Doctoral Thesis

LIST PRICE STRATEGY AND VACANCY RATE IN HOUSING MARKET: THEORETICAL MODEL AND ITS APPLICATION TO 23 WARDS AREA IN TOKYO

(住宅市場における表示価格戦略と空き家率：理論モデルとその東京 23 区への適用)

顧漸萍

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ABSTRACT

Vacant residential house means the residential house without households living in, including the houses for rent, houses for sale and the others like deserted houses. The vacancy rate in Japan that has been soaring and reached 13.5% in 2010 have been a hot topic for the sustainable development of Japan. However, there is lacking pre-condition to discuss the problems of vacant houses, which is what the proper amount of vacant houses is and what the extra is. A certain amount of vacant houses is indispensable for the well-functioning of the housing market and laying the foundation for local vitality. On the other hand, excessive vacant houses including excessive houses from renting or selling 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 economically by causing inefficiency in allocation of resources and disinvestment in the neighborhood, socially by reducing the local life quality, and environmentally by causing potentially dangers, occupying the land to waste resources, degrading the street view and causing poor maintenance in the neighborhood. It is neither economically, socially, and environmentally sustainable to have shortage of vacancies, nor excessive vacancies.

Economists argue that there is the existence of the natural vacancy rate, at

which the housing market is in equilibrium. However the widely researched rent-adjustment theory for the natural vacancy has neither explained the formation of the natural vacancy, nor given a satisfying benchmark for the issue of vacant houses in Japan due to inseparability of the structural vacancies in the theory and the lack of the applicability to housing sale market as well.

Some hints for the formation of natural vacancy can be found in the search theory. The value of vacancy rate in the market equilibrium can exceed zero due to the imperfect information in the housing market. The landlords/home-sellers are in face of the uncertainties in the housing market including heterogeneity of houses, idiosyncratic preferences of tenants/home-buyers, etc. The time cost in the process that the landlords/home-sellers search for tenants/home-buyers would form the natural vacancies in the housing market. Strategies in search process will influence the duration of search, and the natural vacancy rate as well. Advertisements are widely used for search nowadays. The list prices on the advertisements, which can be viewed as the acceptable prices for the landlords/home-sellers, and as the market probe from the landlords/home-sellers to explore the market with the feedbacks from tenants/home-buyers as well, play the fundamental roles in the search process. Empirical evidences show that the process of list prices and prices revisions highly influences the final sale prices and the durations on the market for the housing market. With the uncertainty and complexity of the housing market, the list prices become difficult and critical decisions for the landlords/ home-sellers. Until now, very limited search-theory based theoretical models with the process price revisions in the literatures haven't fully explained the roles of the list price in the housing market, especially the role that list price as the market from the landlord/home-seller to explore the market.

The objectives of the research are: (1) to develop a theoretical model which directly tackles the list price change decisions with an information learning process in housing market; (2) to give the benchmark vacancy rate by the application of the theoretical model to Tokyo for housing market and the management of vacant houses and to establish foundation for determining what is wasteful vacant houses.

For the research results, the research has developed a theoretical model which directly tackles the process of list price revisions incorporating with an information learning process. The model explains the process of list price change in the housing market including the optimal decisions for timings, frequencies for the list price revision as well as the values of the sequence of the list prices. The model gives a natural vacancy rate with the optimal list price strategy as well. The original theoretical model enriches the aspect of the search theory concerning the list-price search strategies and the natural vacancy. Empirically, the research 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 for the housing market. With the application of the theoretical model to the housing market in Tokyo, the natural vacancy rate for the housing sale market is 0.73%, while for the housing rental market is 1.33%. Comparing to actual market situation, there are many excessive vacancies in the housing market, especially in housing rental market. There is 2.56 billion social cost per month in sale market, while 38.56 billion social cost per month in rental market in Tokyo caused by the excessive vacancies, which is against sustainability and responding management policies are in need as well. The natural vacancy rate varies according to variances in the economic situations, behaviors of the seller/landlord as well as the behaviors of the buyer/tenants. The model can be re-applied for the new situations. Policies that increase the cost of list rent revision and improve the information in the housing market will shorten the search process of the landlords to improve the social efficiency. In the short-term, with the consideration of the population/households peak and Olympic Games in Tokyo, the natural vacancy rate may increase due to the increase in volatility and the expectation of the landlords/home-sellers. In the long-term, the natural vacancy rate is expected to decrease.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF EXPRESSIONS

LIST OF ASSUMPTIONS

1. INTRODUCTION

1.1 Overview of Vacant Houses in Japan

Vacant house means the residential houses without households living in including houses for rent, houses for sale and others.

The number of vacant houses in Japan has been soaring since the year of 1958. As shown in Figure 1, according to the land and housing survey, in 2013, the number of the vacant houses has reached 8.19 million, and the vacancy rate has reached 13.5%, which is the highest record in the history. As shown in Figure 2, the houses for rent take the largest part of the vacant houses, which is 57.7% of the total vacancies, while there are much less houses for sale, which is 4.8% of the total vacancies. The rest of 37.5% vacant houses are for others like deserted houses. However, the amount of vacant houses is transferable among the three categories. The houses which can't be rented or sold for a long time would become a deserted house, while a deserted house after reform may return to the housing market.

There are many reasons to form current vacancies in Japan. First is the imbalance in demand and supply. Although Japan have entered into long-term decline stage with the issues of ageing society and shrinking population, large amount of new constructions still be made to support the economy of Japan. Besides imbalance in supply and demand for housing, the property tax system in Japan impedes the flow of the resources in the market to accumulate residential vacancy houses. Also the cost for the demolition of vacant houses is also a barrier for the land resource to flow to the market.

In the expected future, the population is expected to decrease to around 116.62 million by 2030, fall to 99.13 million in 2048, and drop to 86.74 million by 2060 (National Institute of Population and Society Research, 2012), the vacancy rate is expected to continue to increase. In the projection shown in Figure 3, the vacancy rate will be soon over 20% in overall Japan, and reaches 28.5% in next two decades. Even Tokyo, which is considered as the most magnetic metropolitan for young generation in Japan, is also bonded with the high vacancy rate over 28%.

The soaring vacancy rate in Japan attracts the attention of the researchers as well as the national and local governments of Japan to become a hot topic that whether the high vacancy rate is impeding the sustainable development of Japan. Recently, policies and subsidies have been issuing to motivate the housing demolitions in Tokyo as well as many other regions in Japan. The projection for vacant houses with demolition is projected in Figure 3. Although efforts for demolition are draining the fiscal budgets of local government, the vacancy rate will be still over 22% in the year of 2033.

However, there is lacking a pre-condition before dealing with the vacant houses in Japan, because relatively higher vacancy rate is not doomed to be a problem for sustainability. To the opposite, in the real world, there are also cases like vibrant regions with relatively more vacant houses preparing for the further developments of the regions (Belsky, 1992). Until now, there is no research discussing what amount of vacant houses is appropriate, and what the amount that needs the reutilization or demolition is. The focus of the dissertation is on the vacant houses for sale as well as the vacant houses for rent.

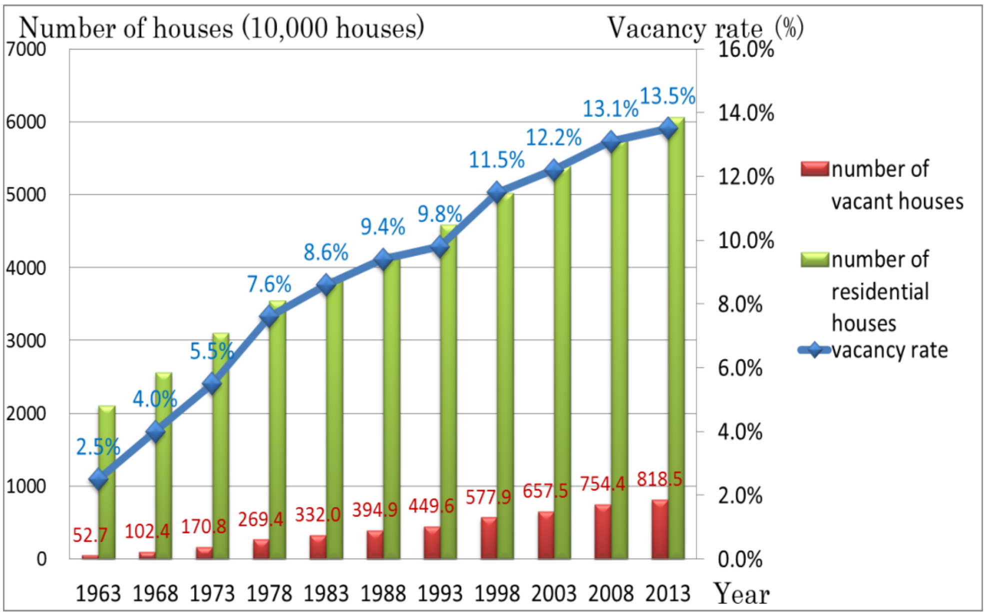

Figure 1: Number of Vacant Houses and Vacancy Rate in Japan

Source: Land and housing survey in 2013

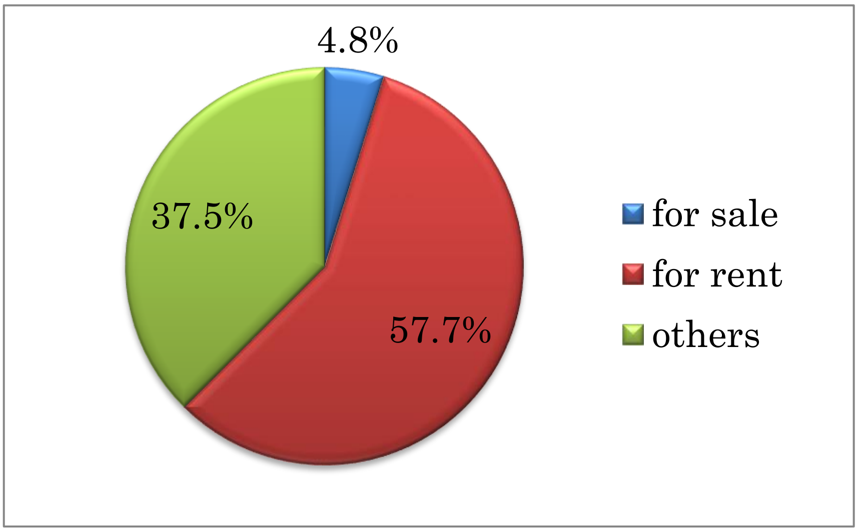

Figure 2: Composition of Vacant Houses in Japan

Source: Land and housing survey in 2013

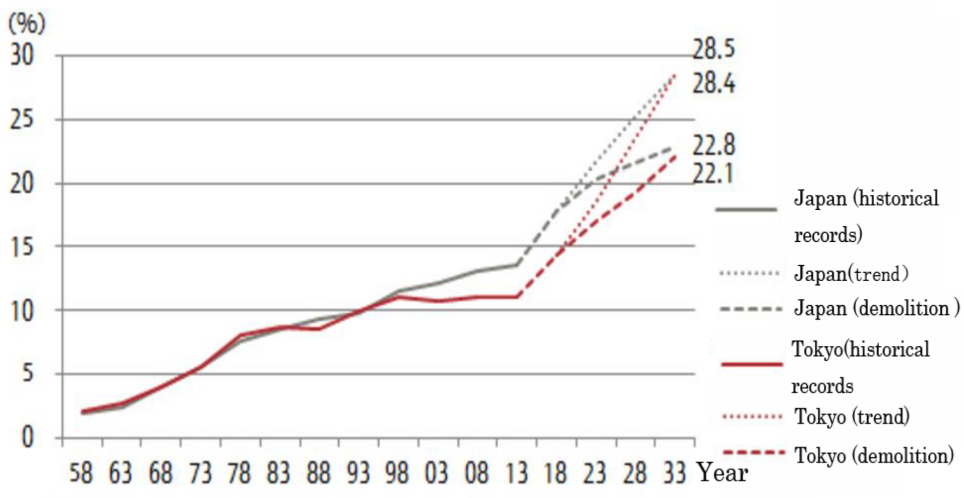

Figure 3: The Projection of the Vacant Houses in Japan and Tokyo

Source: social welfare and population research center

1.2 Sustainability and Natural vacancy

Vacant houses are highly associated with the sustainability of regional or national development. Socially, vacant houses provide the place of residence for people, which is the most basic need of humans. And the style and quality of the vacant houses highly influences the well-beings as well due to its physical and material contributions for daily life quality. Economically, vacant houses are the commodities to be traded in the real estate market. The well-functioning real estate market is the critical factor to enhance the economy (UNECE et.al, 2010). Environmentally, vacant houses occupy the limited land resources. Moreover, vacant houses themselves are part of the environment and the street view as well.

Vacant houses are indispensable for the well-functioning of housing market and lay the foundation for sustainable development. Imagine that if there is no vacant house or a shortage of vacant houses, it will be difficult to make migration because one may need to find someone to exchange houses with him. And it will also be very difficult for the new households to find a place for residence as well. The life quality will be degraded due to a lack of choices of vacant houses to satisfy the needs of residents (Kathryn, 1994). The shortage of vacant houses in the housing market would lead to rapid price increase, which would cause housing speculations and bring large disturbances to economy (Case & Shiller, 2003). The evictions and homelessness will increase due to the high price or rent of the houses which decreases the social inequality and brings the security issues for the society (Kathryn, 1994). Naturally, driven by the higher real estate price, massive expansion without any conservation for environment would be triggered. Hence, shortage of the vacant houses impedes the sustainable development socially by increasing the mismatch between residential needs and quality of the houses and increasing the inequality in the society, economically by causing large disturbances, and environmentally by triggering massive expansion and construction.

On the other hand, excessive vacant houses including the excessive houses from housing sale or rental market, disserted houses, etc. would also be a problem for sustainability. Those vacant houses occupying the locations are wasting the land resources, electricity and gas networks as well as infrastructures and facilities for residence and transportation in the local area. The excessive vacant houses which can be barely sold or rented out in the housing market are usually lacking proper management and would gradually degrade in both the appearance and the quality of the vacant houses to impose external negative influences in the neighborhood. Due to lacking management and maintenance, the appearances of the vacant houses would deteriorate the street view, and even cause potential dangers like sudden collapse, fire, etc. to further deteriorate the residential environment (Ishizaka & Tominaga, 2014). With the deterioration in the residential environment, both the life quality will be degraded for the residents in the neighborhood, and their wealth since the value of the houses in the neighborhood will also decrease if the residents put their housing properties for re-sale in the market (Stephan & Thomas, 2012). The decrease in the value of the housing properties decreases the base of property tax as well as the tax revenue for the local government. There would be fewer financial resources to devote to improvement and maintenance in the public infrastructures in the communities as well as the commercial districts with the decrease in tax revenue (Kromer, 2002). The chain-effects would further degrade the residential environment and local economy in the area to lead to more vacancy in the area. The excessive vacant houses would be like the 'broken windows' that are signaling the decline in the region and imposing a vicious cycle to blight the area by economically causing the diseconomy in the local area, socially degrading life quality of residents in the neighborhood, and environmentally wasting the resources and deteriorating the residential environment.

