tr>
<td>Log likelihood = 28479.801</td>
<td>Wald ( \chi^2(7) = 496867.40 )</td>
</tr>
<tr>
<td>Prob &gt; ( \chi^2 = 0.0000 )</td>
<td></td>
</tr>
</tbody>
</table>

| Independent Variables | Coef. | Std. Err. | z     | P>|z| [95% Conf. Interval] |
|-----------------------|-------|-----------|-------|------------------------|
| ln(areaofhouse)       | 0.763 | 0.001     | 663.050 | 0.000 | 0.761 | 0.765 |
| ln(popinstation)       | 0.028 | 0.001     | 43.890  | 0.000 | 0.026 | 0.029 |
In this section, the methodology will be applied to Tokyo in order to identify the optimal vacancy duration and optimal vacancy rate for the rental housing market in Tokyo.

To apply the theoretical model for optimal vacancy duration, we assume a representative house for the rental housing market in Tokyo, and parameters for the representative house are also needed.

| ln(dist2nursery) | -0.008 | 0.001 | -8.170 | 0.000 | -0.010 | -0.006 |
| ln(dist2station) | -0.059 | 0.001 | -66.450 | 0.000 | -0.061 | -0.057 |
| ln(dist2agedcare) | -0.016 | 0.001 | -18.130 | 0.000 | -0.017 | -0.014 |
| ln(dist2mall) | -0.077 | 0.001 | -95.710 | 0.000 | -0.078 | -0.075 |
| ln(dist2tokyo) | -0.098 | 0.001 | -82.190 | 0.000 | -0.100 | -0.096 |
| _cons | 10.515 | 0.014 | 744.740 | 0.000 | 10.487 | 10.542 |

| ln(σ^2_v) | -3.339 | 0.007 | -471.520 | 0.000 | -3.353 | -3.325 |
| ln(σ^2_u) | -6.332 | 0.116 | -54.360 | 0.000 | -6.560 | -6.103 |
| σ_v | 0.188 | 0.001 | 0.187 | 0.190 |
| σ_u | 0.042 | 0.002 | 0.038 | 0.047 |
| σ^2_v + σ^2_u | 0.037 | 0.000 | 0.037 | 0.038 |

Likelihood-ratio test of σ_u=0: χ^2 (01) = 31.64  Prob>χ^2 = 0.000

Table 4: Estimation for landlords’ reservation rent

5. Optimal vacancy duration and vacancy rate in Tokyo (23 wards)

In this section, the methodology will be applied to Tokyo in order to identify the optimal vacancy duration and optimal vacancy rate for the rental housing market in Tokyo.

To apply the theoretical model for optimal vacancy duration, we assume a representative house for the rental housing market in Tokyo, and parameters for the representative house are also needed.
Assume that the representative house for Tokyo is the house with the attributives that are the mean values of the independent variables in Table 2. With the estimated parameters in Table 3, the standard deviation of natural logarithm of tenants’ reservation prices is 0.1884, and the mean of natural logarithm of tenants’ reservation prices for the representative house is 11.4294. With the estimated parameters in Table 4, the mean of natural logarithm of landlords’ reservation prices for the representative house is 11.2851.

For the arrivals of the potential tenants, according to Figure 5, we assume that the interval to receive one potential tenant is 8.4 days. We assume that the landlord will expect total 10 potential tenants to come, because in the simulation, after 10 potential tenants, the probability of remaining un-rented is less than 1%.

For the time discount, since the interval for each potential tenant to come is just about 8 days, during the interval, we assume there is no time discount. Currently there is no cost in Japan to revise the list rent. For the prior knowledge of the landlord, we assume that before the landlord list a rent, he happens to observe the mean value for the distribution of the tenants’ reservation price, but he is not certain about the observed value.

Due to the complexity of the functions of the theoretical model, numerical simulation method is used for optimization.

Parameters for the simulation are displayed in Table 5. We have Expression (10) as the objective functions for maximization. Because \( c=0 \), the landlord will change the list rent after the visit of each potential tenant due to the change of landlord’ belief on the mean value for the distribution of the tenants’ reservation rents and the number of the rent opportunities left. Hence, we have \( S=N=10 \). \( n_5 = \{2,3,4,5,6,7,8,9,10\} \).

From Expression (6), we have \( (N-1) \) equations as non-linear equality constraints. We have \( U_{n_2} > U_{n_1} \) when \( n \in n_5 \) as \( (N-1) \) non-linear inequality constraints. The interior point method is used for the numerical simulation.