It is not environmentally, socially and economically sustainable to have the shortage of vacant houses, or to have the excessive of vacant houses. An ideal vacancy rate may exist in the between of the two extremes, which satisfies the residential and migration demands in the housing market at same time not causing any of the chain-effects due to the shortage or excessive of vacant houses as discussed above. The ideal vacancy rate can be a significant benchmark to support the management of the housing market as well as the vacant houses.

If there is neither shortage of the vacant houses, nor excessive amount of vacant houses, the housing market is in equilibrium, which means the housing demand equals to the housing supply. Natural vacancy rate means the vacancy rate in the market when the housing market is in the equilibrium. The natural vacancy rate in the market should exceed zero due to the imperfect information of the housing market.

1.3 Imperfect Information, Search and Roles of List Price

Imperfect information always plagues the housing market because of the heterogeneity of houses, idiosyncratic preferences, un-observability of reservation prices, etc. (Shimizu et.al, 2004). Due to imperfect information of the housing market, the landlords/ home-sellers can't immediately find the tenants/home-buyers for their vacant houses, so there is a search process for the landlord/home-sellers to search for the tenants/home-buyers before the transactions. The time duration for the search process before rented out or sold, which is also the time on the housing market, are the frictional cost in the housing caused by the imperfect information. Hence, in the equilibrium housing market, a certain amount of vacant houses are required to compensate the frictional cost in the search process for the well-functioning of the housing market (Rosen & Smith, 1983).

The strategies for search are highly influencing the time on the market, as well as the natural vacancy rate in the housing market equilibrium (Hagen & Hansen, 2010). Nowadays, we use advertisements to attract the potential tenants/home-buyers. In the housing market with imperfect information, list price, which is the price listed on the advertisements, plays as the role to exchange information between the landlords/home-sellers and tenants/home-buyers. The list price conveys several signals. Firstly, list price is an acceptable price for the landlords/home-sellers, at the same time signaling the reservation prices of the landlords/home-sellers which means the lowest prices for the landlords/home-sellers to rent/sell the houses (Yavas & Yang, 1995, Arnold 1999, Anglin 2006, Haurin et al., 2010). On the other hand, list price also plays the role as the market probe from landlords/home-sellers to explore the market (Gu & Asami, 2015). It has been widely proven in the literature that list price have the high prediction power for final sale (Horowitz, 1992), and highly influence the time on the market (Merlo, 2004, Hui et al., 2010).

Due to the imperfect information of housing market, the landlords/home-sellers are in face of a lot of uncertainties in the housing market in deciding the list price. Houses, each as an idiosyncratic commodity in the market, embody varies of the characteristics like structure of the houses, size of the rooms, etc., as well as varies of characteristics of residential environment decided by locations of the houses. Besides the complexity and idiosyncrasy of the housing, the landlords/home-sellers don't know how the tenants/buyers will evaluate the qualities of their properties. For the landlords/home-sellers who intend to maximize the price as the same time minimize the time on the market, it becomes very difficult and critical to decide the list price (Beracha & Seiler, 2014). If the landlord/home-seller sets the list price too high, the search process will be prolonged with large opportunity costs. On the other hand, if the landlord/home-seller sets the list price too low, it may trigger a quick sale but the landlord/home-seller receives less return than keeping the house in the market for enough market exposure.

In the face of numbers of uncertainties in the housing market, for landlords/home-sellers with desire to maximize the deal price while minimize the time on the market, the list price of the houses would be a rather difficult decision (Beracha & Seiler, 2014). Fortunately, the decision on the list price doesn't always have to the final decision since it is possible for the landlords/home-sellers to revise the list price if it is necessary. As explained above, the list price can play as the market probe from the landlords/home-sellers to explore the uncertain market. With the feedbacks for the list price from the buyers, the landlords/home-sellers can update their information for the housing market, and re-consider about the current list price to see if it is necessary to change the list price (Gu & Asami, 2015). The learning and updating process is widely seen is the actual housing market. Hence the sequential decisions on list prices and the learning process are largely deciding the time on the market, as well as the natural vacancy in the housing market.

1.4 Literature Review

The exhaustive literature review ranges from social and environmental influences of vacant houses to economic theories associated with housing vacancies in the housing market have been reviewed.

1.4.1 Studies on Vacant Houses

Vacant house is a complicated issue concerning with right of proprietorship, housing market, national economy, life quality, residential environment and etc. to involve different disciplines including laws, economics, social and environment.

The studies on vacant houses simultaneously emerges with the depopulation issue wide swaths of the U.S., Canada, Europe, and Japan in late 90s (Oswalt & Rieniets, 2007). Initially vacant houses are usually regarded as accompanied phenomena instead of a problem for the shrinking cities (Accordino &Johnson, 2000). As the amount of permanent or long-term vacant houses including the excessive houses from housing sale market or housing rental market as well as the deserted houses accumulated with the process of depopulation, the negative influences of those vacant houses starts to attract the researchers' attention. Accordino &Johnson (2000) studied the negative contagious effects of the excessive vacant houses to increase the crime rate while decrease the local vitality. Han (2014)'s research has confirmed that there is the external dis-economic effect of permanent vacant houses on the housing properties in the neighborhood to not only decrease the values but also extend the time on the market of the nearby housing properties. Evidences show that those long-term vacant houses are not just an accompanied phenomenon for the city decline, but also they could be a 'contagious disease' to impose a vicious cycle to blight the region (Hirokawa & Gonzalez, 2010; Brian 2008; Stephan &Tomas, 2012). There are cities in Japan (Nishihiro et al. 2005; Takeda, 2014), in US (Cohen, 2001; Kroner, 2002; Plerhoples, 2012), as well as Europe (Brian, 2008)are in the face of great environmental, social, and economic challenges brought by the negative influences of excessive vacant houses.

To deal with the excessive vacant houses, Policies to stimulate the housing market to reconnect the long-term vacant houses to the market is considered important (Shimizu, 2014; Kelly, 2013). Using the agriculture or green land to reclaim the vacant houses is also discussed by Sasaki et al. (2010), Yamamoto et al.(2012) and Kroner (2002). There are also some reutilization cases of vacant houses. By diversifying the use of the vacant houses, some vacant houses turn to temporary emergency houses for natural disasters like earth quake , tsunami, etc.(Asami, 2014), while few cases turn to the factory warehouses, shops and experiential houses for tourism (Toshikazu, 2014). On the other hand, in the face of large amount of vacant houses, policies on demolition enforcement are rather important (Takeda, 2014). The demolition rate was simulated in Germany in Clemens et.al (2010)' research.

However, there is lacking pre-condition for the discussion in the above literatures on vacant houses, because it is still not clear that what proper amount of vacant houses is, and what the excessive amount is to cause the negative contagious effects.

1.4.2 Studies on Natural Vacancy Rate

Smith (1974) firstly developed the rent-adjustment mechanism--- in housing rental market, when the market vacancy rate is smaller than the natural vacancy rate, the rent would increase while when the market vacancy rate is bigger than the natural vacancy rate, the rent would decrease--- to empirical evidenced the existence of natural vacancy. From then, based on the rent-adjustment mechanism, various extending researches start to emerge. Gabriel & Nothaft (1988) examined the exogenous and endogenous factors including the pace of development, landlord opportunity costs, dispersion of rents, etc. significantly influence the amount of natural vacancy rate. Sivitanides (1997) and Tse&Fischer (2003) extended the study of natural vacancy to time-varying frameworks to consider the stochastic nature of natural vacancy rates in the time scale. Besides of the incidences of housing vacancies, the duration of vacancy has been considered into natural vacancy rate by Gabriel & Nothaft (2001). The natural vacancy decreases with the increase in web-users (Hagen & Hansen 2010), which empirically evidences that search strategy highly influence the natural vacancy rate.

However, there are some limitations on researches based on the rent-adjustment mechanism. Firstly, the applicability to housing sale market is questionable since it is widely seen that the price increase with the increase in vacancy rate in the housing sale market. Moreover, the structural vacancies---vacancies can be barely sold or rented out until structure changes like sudden increase in population, housing reformations, etc.--- is included in the those studies, which makes the rent-adjustment mechanism based natural vacancies can't be a good benchmark for the management of vacant houses. Moreover, rent-adjustment mechanism based researches are just empirical models, which can't explain the formation of natural vacancy, and how various search strategies form various natural vacancy rates.

1.4.3 Search-theoretical Models

As explained in Chapter 1.3, with imperfect information in the housing market, tenants/home-sellers who cannot instantly find a trading partner, must therefore search for a partner before transaction. The time delay in the process of search, which is a frictional cost leads to the natural vacancies in the housing market. Search theory sprouted from the Koopman (1946)' report titled 'search and screening'. Other than traditional economic theories based on demand and supply, search theory studies the trading frictions in the market (Shi, 2006). More precisely, search theory studies an individual's optimal strategy when choosing from a series of potential opportunities, under the assumption that delaying choice is costly (Glower et al., 1998, Ehrlich, 2013). Mathematically, search theory finds the optimal stopping point in the face of the tradeoffs between sale price and time on the market.

Search theory have been widely applied to the real estate market to study the optimal time on the market or optimal sale price under various market conditions (Yinger, 1981; Clark & Smith, 1982; Jud, 1983; Wheaton, 1990; Dipasouale & Wheaton, 1992; Baryla & Zumpano, 1995; Zumpano et al., 2003; Chen et al., 2008).

Nowadays, list price on the advertisement is the most widely used strategy for search. There are also some empirical studies have evidenced the significant role of the list price in the search process in the housing market. Higher list prices will result in higher deal price but longer time on the market (Merlo 2004). Wit and Klaauw's (2013) research shows that the list-price reductions will accelerate the search process, and the timing and the magnitude of the list-price reduction highly influence when the house will be rented/sold as well as the final deal price of the house.

Within the search-theoretical framework, a few literatures have explored the roles of the list price. In Horowitz's (1992) work, List prices appear to be price ceilings that preclude the possibility of sales at higher prices. Following Horowitz (1992)'s point of view that list prices are highly related to the sellers' reservation prices as well as the final sale prices in the housing market, Knight et al. (1994) find that the list price conveys the signal of seller intent, which makes it the most powerful predictor for the final deal price. At the same time, Knight et al. (1994) point out that list price also highly associates with the time on the market, and in a market driven by the buyer's willingness to pay, list price may extend the time on the market. Two roles of the list price are theoretically explained in the literatures, first of which is the list price is signaling the quality of the house and another is the list price can be considered as an acceptable price for the tenants/sellers (Yavas & Yang, 1995, Anglin 2006, Haurin et al., 2010). Based on the two roles of list price, some extending models have been constructed in literatures. The theory on the roles of list price is applied to real estate auctions by Mayer (1995). In Bucchianeri & Minson (2013)'s study, the initial list price is most important since it anchors the quality of house in the market. Three list pricing strategies, which are “round” price, “just below” price and “precise” price, are compared by Beracha and Seiler (2014). The above models are based on one-period search model, which means the house must be rented or sold within one-period under one list price. The process of list price revision hasn’t been considered in the above models.

However, in the housing market in reality, the decision for list price is not always the final decision. In fact, a seller may sequentially encounter several buyers, and it is possible to show different list prices to different buyers. It is reasonable to consider list price revisions in a multi-period model structure. Lazear (1986) provides a two-period search analytical framework, in which the price is possible to change after one period, which lays the foundation for the price strategical researches in the literature. With exhaustive literature review, few literatures tackle with the price revision process in the housing market listed as follows. Following Lazear (1986), Read

(1988) extends the model into multi-periods and develops a theoretical model for housing market to output the sequence of optimal values for prices. However, in Read (1988)' model, the strategy is decided by the time of the first arrival of potential buyers, the knowledge of seller can't update in the sequential process. Chen &Rothenthal (1996) and Arnold (1999) incorporate multi-stage price bargaining into the search-theoretical framework, in which the landlords/home-sellers compare current negotiating session and outside opportunities, but the landlords/home-sellers can't learn from the process of bargaining. In Zheng et al. (2007)' theoretical model on list price change process, the home-sellers possess the perfect information of the housing market, which is quite unrealistic.

In the housing market with imperfect information, list price exchanges the information between the landlords/home-sellers and the tenants/home-buyers. One fundamental role of list price that has been ignored in the literatures, is that in addition to send the signals from the landlords/home-sellers by list prices, the landlords/home-sellers also receive market information from the feedbacks of the tenants/home-sellers towards the list prices. Hence the landlords/ home-sellers can update the knowledge of market in the sequential process of receiving the tenants/home-buyers with various list prices. With the updating knowledge of the housing market, the landlords/sellers reconsider that if they would like to change the list price. Until now, with the exhaustive literature review, there is no search theoretical model to explain the process of information learning and decision-making with the updating information in the housing market.

1.5 Research Objectives

The focus of research is on the vacant houses for the sale as well as the vacant houses for rent.

From the literature review, although the negative influences caused by the excessive or long-term vacant houses are widely discussed in the literatures (Hirokawa & Gonzalez, 2010; Brian 2008; Stephan &Tomas,

2012), there is no research to define what amount of vacant houses is proper, and what the extra is. Natural vacancy is considered as the proper benchmark, however the studies based rent-adjustment mechanism can't give the theoretical explanation for the natural vacancy, at the same time, the structural vacancies are included in the empirical studies (Smith, 1974; Sivitanides, 1997; Tse&Fischer, 2003). In the search theory, the search process leads to the natural vacancy. List price is evidenced highly influencing the search process and result (Merlo, 2004, Hui et al., 2010), however, search-theoretical models until now haven't fully explained the roles of list price in the housing market, especially the role that the landlord/home-sellers used the list price as the market probe to update information of the housing market.

There are main objectives for the research as follows:

Theoretically, in order to enrich the search theory in the aspect of the roles of the list price, the first objective of the research is to develop a theoretical model which directly tackles the list price change decisions with an information learning process in housing market. A new learning process is incorporated into the structure of multi-stage search-theoretical models to make an original theoretical model for the housing market.

Empirically, in the face the issue of vacant houses challenging the sustainable development in Japan, it is still not clear that what amount of vacant houses is proper and what the excessive amount of vacant houses is. In order to provide a benchmark for housing market and the management of vacant houses, the research aims to give the natural vacancy rate by the application of the theoretical model to Tokyo (23 wards). The natural vacancy rate would be the certain rate of vacant houses is required for the landlord/home-seller to search for the tenant/home-buyer with the ideal list price strategy. Additionally, the natural vacancy rate is the rate that satisfies the goals of the landlords/home-sellers---maximize the price while minimize the time on the market---in the housing market. The natural vacancy rates for the housing sale market as well as the housing rental market in Tokyo (23 wards) will be researched.

1.6 Brief Description of Methodology

The dissertation develops the original theoretical model for optimal list price strategy and natural vacancy rate. The theoretical model explains the process that, in the face of the uncertainties in the potential tenants/home-buyers, in order to maximize the present value of expected return, the landlords/home-sellers make decisions for list price revisions with an information learning process.

In addition, the dissertation specifies the theoretical model for the housing sale market and housing rental market based on the actual market data in 23-wards area of Tokyo. With the specified parameters, numerical simulations are made to calculate natural vacancy rates with optimal list price strategies for housing sale market and housing rental market. And possible scenarios with the variances in the parameters are simulated to discuss the dynamic changes in natural vacancy rate as well as possible recommendations for the management of vacant houses for both housing sale market and housing rental market in 23-wards area of Tokyo.

1.7 Principal Results and Conclusions.

The dissertation develops an original theoretical model to directly explain the process of list price revision with an information updating process. By applying the theoretical model to the housing sale market as well as the housing rental market in Tokyo (23 wards), the research provides an original empirical perspective for the issue of the vacant houses by defining natural vacancy rate as the benchmark to divide vacant houses into the necessary amount of the vacant houses for the functioning of the market and wasteful amount of vacant houses that impose a vicious cycle for sustainability. With the optimal list price strategy, the natural vacant rate for the housing sale market is 0.73%, while the natural rate for the housing rental market is 1.33% in Tokyo 23 wards. Comparing to the actual vacancy rates in the housing sale market and housing rental market, there are a lot of wasteful excessive vacant houses in the housing market causing large social cost. Responding policies are in need to reduce the vacant houses in the housing market. The natural vacancy rate will increase before the year of 2020 and decrease after the year of 2020.

1.8 Main Contents of the dissertation

There are six chapters in the dissertation.

In Chapter 1, the background of the research is introduced. In the face with the issue of the high vacancy ratio in Japan, it is still not clear if the high vacancy rate is impeding the sustainable development of Japan. The natural vacancy rate in the market equilibrium is considered as a reasonable benchmark to decide how much vacancy is needed for the functioning of the market and what the excessive amount is to impose the vicious cycle. In the search theory, natural vacancy is explained as the vacancies that are needed to compensate the trading frictions caused by the imperfect information. With the exhaustive literature reviews, until now the roles of the list price haven't been fully explained and there is no literature set the criteria for the amount of housing vacancies. To fill the theoretical and empirical gaps in the literatures, my research objective is to develop a theoretical model to explain the process of list price revisions with an information learning process. In addition, to apply the model to the housing sale and rental markets in the 23-wards area of Tokyo to provide the natural vacancy rates as the benchmarks for the management of housing market as well as the issue of vacant houses in Tokyo.

In Chapter 2, the original theoretical model for the process of the list price revision with the information learning process is explained. Firstly, the two roles of the list prices and their dynamic relationship among the landlords/home-buyers' expectation on the deal price as well as the time on the market are explained. Following the basic idea of the roles of list price, detailed assumptions and formulas are developed in the chapter.

In Chapter 3, the application of the theoretical model in Chapter 2 to the housing sale market in the 23-wards area of Tokyo. Firstly, the parameters are specified for housing sale market including the distribution of the home-buyers' reservation prices, mean of the home-sellers' reservation prices, the interval of the visits by potential home-buyers, and prior knowledge of the home-sellers, and etc. The numerical simulation with the specified parameters is made, and the natural vacancy rate with the optimal list price strategy is calculated for the housing sale market in Tokyo (23 wards). Scenarios are built to identify the dynamic change of the natural vacancy rate for the housing sale market.

In Chapter 4, the application of the theoretical model in Chapter 2 to the housing rental market in the 23-wards area of Tokyo. Firstly, the parameters are specified for housing rental market including the distribution of the tenants' reservation prices, mean of the landlords' reservation prices, the interval of the visits by potential tenants, prior knowledge of the landlords, etc. The numerical simulation with the specified parameters is made, and the natural vacancy rate with the optimal list price strategy is calculated for the housing rental market in Tokyo (23 wards). Scenarios are built to identify the dynamic change of the natural vacancy rate for the housing rental market.

In Chapter 5, the social costs caused by the excessive houses in the housing market are discussed. Possible recommendations are considered and discussed. In addition, the trend of the change of the natural vacancy rate for the housing market is discussed in the chapter.

In Chapter 6, concluding remarks on the theoretical model and the natural vacancy rates for the housing sale market as well as the housing rental market in Tokyo are stated. Possible recommendations are made for the management of housing market as well as the issue of vacant houses. Possible future extensions for the research are also mentioned.

2. THEORETICAL MODEL

In the chapter, a search-theory based theoretical model which explains the decisions for the list price revisions with information updating process will be developed.[1]

2.1 Conceptual Framework

In the theoretical model, in the face of the uncertainties in the market, the landlords/home-sellers will try to find the optimal list price strategy to maximize the price while minimize the time on the market. The optimal list price strategy includes the optimal frequencies of price revisions, the optimal timings to revise the price as well as a sequence of optimal values for the list prices. Also, the theoretical model can produce the natural vacancy duration on the market with the optimal list price. With the natural vacancy duration, the natural vacancy rate for the housing market can be calculated to be the benchmark to manage the vacant houses.

As shown in Figure 4, due to the imperfect information in the housing market, the landlords/home-sellers are in the face of numbers of

[1] Part of the content in Chapter 2 are paraphrased from Gu, J.P., and Asami, Y. 2015. Search and list price strategies in the housing market with imperfect information. Review of Urban & Regional Development Studies, in the process of reviewing

uncertainties on the demand side. List price plays important roles to exchange information between the landlords/home-sellers and potential tenants/home-buyers. Two roles of the list price are emphasized in the theoretical model. One is that the list price is considered as an acceptable price for the landlords/home-sellers. The other is that the landlords/home-sellers use the list price as the market probe for the market exploration. With receiving the feedbacks from the potential tenants/home-buyers towards the list prices, the landlords/home-sellers will update their knowledge on the housing market, and re-consider that if it is necessary to revise the list price.

The model which will be developed in the section is a multi-stage search-theoretical model with an information updating process. The market probe role of the list price to update the information of the landlords/home-sellers in the housing market hasn't been developed in the search-theoretical models in the literatures until now, and it will be one of the major contributions the research to enrich the search theory.

Table 1 shows the summary of the parameters and variables that will be used in the theoretical model. In order to describe the process of decision-making on the initial list price, information updating as well as decisions on list price revisions, several assumptions will be made.

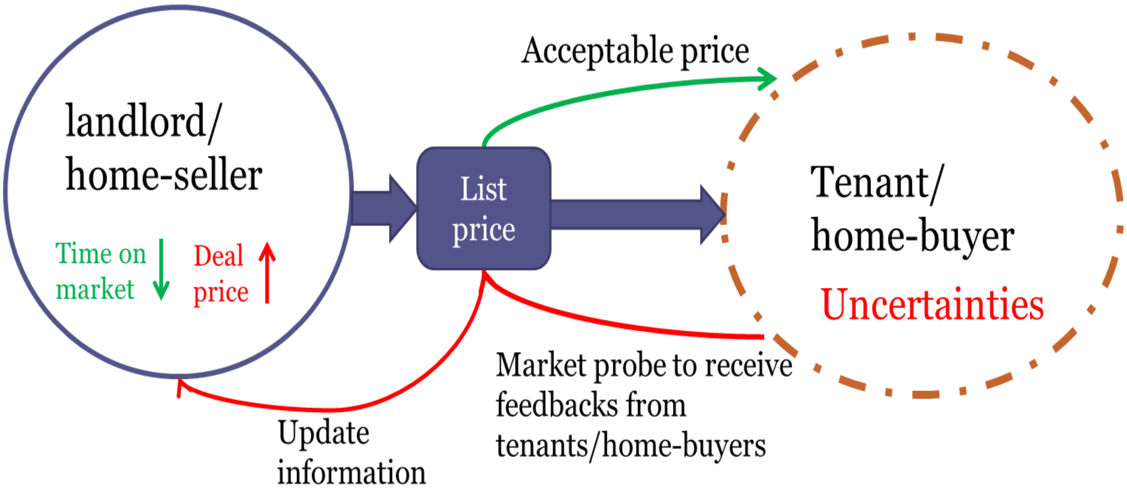

Figure 4: The Roles of list price in the housing market

Table 1: Summary of the Parameters and Variables

Parameters	Description
σ	Standard deviation of the distribution of tenants/home-buyers' reservation prices
m^*	Mean of the distribution of tenants/home-buyers' reservation prices
t_0	The time interval to receive one visit from the potential tenants/home-buyers
r	The landlord/seller' reservation price
c	Cost triggered by changing the list price
N	Maximum number of the potential tenants/buyers
δ	Time discount ratio
k	Number of observations before the landlord/seller lists a price
$\frac{\sum_{j=1}^{k} x_j}{k}$	Mean of the observations before the landlord/seller lists a price
Occupied duration	Expectation of duration of residence
Variables	Description
m	The landlord/seller's estimated mean values for the distribution of tenants/buyers

p	List prices

The vacancy rate is calculated from the perspective of the durations as shown in Expression 1.

$$\text{Natural vacancy rate} = \frac{vacancy\ duration}{vacancy\ duration + \ occupied\ duration}$$

Expression 1

where the vacancy duration is the duration on time the market with optimal list price strategy and occupied duration is the duration of residence.

2.2 Theoretical Model for Housing Sale Market

Firstly, to describe the market, there are two assumptions for the market as the follows:

Assume that for a house with the quality $\boldsymbol{m}^*$, the distribution of the reservation prices of the home-buyers is a log-normal distribution with $\boldsymbol{m}^*$as the mean while $\boldsymbol{\sigma}$ as the standard deviation.

Assumption 1

Reservation prices of the home-buyers mean the highest prices that the home-buyers will pay for a certain quality of houses. And on the home-seller' side, there is assumption 2.

Assume that the home-seller knows the standard deviation $\boldsymbol{\sigma}$ for the home-buyers' distribution, but due to the imperfect information, the seller doesn't know the mean $\boldsymbol{m}^*$ for the home-buyers' distribution.

Assumption 2

Not aware of the mean for the home-buyers' distribution, the home-seller is in the face of the uncertainty for the home-buyers. However, the home-seller will estimate the mean for the home-buyers' distribution based on his knowledge on the housing market which includes the prior knowledge before he lists the price as well as the updated information in the process of list price revisions. Different home-sellers have different prior knowledge on the housing market. The prior knowledge is from the previous experiences as well as the surveys and observations of the housing market, which will highly influence how the home-seller makes decisions on list price. Assumption 3 is for the prior knowledge of the home-seller.

Assume that before the home-seller lists the initial price, he has observed some samples of the home-buyers' reservation prices. The home-seller has observed k reservation prices, which are $\{\boldsymbol{x_1}, \boldsymbol{x_2}, \boldsymbol{x_3}, \dots, \boldsymbol{x_k}\}$. The home-seller will estimate the first mean value for the distribution of the home-buyers' reservation prices by maximum log-likelihood.

Assumption 3

With Assumption 3, the formula for the log-likelihood is as the follow. $m(1)$ is the home-seller's first estimated mean for the distribution of home-buyers' reservation prices.

$$MAX.\ \log \prod_{j=1}^{k} \phi\left(\ln(x_j); m, \sigma^2\right)$$

$$\boldsymbol{m(1) = \widetilde{m} = \frac{\sum_{j=1}^{k} \ln(x_j)}{k}}$$

Expression 2

where ϕ() is the probability density function for normal distribution.

Since the final deal price almost equals to the final list price in the housing market in Japan (Shimizu et al., 2004), there is basically not much negotiation on price between the home-sellers and the home-buyers. The transaction will be done under the condition in Assumption 4.

Assume that the buyers will rent/buy the house only when their reservation prices are higher than the list or equal to the list price.

Assumption 4

With Assumption 4, the home-seller' expected probability to sell the house at the list price p is as the Expression 3.

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

Expression 3

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

The home-seller has two goals which are to maximize the deal price at the same to minimize the time on the market. To avoid two objectives, time discount is used in the model to discount the future return, and then both the price and time on the market can be considered in one function, which is specifically described in Assumption 5.

Assume that the home-seller will maximize the expected present value of return.

Assumption 5

With Assumption 5, in the first stage, the expected present value of return is the expected return from the first stage plus the expected return from the future as the Expression 4. $m(1)$ is the landlord/seller first estimated mean value for the distribution of the tenants/home-buyers' reservation prices. $p(1)$ is the initial list price by the home-seller.

$$\text{MAX.} \quad \left(1-\Phi(\ln(p(1)); m(1), \sigma^2)\right)(p(1)-r)+\Phi(\ln(p(1)); m(1), \sigma^2)\delta f(2)$$

Expression 4

where δ is the future discount ratio; $f(2)$ is the future return in the first stage; r is the reservation price of the home-seller, reservation price of the home-seller means the lowest price that the home-seller can accept to sell a certain quality of the houses.

Since the theoretical model is focus on the home-sellers' search, the home-buyers' search is simplified in Assumption 6.

Assume that there are maximum N potential home-buyers will visit the home-seller, and the time interval for each visit is t_0.

Assumption 6

With Assumption 6, the potential home-buyers will come at a constant time interval. For each visit from the potential home-buyers, there will be two outcomes, which are the visitor buys the house and the visitor doesn't buy the house. For the two outcomes, detailed descriptions are from Assumption 7 to Assumption 9.

Assume that for each visit from each potential home-buyer, if the home-buyer has the reservation price higher than the list price or reservation price equals to the list price (Assumption 4), he will buy the house, and then the process ends.

Assumption 7

For the case that the visitor doesn't buy the house is described in Assumption 8 and Assumption 9.

Assume that for each visit from each potential home-buyer, if he doesn't buy the house, the home-seller will receive the fact that one potential home-buyer visits but doesn't buy the house at the list price, and he will re-estimate the mean value for the distribution of the home-buyers' reservation prices by maximum log-likelihood.