Table 5 shows the specified parameters for the housing rental market in Tokyo. Figure 7 shows the result for the representative house in Tokyo. As shown in Figure 6, the landlord’s expectation on the mean value for the potential tenants’ reservation rents is decreasing with receiving the facts that the potential tenants’ haven’t rented the house. The landlord will take the strategy that initially lists the rent higher, if the house hasn’t been rented out as he expected, the landlord will gradually reduce the rent.

With the optimal list rent strategy, assuming that after the visits from ten potential tenants, the landlord will list his reservation price. The expected optimal duration for rent with the optimal list price strategy is 1.3882 months. The optimal vacancy rate which means the vacant rate that maximize the landlord’s expected present value of return with the optimal list price strategy is 1.96% for the rental housing market. The expected rental price is 102,680 JPY.

In Table 6, Return means the return of the objective function in the simulation, which means the extra expected return than list the reservation price during the search process. The simulation result indicates that the landlord can receive 4,839 JPY more than he directly lists his reservation price during the search process. Comparing the vacancy rate, there is a big difference from the optimal situation and the actual situation. However, comparing the time on the market, though the time on the market for the actual situation is slightly longer, the two statistics are quite close. The two facts implies that in the housing rental market in Tokyo, there is large part of the vacancies are structural vacancies which can barely be rented out until structural changes like sudden increase in population, house reformation, etc. Those structural
vacant houses for rental will stay vacant for a considerably long time to cause the vicious chain effects discussed in the introduction section. With the optimal vacancy rate, 53,094 vacant houses are needed for the functioning of the housing rental market in Tokyo. There are currently 372,206 vacant houses are excessive vacant houses in the housing rental market in Tokyo. To opportunity cost of those excessive vacant houses in the housing rental market, which equals to the average rent multiplies the time, there will be 442.3 billion social costs per year caused by the excessive vacant houses in housing rental market Tokyo. Responding policies are necessary to reduce the vacant houses for rent and reconcile the negative effect caused by those excessive vacant houses in the rental housing market. Comparing the expectation of the rent in simulation with the average rent in actual real estate market, by improving the price list strategy, there are still potentials in Tokyo for landlords to further save the time for search while increase the return of the rent.

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Values for simulation</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\sigma$</td>
<td>0.1884</td>
</tr>
<tr>
<td>$m^*$</td>
<td>11.4294</td>
</tr>
<tr>
<td>$r$</td>
<td>11.2851</td>
</tr>
<tr>
<td>$c$</td>
<td>0</td>
</tr>
<tr>
<td>$N$</td>
<td>10</td>
</tr>
<tr>
<td>$\delta$</td>
<td>1</td>
</tr>
<tr>
<td>$k$</td>
<td>1</td>
</tr>
<tr>
<td>$t_0$</td>
<td>8.4 days</td>
</tr>
<tr>
<td>$\frac{\sum_{j=1}^{k}X_j}{k}$</td>
<td>11.4294</td>
</tr>
</tbody>
</table>

**Table 5 simulation results for the representative house in Tokyo**

![Figure 7: simulation result](image-url)
Table 6 Comparison of optimal situation and actual market situation

<table>
<thead>
<tr>
<th></th>
<th>Simulation(optimal)</th>
<th>Actual market situation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Return (1000JPY)</td>
<td>4.839</td>
<td>99.044</td>
</tr>
<tr>
<td>rent (1000JPY)</td>
<td>102.680</td>
<td>99.044</td>
</tr>
<tr>
<td>Time on the market</td>
<td>1.388</td>
<td>1.690</td>
</tr>
<tr>
<td>(months)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vacancy rate (%)</td>
<td>1.963</td>
<td>15.700</td>
</tr>
</tbody>
</table>

Source: rent and time on the market for the actual market situation is processed from At Home Ltd. 2012; Vacancy rate for actual market simulation is from land and housing survey in 2013

6. Scenarios Analyses

Scenarios with the variances in parameters will be discussed in the section. The baseline is the simulation in Figure 6.

In Figure 8 and Table 7, scenarios with different cost for the rent revisions are compared. In many real estate agencies, advertisement fee is about 10,000 JPY, if it is assumed that the landlord has to issue a new advertisement if he wants to revise the list rent, the cost of rent revision is 10,000JPY. So we use 1,000 JPY and 10,000JPY as the costs for the scenarios analyzes.