Assumption 8

With Assumption 7 and Assumption 8, for the n-th potential home-buyer comes, $n \in [2, N]$, which means (n-1) potential home-buyers have visited but haven't rented or bought the house, the log-likelihood can be written as Expression 5.

$$MAX. \quad \log \prod_{j=1}^{k} \phi(\ln(x_j); m, \sigma^2) \prod_{i=1}^{n-1} \Phi(\ln(p(i)); m, \sigma^2)$$

Expression 5

The first order condition for Expression 5 is as Expression 6.

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

Expression 6

For each visit from the potential home-sellers, if they don't buy the house, the home-seller will consider if he wants to revise the list price with the updating information, which is described in Assumption 9.

Assume that for each visit from each potential tenant/home-buyer, if the home-buyer doesn't rent/buy the house, the home-seller receives a chance to revise the list price for the next home-buyer.

Assumption 9

In Assumption 9, the decision that whether change the list price or not is based on maximization of the utility functions which is based on the expected present value of return as assumed in Assumption 3. Similar to Expression 4, for the n-th potential home-buyer comes, $n \in [2, N]$,which means (n-1)-th potential home-buyer doesn't buy the house, the utility functions including the expected present value of return of keeping the current list price as well as the expected present value of return of revising the list price are as the follows.

$$\text{MAX.} \quad U_n\{U_{n1}, U_{n2}\}$$

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

$$\text{where } p(n) = p(n-1)$$

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

where $p(n) \neq p(n-1)$; c is the cost for list price revision and $c \in [0, +\infty)$

Expression 7

When the $(n+1)$-th tenant/buyer comes, if the $(n+1)$-th tenant/buyer doesn't rent/buy the house, according to Assumption 9, there will be a similar utility expression as Expression 7, denoted as $U_{n+1}(U_{(n+1)1}, U_{(n+1)2})$. The future return from n-th stage denoted as $f(n+1)$, equals to the maximum value of the utility of $(n+1)$-th stage. We can write the relationship as Expression 8.

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

Expression 8

The decision making process will be repeated from the Assumption (7) to Assumption (9) for each visit of the potential home-buyers until the home-seller encounters maximum N numbers of the home-buyers as assumed in Assumption 6.

When the N-th home-buyer comes, which is the last home-buyer, there is no future return. Similar to Expression 7, the utility function for the N-th stage is as the follow.

$$\text{MAX.} \quad U_N\{U_{N1}, U_{N2}\}$$

$$U_{N1} = \left(1 - \Phi(\ln(p(N)); m(N), \sigma^2)\right)(p(N) - r) \qquad p(N) = p(N-1)$$

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

Expression 9

Assume that the home-seller lists S different prices, $S \in [1, N]$, and changes the list prices 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, $i \in [1, N - 1]$ and $n_s(i) \in [2, N]$. With the recurrence relation associated with the utility function and future return in Expression (8), deriving from the N-th stage, the Expression 4 can be rewritten as the follow.

$$\left(1 - \Phi(\ln(p(1)); m(1), v^2)\right)(p(1) - r) + \sum_{i=2}^{N} \prod_{j=1}^{i-1} \Phi(\ln(p(j)); m(j), v^2) \left(1 - \Phi(\ln(p(i)); m(j), v^2)\right)(p(i) - r)\sigma^{i-1} - \sum_{i=2}^{S} \prod_{j=1}^{n_s(i-1)-1} \Phi(\ln(p(j)); m(j), v^2)\, \sigma^{n_s(i-1)-1}\, c$$

Expression 10

The model is an optimization problem with constrains. Expression 10 is the objective function. Expression 6 will be the equality constrains. And Expression 7 will be the inequality constrains. The model can be solved by integer-mixed genetic algorithm, or by other widely used numerical simulation methods with the enumeration of all possible S and n_s.

The outputs of the model will be the home-seller's estimated mean values for every stage, the list prices for every stage and the return of the objective function which means the expected extra return than list the home-seller's reservation price. With the list prices, the expectation of sale price, the expectation of time on the sale market, and the natural vacancy rate for housing sale market can be calculated.

2.3 Theoretical Model for Housing Rental Market

The basic idea and assumptions for the housing rental market is the same with the housing sale market, which is explained in Section 2.2. However, there is a difference in dealing with the return because in the housing sale market, the sale prices are paid in one time while in the housing rental market, the rents are paid every month. Hence the time duration should be considered in the return in the housing rental market.

In the housing rental market, at the initial stage, the expression for the expected present value of return during the search process shown as the follow is revised from the Expression 4. Because there is an interval for the next tenant to come, t_0 which means the interval for one visitor to come, is added to the original function.

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

Expression 11

Similarly, the Expression 7 should be revised to the follow:

$$\text{MAX.}\quad U_n(U_{n1},U_{n2})$$

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

$$\text{where } p(n)=p(n-1)$$

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

$$\text{where }\ p(n)\neq p(n-1)$$

Expression 12

Hence, the objective function for the housing rental market is as the following expression.

$$\begin{aligned}&\left(1-\Phi(\ln(p(1)); m(1),v^2)\right)(p(1)-r)t_0\\&\quad+\sum_{i=2}^{N}\prod_{j=1}^{i-1}\Phi(\ln(p(j)); m(j),v^2)\left(1-\Phi(\ln(p(i)); m(j),v^2)\right)(p(i)\\&\quad-r)\sigma^{i-1}t_0-\sum_{i=2}^{S}\prod_{j=1}^{n_s(i-1)-1}\Phi(\ln(p(j)); m(j),v^2)\,\sigma^{n_s(i-1)-1}\,c\end{aligned}$$

Expression 13

3. HOUSING SALE MARKET IN 23-WARDS AREA OF TOKYO

The theoretical model is applied to the housing sale market in the 23-wards area of Tokyo in the Chapter.[2]

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[2] Part of the content in Chapter 3 are paraphrased from Gu, J.P., and Asami, Y. 2015. Search and list price strategies in the housing market with imperfect information. Review of Urban & Regional Development Studies, in the process of reviewing

3.1 Parameters Specification for Housing Sale Market in Tokyo (23 Wards)

3.1.1 Distributions for Reservation Prices of the Home-Buyers and the Home-Sellers

In the imperfect competitive housing market, the reservation prices can't be directly observed. Instead of reservation prices, the transactions made at the market prices. In a random transaction in the housing sale market, the deal price is higher than the seller' reservation price while lower than the buyer's reservation price. Following Huang et al. (2001), the differences between the reservation price and market price can be represented by the inefficiency term in the stochastic frontier analysis. Following Aigner et al. (1977)' formation of stochastic frontier analysis, the market price is constructed as the follow.

$$p_i = p_i^{buyer} * \exp(-u_i^{buyer})$$

Expression 14

where p_i is the deal price for the i-th house; p_i^{buyer} is the buyer's reservation price for the i-th house. $\exp(-u_i^{buyer})$ is the term to represent the difference between the buyer' reservation price and market price for the i-th house, $\exp(-u_i^{buyer}) \in (0,1]$ because the buyer' reservation price is higher than the market price. $u_i^{buyer} \in [0, +\infty)$, and u_i^{buyer} is assumed to be an exponential distribution.

Similarly, from the sellers' reservation prices, the market prices can be also constructed as the Expression 15.

$$p_i = p_i^{seller} * \exp(u_i^{seller})$$

Expression 15

where p_i is the market price for the i-th house, p_i^{seller} is the reservation price of the seller for the i-th house. $\exp(u_i^{seller})$ is the term to represent the difference between the seller' reservation price and the market price for the i-th house, $\exp\left(u_i^{seller}\right) \in [1, +\infty)$ because the seller' reservation price is lower than the market price. $u_i^{seller} \in [0, +\infty)$, and u_i^{seller} is assumed to be an exponential distribution.

Empirically, both buyers' reservation prices and sellers' reservation prices are determined by the composition of characteristics of the houses and an error term to capture the individual random effects.

$$p_i^{buyer} = f(Z_i, \beta) * \exp(v_i^{buyer})$$

Expression 16

$$p_i^{seller} = f(Z_i, \beta) * exp(v_i^{seller})$$

Expression 17

where Z_i is a vector of quantities of tract characteristics for the i-th house, β is a vector of per unit prices for tract characteristics, $\exp(v_i^{buyer})$ is a log-normally distributed term representing for buyers' individual preferences for the evaluation of houses, and $\exp(v_i^{seller})$ is a log-normally distributed term representing for individual difference in sellers' evaluation on the house. The distributions of v_i^{buyer} and v_i^{seller} are assumed to be normal distributions.

Substitute Expression 16 into Expression 14, rewrite Expression 14 as the follow.

$$p_i = f(Z_i, \beta)\ exp(v_i^{buyer})\ exp(-u_i^{buyer})$$

Expression 18

Similarly, substitute Expression 17 into Expression 15 to achieve Expression 19.

$$p_i = f(Z_i, \beta)\ exp(v_i^{seller\cdot})\ exp(u_i^{seller})$$

Expression 19

Taking natural logarithm of the both sides of Expression 18 and Expression 19, and assuming there are k characteristics of the houses as the inputs to decide the quality, there are Expression 20 and Expression 21 for the estimation.

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

Expression 20

where v_i^{buyer} is standard normal distribution decided by standard deviation σ_v^{buyer}; u_i^{buyer} is exponential distribution decided by σ_u^{buyer}.

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

Expression 21

where v_i^{seller} is standard normal distribution decided by standard deviation σ_v^{seller}; u_i^{seller} is exponential distribution decided by σ_u^{seller}.

Following Aigner et al. (1997) and Belotti et al. (2013), assuming there are N samples for estimation, the log-likelihood functions for Expression 20 and Expression 21 are as Expression 22 and Expression 23.

$$\ln L = \sum_{i=1}^{N} \left\{ -ln\sigma_u^{buyer} + \frac{{\sigma_v^{buyer}}^2}{2{\sigma_u^{buyer}}^2} + ln\Phi\left(\frac{\beta_0 + \sum_{j=1}^{k} \beta_j \, ln(z_{ij}) - \ln(p_i) - \frac{{\sigma_v^{buyer}}^2}{\sigma_u^{buyer}}}{\sigma_v^{buyer}} \right) + \frac{ln(p_i) - \beta_0 - \sum_{j=1}^{k} \beta_j \, ln(z_{ij})}{\sigma_u^{buyer}} \right\}$$

Expression 22

$$\ln L = \sum_{i=1}^{N} \left\{ -ln\sigma_u^{seller} + \frac{{\sigma_v^{seller}}^2}{2{\sigma_u^{seller}}^2} + ln\Phi\left(\frac{ln(p_i) - \beta_0 - \sum_{j=1}^{k}\beta_j\, ln(z_{ij}) - \frac{{\sigma_v^{seller}}^2}{\sigma_u^{seller}}}{\sigma_v^{seller}} \right) + \frac{\beta_0 + \sum_{j=1}^{k}\beta_j\, ln(z_{ij}) - ln(p_i)}{\sigma_u^{seller}} \right\}$$

Expression 23

The data samples are from the advertisements of the houses for sale in Tokyo (23 wards) from2008 to 2012 from At Home Co. Ltd. Each advertisement contains the information of list price, basic information of the house, and the location coordinates. Using the location coordinates in the GIS and the GIS data of the infrastructures in Tokyo 23 wards from Ministry of Land, Infrastructure and Transport Ministry of Land Policy Bureau to calculate the variables for the residential environment of houses based on their locations. Each sample contains the information from serval advertisements—from the first advertisement until it is sold—and the residential environment information from GIS analysis. There are total 45,324 samples for the housing sale market for the estimation.

The variables for the estimation of reservation prices of buyers and sellers are shown in Table 2. Deal price is the dependent variables. Independent variables are including the size of the house as well as the accessibilities of the residential environment. The house with the average quality, which means the house with the mean values for its attributives in Table 2 will be the representative house for the housing sale market in Tokyo (23 wards).

The results for maximum log-likelihood for Expression 22 and Expression 23 are displayed in Table 3 and Table 4. All independent variables are significant. Using the coefficients in Table 3, the mean value for log-normal distribution of the buyer's reservation prices for the house with average quality is17.2154, and the standard deviation is 0.2769. Using the coefficients in Table 4, the mean value for the log-normal distribution of the seller's reservation prices for the house with average quality is 16.9954, and the standard deviation is 0.2919. Hence, the distribution for the home-buyers' reservation price is log-normal (17.2154, 0.2769), while the distribution for the home-sellers' reservation price is log-normal (16.9954, 0.2919). Put the mean values 17.2154 and 16.9954 for the lognormal distributions into real value of the money should be 29,960,787.46 JPY and 24,044,095.14 JPY.

Table 2: Description for the Variables for Housing sale market

Variables	Description	Mean	Std. Dev.	Min	Max
ln(dealprice)	natural log of the deal price	17.0865	0.6721	14.5574	20.7233
ln(areaofhouse)	natural log of the area of the house	3.9729	0.5579	1.3863	6.8522
ln(popinstation)	natural log of number of people take off at the nearest station in a day	9.7723	0.9253	6.5653	13.0544
ln(dist2nursery)	natural log of the distance to the nearest nursery	5.7762	0.5845	1.6633	7.1466
ln(dist2tokyo)	natural log of the distance from the nearest station to Tokyo station	8.9590	0.5601	6.4418	9.8813
ln(dist2station)	natural log of the distance to the nearest station	6.0807	0.6543	1.6803	7.8096
ln(dist2mall)	natural log of the distance to the nearest shopping mall	7.4863	0.7930	2.3474	8.9687
ln(dist2university)	natural log of the distance to the nearest university	7.1205	0.8911	2.7587	9.0281

Source: 45,324 samples from At Home Ltd. from 2008 to 2012

Table 3: Estimation Results for the Distribution of Buyers' Reservation Prices

Stoc. frontier normal/exponential model						Number of obs = 45324
						Wald $\chi^2(7)$ = 177131.31
Log likelihood = -10504.858						Prob > χ^2 = 0.0000
In(dealprice)	Coef.	Std. Err.	*z*	*P>z*	[95% Conf.	Interval]
In(areaofhouse)	1.1169	0.0027	415.6300	0.0000	1.1116	1.1221
ln(popinstation)	0.0382	0.0016	23.5800	0.0000	0.0350	0.0414
ln(dist2nursery)	-0.0058	0.0025	-2.3300	0.0200	-0.0106	-0.0009
ln(dist2tokyo)	-0.0496	0.0031	-15.8400	0.0000	-0.0558	-0.0435
ln(dist2station)	-0.0403	0.0024	-16.5900	0.0000	-0.0451	-0.0356
ln(dist2mall)	-0.0804	0.0023	-35.7400	0.0000	-0.0848	-0.0760
ln(dist2university)	-0.1285	0.0019	-67.9400	0.0000	-0.1322	-0.1248
_cons	14.6452	0.0336	435.9600	0.0000	14.5794	14.7111
$\ln(\sigma_v^2)$	-2.5680	0.0118	-217.4400	0.0000	-2.5912	-2.5449
$ln(\sigma_u^2)$	-4.0976	0.0514	-79.7500	0.0000	-4.1983	-3.9969
σ_v	0.2769	0.0016			0.2737	0.2801
σ_u	0.1289	0.0033			0.1226	0.1355
$\sigma_v^2 + \sigma_u^2$	0.0933	0.0006			0.0920	0.0946
Likelihood-ratio test of σ_u=0: $\bar{\chi}^2(01)$ = 2.7e+02 Prob>=$\bar{\chi}^2$= 0.000						

Table 4: Estimation Results for the Distribution of Sellers' Reservation Prices

Stoc. frontier normal/exponential model					Number of obs = 45324	
					Wald $\chi^2(7)$ = 171827.24	
Log likelihood = -10615.075					Prob > χ^2 = 0.0000	
In(dealprice)	Coef.	Std. Err.	*z*	*P>z*	[95% Conf. Interval]	
In(areaofhouse)	1.1150	0.0027	409.7100	0.0000	1.1097	1.1204
ln(popinstation)	0.0387	0.0016	23.7500	0.0000	0.0355	0.0419
ln(dist2nursery)	-0.0067	0.0025	-2.6800	0.0000	-0.0116	-0.0018
ln(dist2tokyo)	-0.0473	0.0032	-14.9500	0.0000	-0.0535	-0.0411
ln(dist2station)	-0.0397	0.0024	-16.3400	0.0000	-0.0445	-0.0350
ln(dist2mall)	-0.0815	0.0022	-36.3900	0.0000	-0.0858	-0.0771
ln(dist2university)	-0.1258	0.0019	-67.5500	0.0000	-0.1295	-0.1222
_cons	14.3974	0.0343	420.1400	0.0000	14.3302	14.4645
$ln(\sigma_v^2)$	-2.4629	0.0123	-199.5200	0.0000	-2.4871	-2.4387
$ln(\sigma_u^2)$	-4.7909	0.1103	-43.4300	0.0000	-5.0071	-4.5747
σ_v	0.2919	0.0018			0.2884	0.2954
σ_u	0.0911	0.0050			0.0818	0.1015
$\sigma_v^2 + \sigma_u^2$	0.0935	0.0006			0.0923	0.0947
Likelihood-ratio test of σ_u=0: $\bar{\chi}^2(01) = 50.31$ Prob>=$\bar{\chi}^2$= 0.000						

3.1.2 Duration of Residence for the Owner-occupied Houses

The duration of residence is based on the question in land and housing survey, which is how long you have been in your last residence. Weibull distribution is a distribution widely used for the estimation of survival time. The cumulative function for Weibull distribution is as Expression 24 (Weibull, 1951).

$$\mathrm{CDF} = \begin{cases} 1 - e^{-\left(\frac{x}{c_1}\right)^{c_2}} & x \geq 0 \\ 0 & x < 0 \end{cases}$$

Expression 24

The samples for estimation are cumulative probabilities of duration of residence for owner-occupied houses from land and housing survey as shown in Table 5. Gauss-Newton method is used to estimate the coefficients c_1 and c_2 in the cumulative function for Weibull distribution.

The result of the curve fitting is shown in Figure 5. $R^2 = 0.9984$. The overall fitness is very high. $c_1 = 21.2446, c_2 = 1.2401$, and $\mathrm{cdf} = 1 - e^{-(\frac{x}{21.2446})^{1.2501}}$. The probability density function of the Weibull distribution is shown in Figure 6. The expectation of residence duration for owner-occupied houses is

$$\int_0^{+\infty} \frac{1.2401}{21.2446} \left(\frac{x}{21.2446}\right)^{0.2401} e^{-(x/21.2446)^{1.2401}} x\,dx \approx 19.7851\ years.$$

Table 5: Samples for the Residence Duration for Owner-occupied Houses

	cumulative frequency	cumulative probability
under 1year	46400	0.0236
under 2 years	98,600	0.0501
under 3 years	170,300	0.0866
under 4 years	254,400	0.1293
under 5 years	315,400	0.1603
under 10 years	603,200	0.3066
under 15 years	904,900	0.4599
under 20 years	1,226,400	0.6233
total	1,967,500	1.0000

Source: land and housing survey in 1998

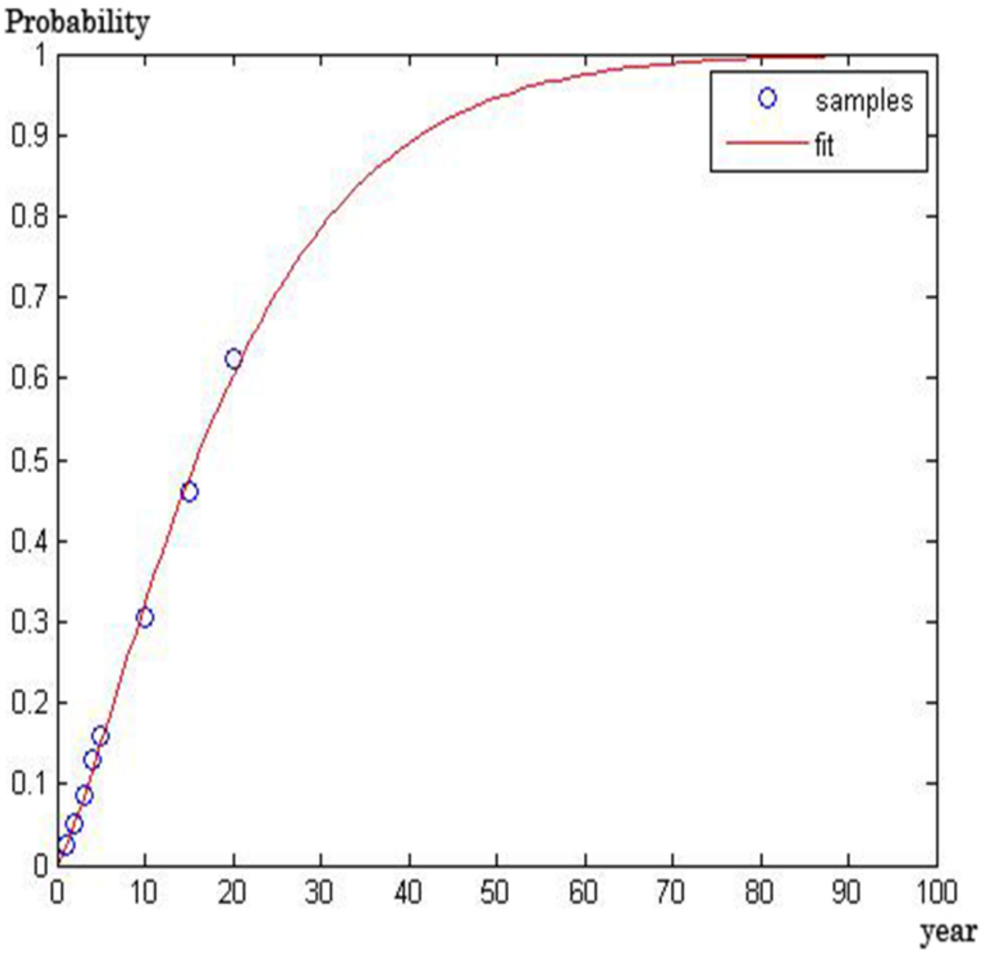

Figure 5: Cumulative Probability of Weibull Distribution for Housing Sale Market

Source: samples are from land and housing survey 1998

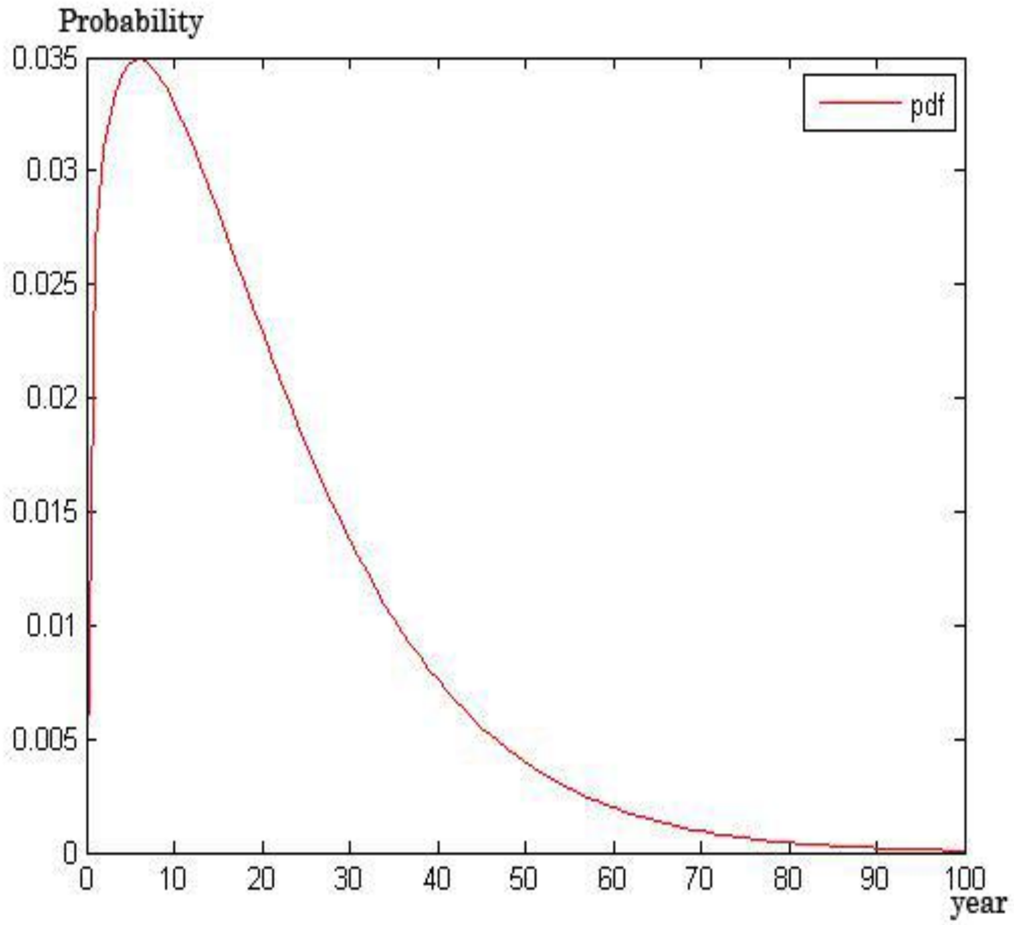

Figure 6: Probability Density for Weibull Distribution for Housing Sale Market

3.1.3 Buyers' search and time discount rate

For the search of the potential home-buyers, the information is based on the survey on the users for the websites of real estate agencies in 2014 (RSC, 2014) shown in Figure 7 and Figure 8. From Figure 7, the home-buyers will averagely visit 5.2 houses before purchase a house. From Figure 8, the home-buyers will averagely spend 2.8185 months for the search process before purchase a house. Hence, averagely the interval duration for one potential home-buyers visit a house is about 16 days.

For the maximum number of the potential buyers, the number should be big enough. Assume the maximum number of the potential buyers is 10, because in the simulation, after the visits from 10 potential buyers, the probability of remain unsold is less than 1%.

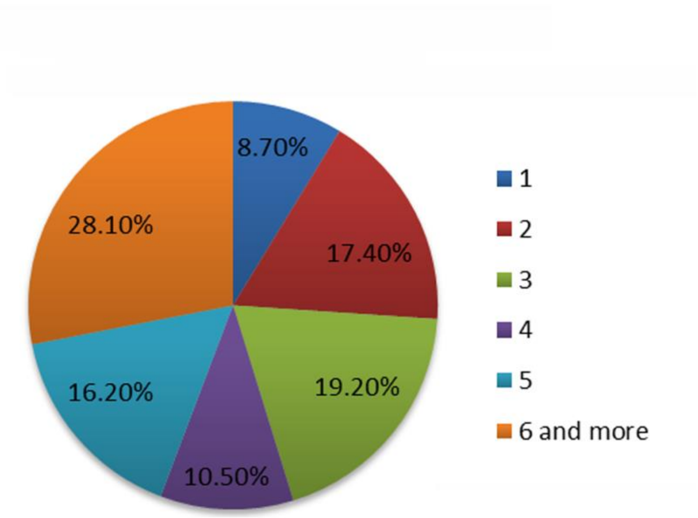

Figure 7: Number of Houses Visited before Home-buyers

Purchase a House

Source: RCS 2014

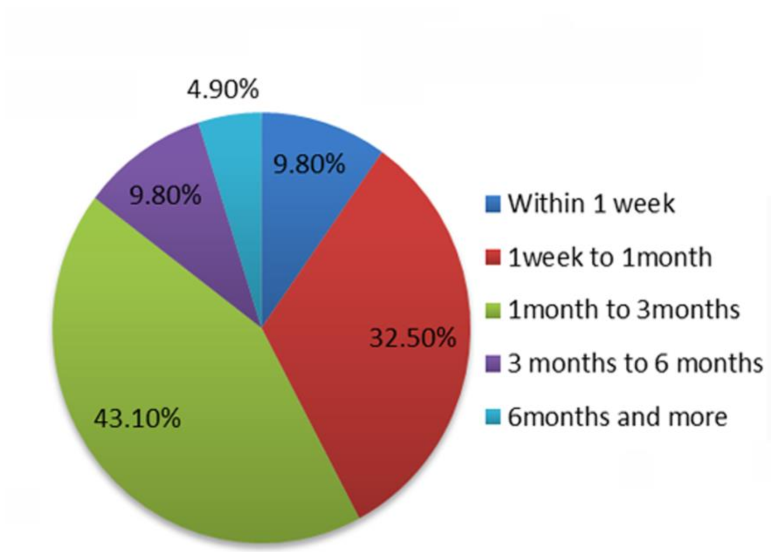

Figure 8 Duration of Search of the Home-buyers

Source: RCS 2014

The savings interest rate will be used for the time discount rate for the simulation. The average saving interest rate in Kanto area is 0.025% (Yahoo Finance, 2015). The time discount factor is 1-0.025%, which equals to 0.9975.

3.1.4 Prior knowledge of the home-sellers calibration and model validation.

Since there is no direct information on home-sellers' prior knowledge, the information of the list price in actual housing sale market in Tokyo (23 wards) is used to calibrate the parameters for the home-sellers prior knowledge. Figure 9 shows the actual list price discounts in the housing sale market. The expectation of the list price discount is -9.24% in the actual housing sale market in Tokyo (23 wards).