In all scenarios, the landlord’s expectation of the mean value for the potential tenants’ reservation rents decreases with receiving the facts that the visited tenants haven’t rented the house. In Figure 8, we find that with the relatively higher list rent, the landlord reduces his expectation on the mean slower and vice versa. It is reasonable to consider that for a landlord listing a relatively lower rent with relatively higher rent rate, the fact that one potential tenant visits the house but doesn’t rent the house, will influence the confidence of the landlord more than the landlord who lists a higher rent with a lower anticipating rent rate. The previous potential tenants who refuse to rent the house reduce the confidence of the landlord more than the potential tenants come afterwards, which is because the value of one piece of information decreases with the accumulation in amount of the information. In all scenarios, the landlord will list a relatively higher rent at the initial stages and gradually reduce the rent with the decreases in the belief on the mean value for the potential tenants’ distribution and limited opportunities left to rent the house.

The landlord will identify the optimal frequency to revise the price, the best timings to revise price, and the optimal values of the sequence of the list rents. With the increase in the cost of rent revision, the landlord reduces the frequency to revise the price. With the consideration of fewer chances to adjust his list price, the landlord will intend to list a lower initial rent. Since the landlord will list a lower initial rent when there is increase in the cost of price revision, he loses the opportunities to rent the house at higher rents, the expected return is smaller than the baseline in the Table 6. However, with the lower initial list rents, the time on the market is smaller so that the optimal vacancy rate is smaller. In housing rental a market with higher cost to revise the list rent, the optimal vacancy rate is smaller.
Figure 8 Scenarios for the variances in cost of rent revision

Table 7 Comparison of scenarios for the cost of rent revision

<table>
<thead>
<tr>
<th></th>
<th>baseline</th>
<th>c=1000</th>
<th>c=10000</th>
</tr>
</thead>
<tbody>
<tr>
<td>Return (1000 JPY)</td>
<td>4.839</td>
<td>4.751</td>
<td>4.533</td>
</tr>
<tr>
<td>time on the market</td>
<td>1.388</td>
<td>1.316</td>
<td>1.306</td>
</tr>
<tr>
<td>(months)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vacancy rate (%)</td>
<td>1.962</td>
<td>1.862</td>
<td>1.847</td>
</tr>
</tbody>
</table>

Figure 9 and Table 8 compares the scenario for different landlord’s prior expectation on the market. Before the landlord list his first rent, the landlord has the prior expectation on the quality of his house based on his prior observations in the market, which is assumed in the assumptions in the section of methodology. In the first scenario, the prior expectation of the landlord is one standard deviation higher than the one in the baseline, while in the second scenario, the prior expectation of the landlord is one standard deviation lower than the one in the baseline.

In the scenario with higher prior expectation on the quality of the house, the landlord will list a higher initial list rent. With the updating information from the feedback of the tenants, he will gradually adjust his belief of the housing rental market and his list rents. The adjustment process is prolonged than the baseline due to the higher prior expectation. Hence, for the housing rental market, where the real estate price is expected to increase, the landlord would like to spend more time for search and leads to a higher optimal vacancy rate.

On the other hand, in the scenario with lower prior expectation of the quality of the house, the landlord intends to list a lower initial rent which may trigger a quick deal with the risk of receiving less rent than with enough market exposure. For the housing rental market, where the rent is expected to decrease, the landlord may want to rent the property quickly by setting the list rent lower and leads to a lower optimal vacancy rate.
Table 8 Comparison of the scenarios for the landlord’s prior knowledge

<table>
<thead>
<tr>
<th></th>
<th>baseline</th>
<th>higher prior expectation</th>
<th>lower prior expectation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Return (1000 JPY)</td>
<td>4.779</td>
<td>8.895</td>
<td>1.899</td>
</tr>
<tr>
<td>Time on the market (months)</td>
<td>1.388</td>
<td>1.816</td>
<td>1.035</td>
</tr>
<tr>
<td>Vacancy rate (%)</td>
<td>1.962</td>
<td>2.550</td>
<td>1.469</td>
</tr>
</tbody>
</table>

Figure 10 and Table 9 shows the comparison of the scenarios for the variances in volatility of tenants’ reservation price. In the first scenario, the standard deviation for the distribution of the tenants’ reservation rent is doubled, while in the second scenario, half value of the standard deviation is used for the simulation.

In the scenario with double volatility, the potential tenants’ reservation rent are more dispersed, accordingly there will be more disparity in the landlord’ estimations for the tenants’ distribution and also more disparity in the list rents of the landlord. More dispersed tenants’ reservation prices would cost more time for the landlord to estimate the distribution of the tenants and adjust the rent since there is more heterogeneity of the tenants. For a housing rental market, more heterogeneity in tenants’ preferences leads to longer time on the market and larger optimal vacancy rate.