Since the home-sellers may consult the real estate agencies for the information of the market before they issue their advertisements for sale, they may acquire relatively accurate information on the reservation prices of the potential home-buyers. So assume that the average value of the home-seller' observations equals to the mean value for the distribution of the home-buyers' reservation prices, which means $\frac{\sum_{j=1}^{k} x_j}{k}$=17.2154. But the home-sellers are not certain about the value.

For the number of the observations before listing the price (k), simulation experiments made with different values are shown in Figure 10. The value for k bigger, the discount rates are larger. Table 6 shows expectations of the list price discount rates with various values for k. When k=100, the expectation of the discount rate is -9.04%, which is very close to the expectation of the actual list price discounts in the housing sale market in Tokyo (23 wards). Hence, the home-seller observes 100 samples of the reservation prices of the home-buyers before he lists the price on the advertisement in the housing sale market in 23 wards area of Tokyo.

Table 7 shows the summary of the parameters specified for the housing sale market in Tokyo 23 wards. The parameters will used for the simulation of the theoretical model described in Chapter 2 to achieve the results in the following section.

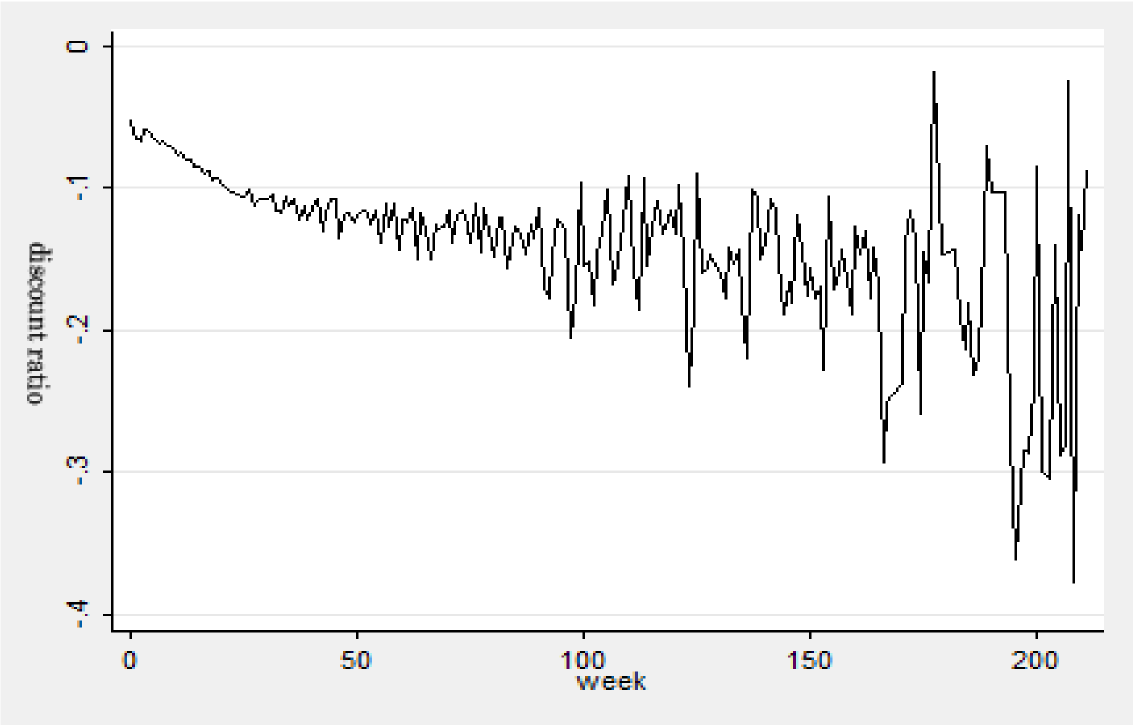

Figure 9: List Price Discounts in Actual Housing Sale Market in Tokyo

Source: Sample samples from At Home Co. Ltd. 2008-2012

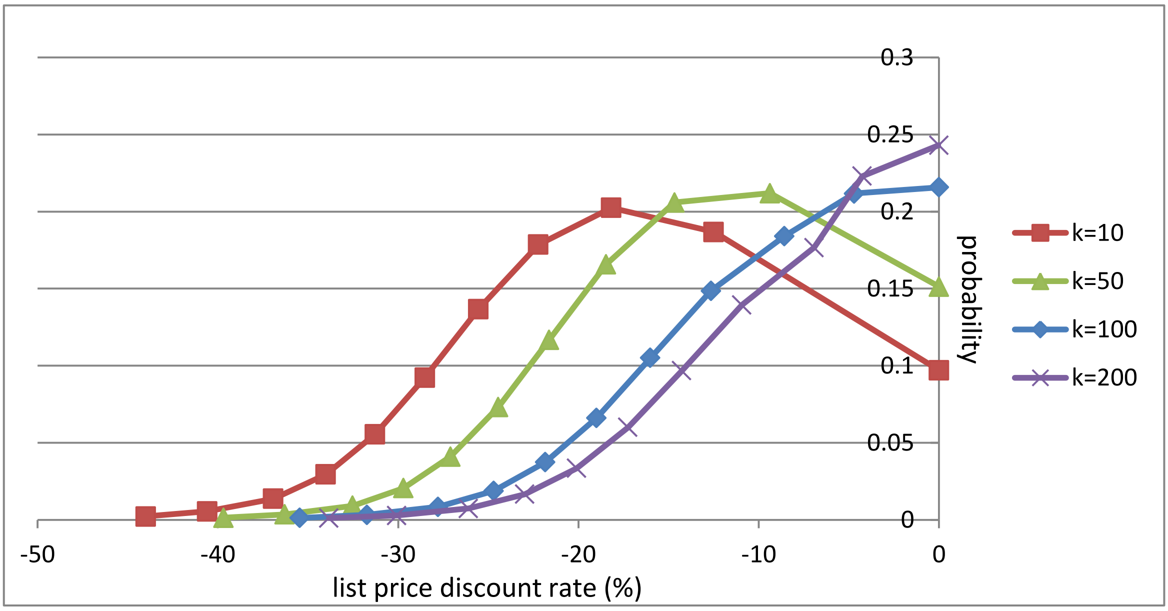

Figure 10: Experiments for Number of the Observations before List Price for Housing Sale Market

Table 6: Expectation of the List Price Discount Rate for Housing Sale Market

Value of k	10	50	100	200
Expectation of list price discount rate(%)	-19.66	-14.57	-9.04	-7.47

Table 7: Summary of the Parameters for the Housing Sale Market

Parameters	Values	references
σ	0.2769	Estimation
m^*	17.2154	Estimation
t_0	16.3 days	RCS 2014
r	16.9954	Estimation
c	0	Websites of real estate agencies
N	10	Assumption
δ	0.9975	Yahoo Finance
k	100	Model calibration
$\frac{\sum_{j=1}^{k} x_j}{k}$	17.2154	Assumption
Occupied duration	19.7851 years	Estimation

3.2 Result for List Price Strategy and Natural Vacancy Rate in the Housing Sale Market

With the parameters specified in Table 7, numerical simulation for the theoretical model described in Chapter 2 is made to achieve the list price strategy and natural vacancy rate for the housing sale market in Tokyo (23 wards).

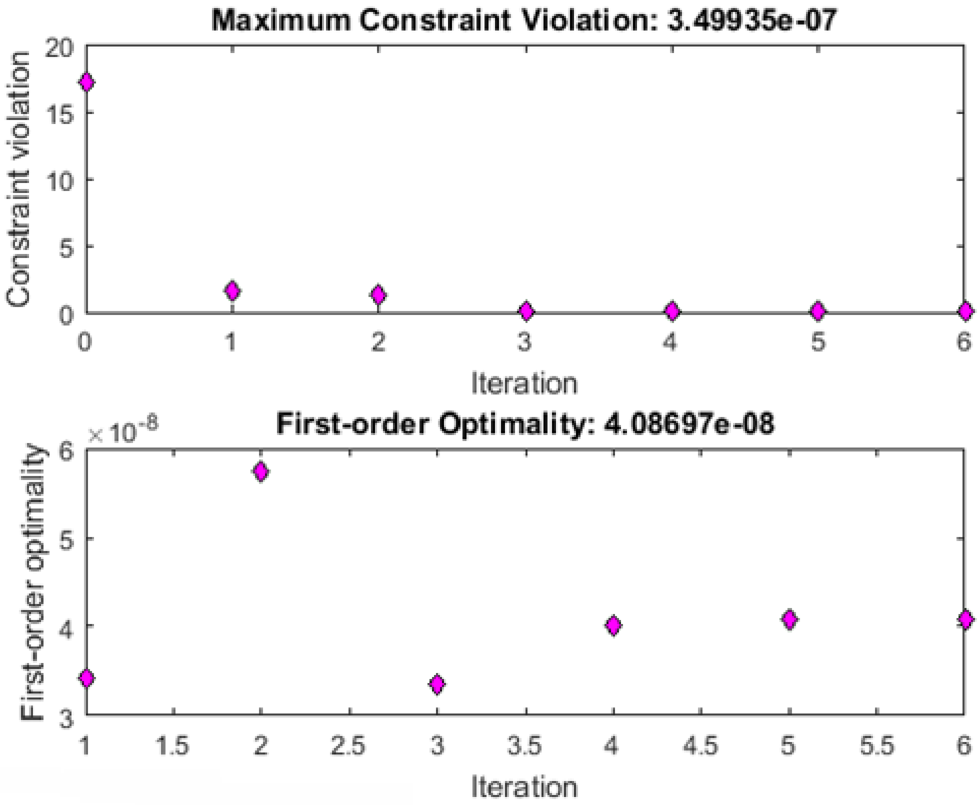

Figure 11: Iterative Processes for Numerical Simulation for the Housing Sale Market

Figure 11 shows the iterative process for the numerical simulation.

The values for the maximum constraint violation and first-order optimality are small enough to guarantee the accuracy of the solution achieved by the numerical simulation.

Figure 12 shows the result of list price strategy based on the house with average quality for the housing sale market in Tokyo (23 wards). m means the home-seller's estimated mean value for the distribution, which also indicates the confidence of the home-seller for the quality of his house. As shown in Figure 12, the home-seller will estimate the mean value for the distribution of potential buyers' reservation prices at every stage. And the confidence of the home-seller on the quality of his house decreases with the increase in the number of potential buyers visited and didn't buy the house. The home-seller will take the strategy that initially lists a higher list price and gradually reduce the list price with the decrease in the confidence on the quality of the house as well as time pass in the housing sale market.

As shown in Table 8, the home-seller in the simulation expects 9.98 million JPY extra return than just list the reservation price. The expected sale price is 33.9 million JPY, which is consistent with the actual situation. The expectation of the discount rate of the price is 0.9%, which is also consistent with actual situation. The facts that the expectation of sale price and the expectation of the discount rate are consistent with actual situation imply the model has the good simulation power for the actual situation.

The expected duration for rent with the optimal list price strategy is 1.7562 months, however, the actual time on the market is over 4 months, which indicates that the price adjustment price is much slower in the actual market than the simulation case so that there is the potential for the home-sellers to shorten the time on the market without losing the return by improving the list price strategy.

The natural vacancy rate that maximizes the landlord's expected present value of return with the optimal list price strategy is 0.73% for the rental housing market. The actual vacancy rate in the housing sale market in Tokyo (23 wards) is 2.01%. The difference in the vacancy rates between the actual situation and simulation is consistent with the difference in durations on the market between the actual situation and simulation. Hence, in the actual housing sale market in Tokyo (23 wards), the slow adjustment process for the list prices has prolonged the duration on the market, which leads to a higher vacancy rate than the natural vacancy rate that the market needs.

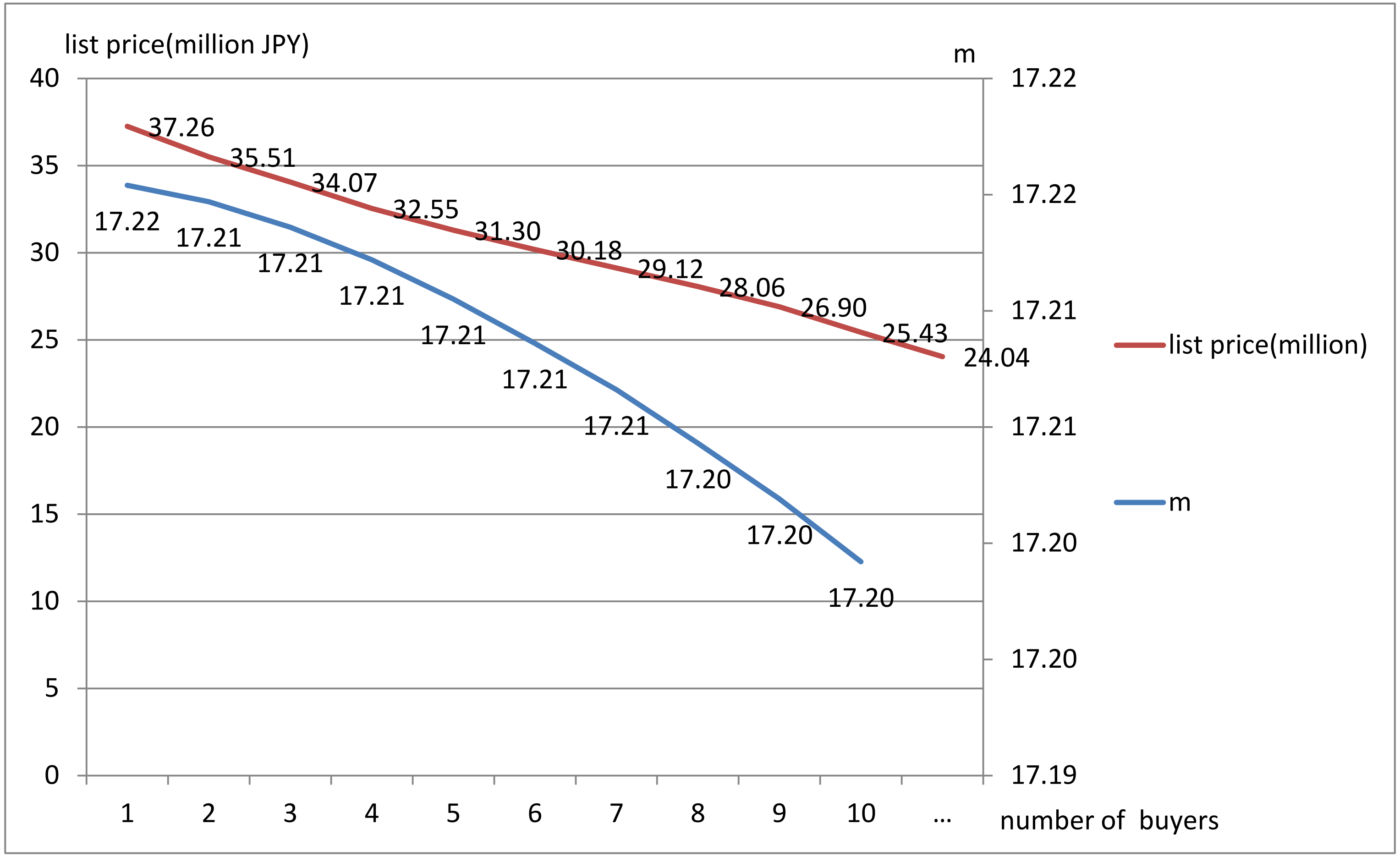

Figure 12: Result of the List Price Strategy for the Housing Sale Market

Table 8: Comparison between the Simulation Result and Actual Sale Market

	Simulation	Actual sale market	reference
Expected extra return than list reservation price (million JPY)	9.98		
sale price(million JPY)	33.89	33.85	average of sale samples from At Home Co. Ltd. 2008-2012
Price change (%)	-9.04	-9.24	average of sale samples from At Home Co. Ltd. 2008-2012
Time on the market (month)	1.7562	4.9377	expectation of sale samples from At Home co. Ltd. 2008-2012
Vacancy rate (%)	0.73	2.01	land and housing survey 2013

Source: the values for the actual sale market are calculate from At Home co. Ltd 2008-2012 and land and housing survey in 2013

3.3 Scenarios Analysis for Housing Sale Market

Scenarios with the variances in parameters will be discussed in the section to see the dynamic changes in the natural vacancy rates concerning with the changes in cost of price revision, volatility of home-buyers' reservation prices as well as home-sellers' prior knowledge. The baseline for the scenarios comparisons is the result in Section 3.2.

In all scenarios, the home-sellers expectation of the mean value for the potential home-buyers' reservation prices decreases with receiving the facts that the visited home-buyers haven't bought the house. In addition, the home-sellers intend to list a higher initial list price, and gradually reduce the price in the process of search.

Figure 13 compare the scenarios for different cost for the list price revision. According to the information on the websites of the real estate agencies, although currently there is no cost to revise the list prices, there is the fee ranging from 10,000 JPY to 30,000 JPY paid to issue the housing sale advertisements. Assume that if the home-sellers want to change the list price, they have to issue a new advertisement. With the keeping the other parameters same with the baseline simulation, two scenarios are built based on the cost of the price revisions are 10,000 JPY and 30,000 JPY.

In Figure 13, even when the cost has been increased to 30,000 JPY to revise the list price, the home-seller still intends to revise the list price for every stage, because the return of revising the list price is much larger than 30,000 JPY. The scenario for the cost is 10,000 JPY and the scenario for the cost is 30,000 JPY return the same results with the baseline case. Hence, in the housing sale market, unless the cost for the list price revision is very large, which is not possible in the reality, the cost for the list price revision hardly influences the list price strategy as well as the natural vacancy rate.

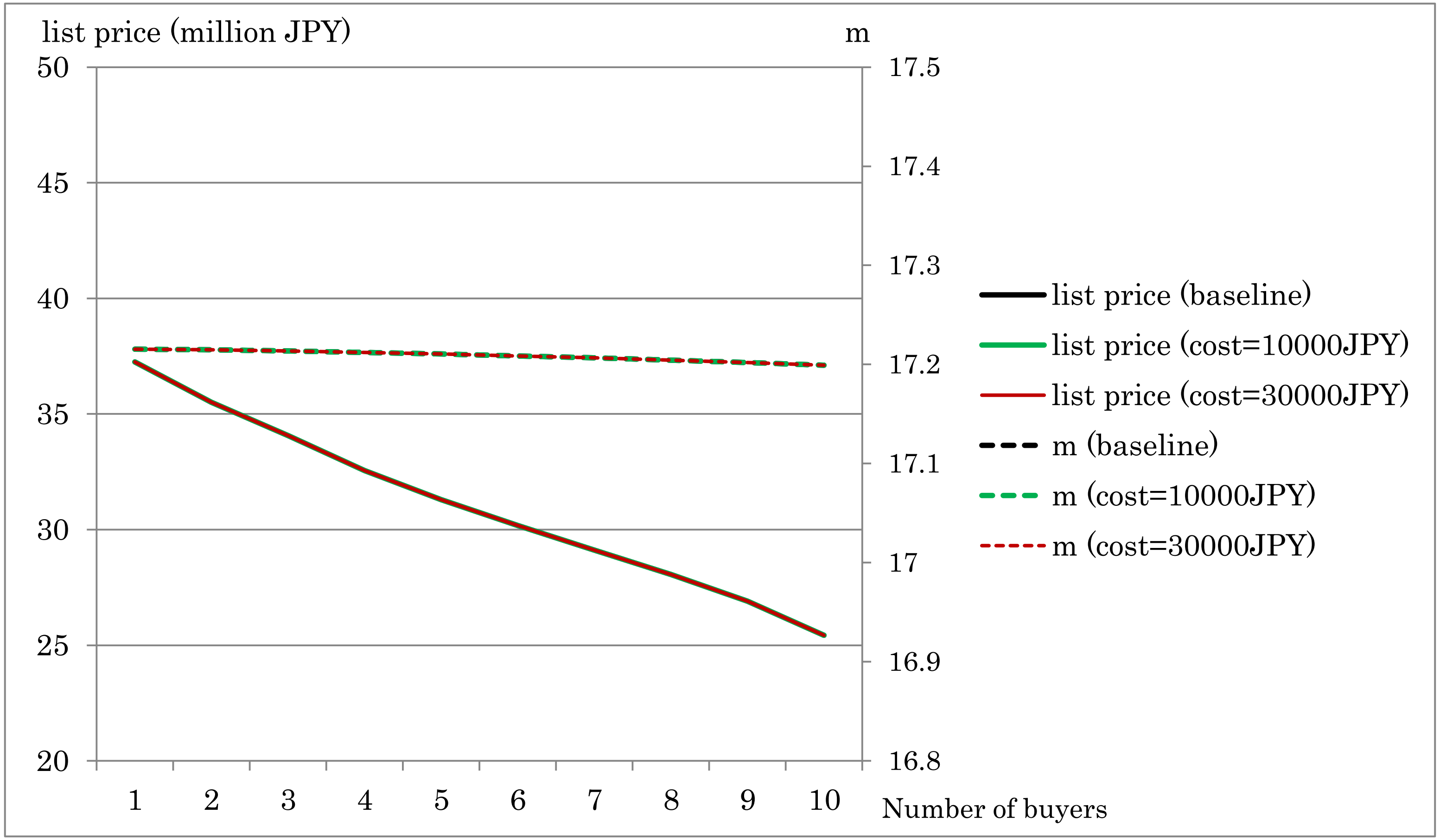

Figure 13: Scenarios for the Variances in Cost for List Price Revision in the Housing Sale Market

The scenarios for variances in the home-sellers' prior expectations are compared in Figure 14 and Table 9. Before the home-sellers issue the advertisements with the list prices, the home-sellers have the prior expectation on the qualities of their houses based on the attributives of the houses as well as the their previous experiences and knowledges of the housing sale market, which is described in details in the assumptions in Chapter 2. With the other parameters same with the baseline simulation, the scenario with the prior expectation that is one standard deviation lower than the baseline, and the scenario with the prior expectation that is one standard deviation higher than the baseline are compared here.

In the scenario with higher prior expectation on the quality of the house, the home-seller lists a higher initial list price. With receiving the facts that the potential buyers visited the house but didn't buy the house, the home-seller adjusts the initial expectation as well as the list prices. However, the higher prior expectation prolongs the process of the adjustments for the expectation as well as the list price so that the duration on the market is longer and the natural vacancy rate is bigger in the scenario with higher prior expectation.

Conversely, in the scenario with lower prior expectation, the home-seller intends to list a lower initial list price because he is not so confident with the quality of his house. Lower list price has the risk to trigger a quick sale but lose the sale price comparing to the baseline, at the same time the duration on the market will be smaller.

In the housing sale market, there are various home-sellers with various prior expectations on the qualities of their houses. However, if the average real estate price in the housing sale market is expected to increase, the home-sellers in the market have the overall higher prior expectations for their houses so that the overall time on the market is longer. Conversely, if the average real estate is expected to decline, the home-sellers in the market have the overall lower expectation for their houses so that the overall time on the market is shorter. Hence, in the housing sale market, if the average price in the housing sale market is expected to increase, the natural vacancy rate is higher. On the other hand, if the average price in the housing sale market is expected to decrease, the natural vacancy rate is lower.

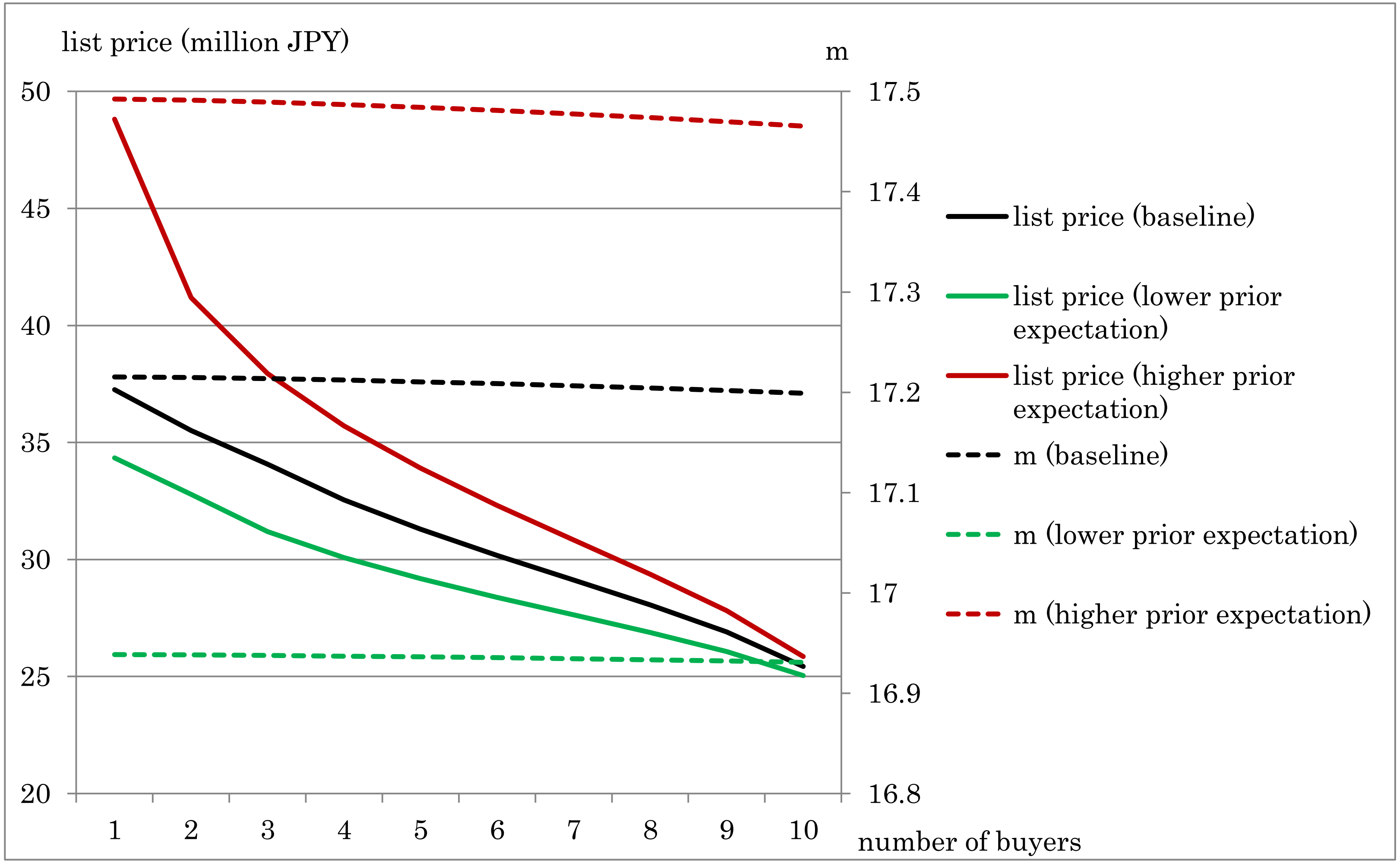

Figure 14: Scenarios for the Variances in Skewness of Home-Sellers' Prior Expectation in the Housing Sale Market

Table 9: Comparison of Scenarios for the Variances in Skewness of Home-sellers' Prior Expectation in the Housing Sale Market

	baseline	lower prior expectation	higher prior expectation
Expectation of price (million JPY)	33.8870	32.1260	35.2240
Time on the market (month)	1.7562	1.3969	2.5487
Natural vacancy rate (%)	0.7341	0.5848	1.0618

The reliability of home-sellers' prior knowledge also matters. The results for scenarios for the variances in the reliability of the home-seller' prior knowledge in the housing sale market are displayed in Figure 15 and Table 10. Before the home-sellers issue the advertisements with the list prices, the home-sellers gain the prior expectation on the qualities of their houses from several observations of the home-buyers' reservation prices, which is described in details in the assumptions in Chapter 2. The more samples the home-sellers observe before issue the advertisement, the more reliability their prior knowledge is. With the other parameters same with the baseline simulation, for the scenario for the lower reliability of prior knowledge, the home-seller observes 10 samples of home-buyers' reservation prices before he issues the advertisement, while for the scenario for the higher reliability of prior knowledge, the home-seller observes 200 samples of home-buyers' reservation prices before he issues the advertisement.

With the lower reliability of prior knowledge, the home-seller intends to adjust his mind more during the time on the market that is why the curve of m is much steeper than baseline. And the home-seller initial lists a higher price, and adjust the list price more during the time on the market with the adjustment in his expectation for the market. Lack of the reliability of prior knowledge for the market, the home-seller needs more time to learn and more time to adjust the list prices, hence the time on the market is larger.

On the other hand, if the home-seller is familiar with the housing sale market and considers his prior knowledge is reliable, he barely changes his expectation for the market, which is why the curve of m is slight more flat than the baseline. Nowadays, with the help of real estate agencies and information on the internet, the home-sellers can have the quite reliable prior knowledge, so the curve of m for baseline is also quite flat. Although with slight less adjustment in the expectation for the market for the scenario with higher reliability in the prior knowledge, the home-seller initially lists a lower price, and adjusts less in the list prices during the sale process, which leads to the shorter time on the market.