On the other hand, in the scenario with half of the volatility in the market, the potential tenants’ reservation rent will be more concentrated in a smaller range. It is easier for the landlord to identify the proper list rent for the market. So the adjustments among the list rents are smaller than the baseline case. For a housing rental market, if there is less volatility in the potential tenants’ reservation price, the search time would be smaller so that the optimal vacancy rate would be smaller.
Table 9 Comparison of the scenarios for the volatility of tenants’ reservation prices

<table>
<thead>
<tr>
<th></th>
<th>baseline</th>
<th>double volatility</th>
<th>half volatility</th>
</tr>
</thead>
<tbody>
<tr>
<td>Return (1000 JPY)</td>
<td>4.779</td>
<td>8.160</td>
<td>3.661</td>
</tr>
<tr>
<td>time on the market</td>
<td>1.388</td>
<td>1.620</td>
<td>0.880</td>
</tr>
<tr>
<td>Vacancy rate (%)</td>
<td>1.962</td>
<td>2.285</td>
<td>1.255</td>
</tr>
</tbody>
</table>

Figure 11 and Table 10 show the comparison of the scenarios for different time discount. For ordinary landlord, it is reasonable to have the savings interest rate as the time discount. However, if there are any financial investments involved in the process, there would be higher time discounts. 4% is officially used for the public projects. Hence, we set 2% for the first scenario and 4% for the second scenario.

If the time discount is higher, the landlord would be less patient. With a higher time discount, the landlord intends to list lower initial rent with higher anticipating rent out probability to try to rent the house at earlier stages. But with a relatively lower initial list rent, the landlord becomes more reluctant to further reduce the rent so that the reductions between the rent adjustments are smaller than the baseline case. In the housing rental market, if the money is discounted fast with time, the optimal vacancy rate inclines to be small because the landlords try to rent the house earlier.
According to the scenarios analyses, the optimal vacancy rate varies according to the variances in the economic situations, the landlords’ behaviors as well as the tenants’ behaviors. Policies that increase the cost of list rent revision and increase the time discount ratio in the housing will shorten the search process of the landlords to improve the social efficiency.

In Tokyo, the population peak will be reached in 2020. Also the Olympic Games will be held in Tokyo in 2020, which will attract large amount of visitors. Before or around the year of 2020, the population will still increase in Tokyo, and the landlords would expect that rent will increase in the market in the short-term to hold a higher prior expectation on the quality of their houses. At the same time, the Olympic Games will be a big disturbance for the housing rental market, the volatility of the rent will increase in the short-term. Hence, before or around the year of 2020, with the increase in landlords’ expectation and volatility of the rent, the optimal vacancy rate would in increase during the period.

In the long-term, after the year of 2020, there will be a long-term population decline in Tokyo, while the economy will be stagnant. The landlords may expect that the rent will decrease in the housing rental market, and then they would have a lower expectation on their houses and try to rent them out fast. Hence, the optimal vacancy rate for the housing rental market in Tokyo is expected to decline in the long-term.

7. **Concluding remarks**

The paper provides a new empirical point of the view to look at the vacant houses issue by providing an optimal vacancy rate which maximizes the landlord’s expected return with the optimal list rent strategy with information learning process. In empirical study of the housing
rental market in Tokyo, the landlord will initially list a relatively higher list rent with a relatively lower anticipating rent out rate, and gradually reduce the list rent with time on the market and adjustment in his belief on the distribution of the tenants.

With the optimal list price strategy, the optimal vacant rate for the rental housing market is 1.96% in Tokyo. Comparing to the actual vacant rate in the housing rental market, the result implies that there is large part of the vacant houses for rent are the structure vacancies which can be barely rented out and cause the negative economic, social and environmental effects. There will be 442.3 billion JPY social costs per year caused by the excessive vacant houses in housing rental market Tokyo. Responding policies are in need to reduce the vacant houses in the rental market. There are still potentials in Tokyo for the landlord to save the time for search without losing the rent by improving the list price strategy.

The optimal vacancy rate varies according to the market situation, types of the landlords as well as behaviors of the tenants. Policies that increase the cost of list rent revision and increase the time discount ratio in the housing will shorten the search process of the landlords and reduce the vacancy rate for search to improve the social efficiency. In the short-term, with the consideration of the population peak in 2020 and Olympic Games in Tokyo, the optimal vacancy rate for the housing rental market may increase due to the increase in volatility and the expectation of landlords. In the long-term, the optimal vacancy rate for the housing rental market in Tokyo is expected to decrease.

The optimal vacancy rate in the paper is the vacancy rate that is focus on the landlord’ search and maximizes the landlord’s expected present value of return. For the future extensions, the tenants’ search should be also considered into the model to get the optimal vacancy rate for both landlords and tenants.

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