In the housing sale market, there are various home-sellers who get various information sources with different reliabilities. However, if in the housings sale market where the real estate information is less accessible, the home-sellers in the market have the overall lower reliability in the prior knowledge for the market so that the overall time on the market is longer. Conversely, if in the housings sale market where the real estate information is more accessible, the home-sellers in the market have the overall higher reliability in the prior knowledge for the market so that the overall time on the market is shorter. Hence, in the housing sale market, if in the housings sale market where the real estate information is less accessible, the natural vacancy rate is higher. On the other hand, if in the housings sale market where the real estate information is more accessible, the natural vacancy rate is lower.

Figure 15: Scenarios for the Variances in the Reliability of the Home-seller' Prior Knowledge in the Housing Sale

Market

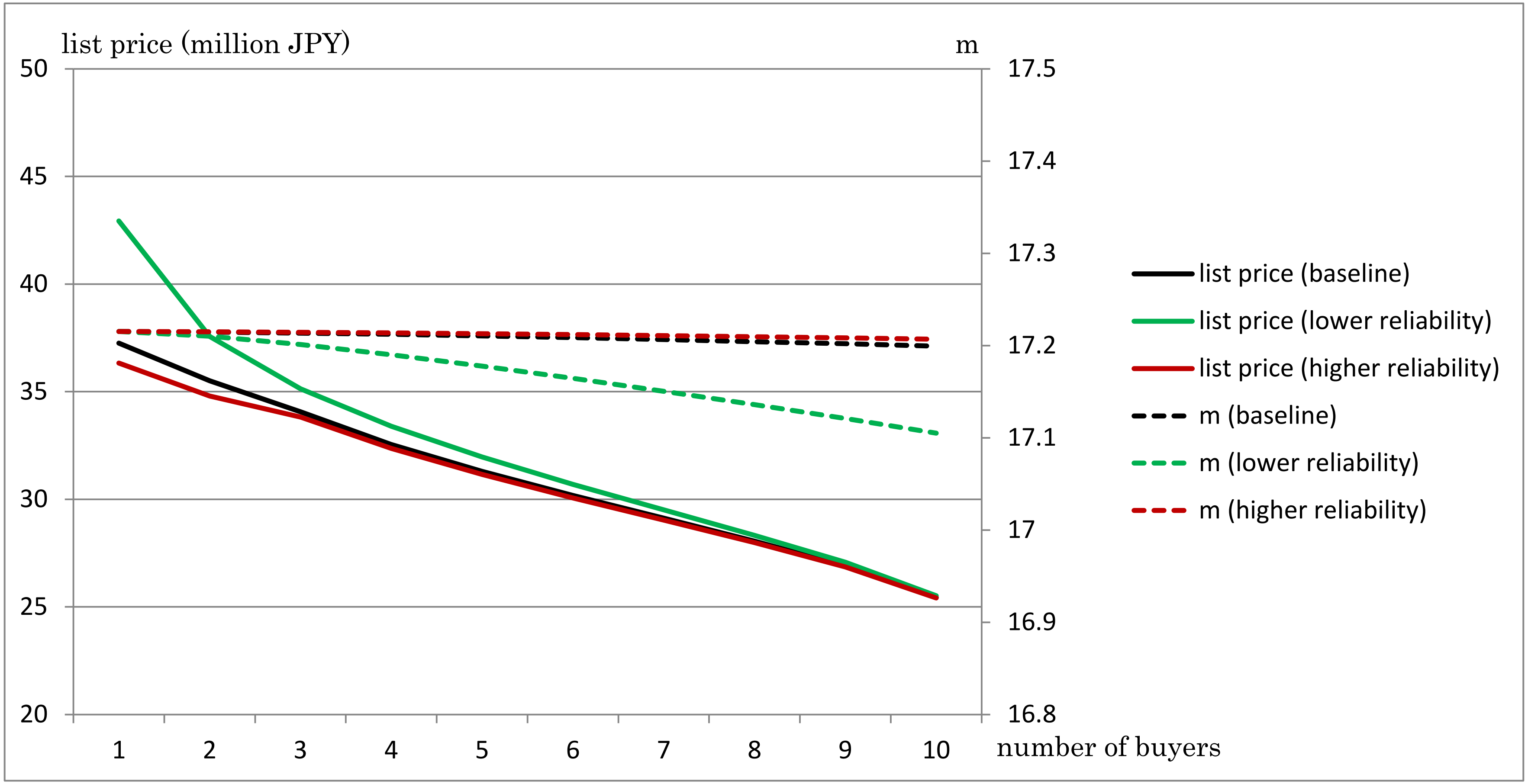

Table 10: Comparison of Scenarios for the Variances in the Reliability of the Home-seller' Prior Knowledge in the Housing Sale Market

	baseline	lower reliability	higher reliability
Expectation of price (million JPY)	33.8870	34.4910	33.6200
Time on the market (month)	1.7562	2.0895	1.6763
Natural vacancy rate (%)	0.7341	0.8722	0.7009

Figure 16 and Table 11 shows the comparison of the scenarios for the variances in volatility of home-buyers' reservation price. With the other parameters same with the baseline simulation, the scenario with double volatility is built based on the double of the standard deviation for the distribution of the potential home-buyers' reservation prices, while the scenario with half volatility is built with the half of the standard deviation for the distribution of the potential home-buyers' reservation prices.

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

On the other hand, in the scenario with half of the volatility in the market, the potential home-buyers' reservation prices will be more concentrated in a smaller range. It is easier for the home-sellers to identify the proper list rent for the market. So the adjustments among the list prices are smaller than the baseline case. For a housing sale market, if there is less volatility in the potential home-buyers' reservation price, the search time would be smaller so that the natural vacancy rate would be smaller.

Figure 16:　Scenarios for the Variances in Volatility of Home-buyers' Reservation Prices in the Housing Sale Market

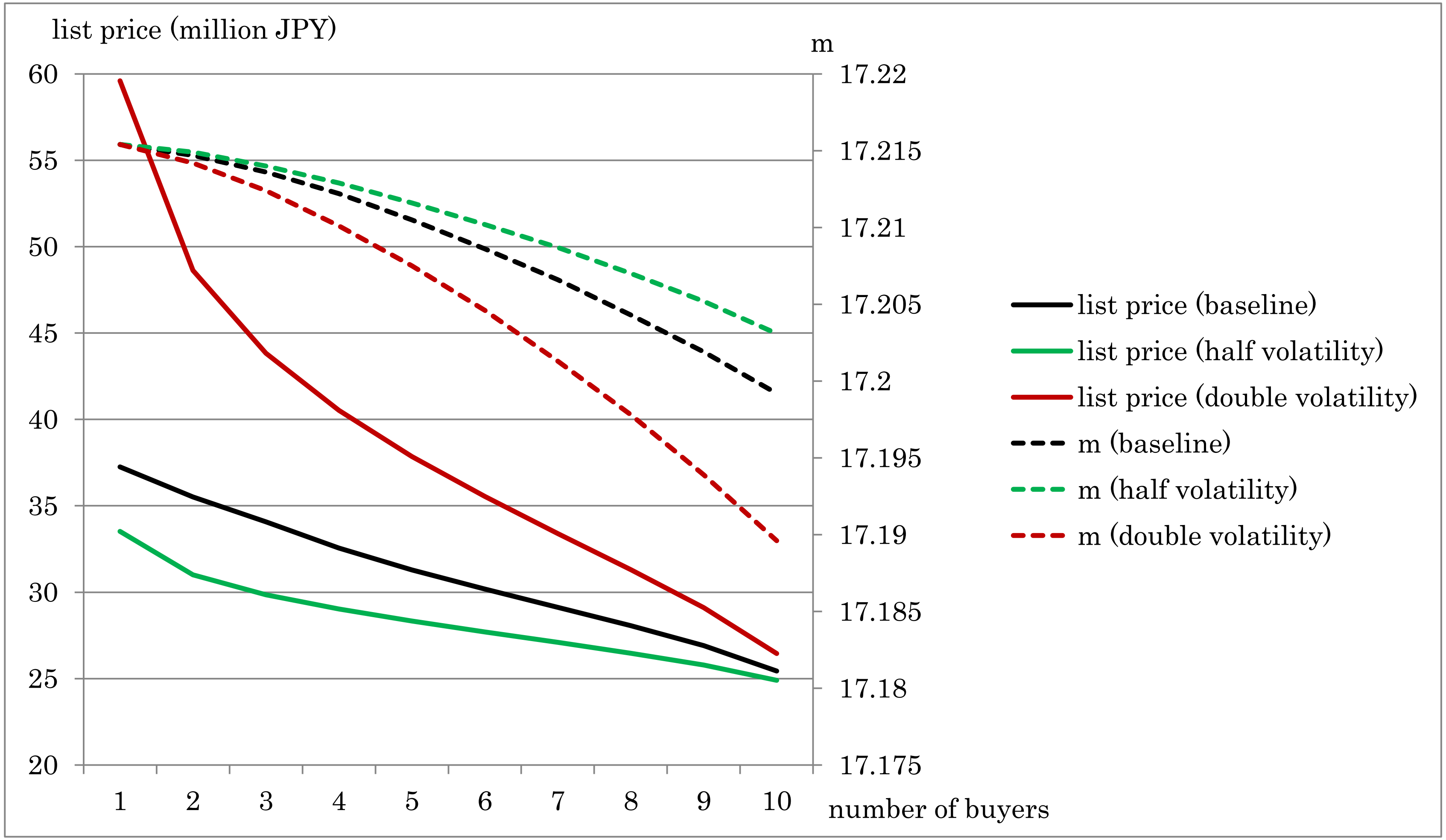

Table 11: Comparison of Scenarios for the Variances in Volatility of Home-Buyers' Reservation Prices in the Housing

Sale Market

	baseline	half volatility	double volatility
Expectation of price (million JPY)	33.8870	3.0700	42.1920
Time on the market (month)	1.7562	1.4285	2.2427
Natural vacancy rate (%)	0.7341	0.5979	0.9355

4. HOUSING RENTAL MARKET IN 23-WARDS AREA OF TOKYO

The theoretical model is applied to the housing rental market in the 23-wards area of Tokyo in the Chapter.[3]

4.1 Parameters Specification for Housing Rental Market in Tokyo (23 Wards)

4.1.1 Distributions for the Reservation Prices of the Tenants and the Landlords

Following the method used in section 3.1.1, the relationship between the market rent and reservation prices in the housing rental market can be constructed as the follows.

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

Expression 25

where p_i is the market rent; z_{ij} is the characteristics of houses as the inputs to decide the quality of the houses; β_0 is the constant; β_j is the vector of per unit prices for the j-th tract characteristic; v_i^{tenant} is standard normal distribution decided by standard deviation σ_v^{tenant} to represent the tenants'

[3] Part of the content in Chapter 4 are paraphrased from Gu, J.P., and Asami, Y. 2015. Search duration and optimal vacancy rate for rental housing market in Tokyo. Urban and Regional Planning Review, in the process of reviewing

individual preference; u_i^{tenant} is exponential distribution decided by σ_u^{tenant} to represent the difference between the log-distribution of market rent and the log-distribution of the tenants' reservation prices.

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

Expression 26

where $v_i^{landlord}$ is standard normal distribution decided by standard deviation $\sigma_v^{landlord}$ to represent the individual effects for the evaluation of the house; $u_i^{landlord}$ is exponential distribution decided by $\sigma_u^{landlord}$ to represent the difference between the log distribution of market rent and the log distribution of the landlords' reservation prices. The log-likelihood functions for Expression 25 and Expression 26 are as the follows for maximization.

lnL

$$= \sum_{i=1}^{N} \left\{ -ln\sigma_u^{tenant} + \frac{\sigma_v^{tenant^2}}{2\sigma_u^{tenant^2}} + ln\Phi\left(\frac{\beta_0 + \sum_{j=1}^{k} \beta_j \, ln\left(z_{ij}\right) - \ln(p_i) - \frac{\sigma_v^{tenant^2}}{\sigma_u^{tenant}}}{\sigma_v^{tenant}} \right) + \frac{ln(p_i) - \beta_0 - \sum_{j=1}^{k} \beta_j \, ln\left(z_{ij}\right)}{\sigma_u^{tenant}} \right\}$$

Expression 27

lnL

$$= \sum_{i=1}^{N} \left\{ -ln\sigma_u^{landlord} + \frac{\sigma_v^{landlord^2}}{2\sigma_u^{landlord^2}} + ln\Phi\left(\frac{ln(p_i) - \beta_0 - \sum_{j=1}^{k} \beta_j \, ln\left(z_{ij}\right) - \frac{\sigma_v^{landlord^2}}{\sigma_u^{landlord}}}{\sigma_v^{landlord}} \right) + \frac{\beta_0 + \sum_{j=1}^{k} \beta_j \, ln\left(z_{ij}\right) - ln(p_i)}{\sigma_u^{landlord}} \right\}$$

Expression 28

The data samples are from the advertisements for the houses for rental in Tokyo 23 wards in 2012 from At Home Co. Ltd. A sample is the house has been rented out from At Home Co. Ltd in 2012. Residential environment of the samples are attained based on the coordinates of the locations of the samples and the information of infrastructures from Ministry of Land, Infrastructure and Transport Ministry of Land Policy Bureau. A sample contains the information from several advertisements from the first advertisement until it has been rented out, and the information for the residential environment based on the location of the house.

Table 12 shows the descriptions for the variables for the estimation. Dependent variable is the natural logarithm value of deal rent in the housing rental market. Independent variables are the characteristics of the houses including the sizes of the houses as well as the residential environment of the houses to represent the quality of the houses. There are total 126,293 samples for the housing rental market in Tokyo (23 wards). The house with the average quality, which means the house with mean values for the attributives of the houses in

Table 12, will be the representative house for the housing rental market in Tokyo (23 wards) in the simulation.

The result of the estimation for the tenants' reservation price is displayed in Table 13, while the result of the estimation for the landlords' reservation price is displayed in Table 14. With the coefficients in Table 13, the mean value for the log-normal distribution of the tenants' reservation prices for the house with average quality is 11.4294, and the standard deviation for the distribution is 0.1884. With the coefficients in Table 14, the mean value for the log-normal distribution of the landlords' reservation prices is 11.2851, and the standard deviation for the distribution is 0.1610. Hence, for the house with average quality in the housing rental market in Tokyo (23 wards), the distribution of the tenants' reservation price is log-normal (11.4294, 0.1884), while the distribution of the landlords' reservation price is log-normal (11.2851, 0.1610). To transfer the mean values 11.4284 and 11.2851 for the lognormal distribution for real values for the money should be 91,894.83

JPY and 79,626.32 JPY.

Table 12: Descriptions for Variables for the Housing Rental Market

Variables	Description	Mean	Std. Dev.	Min	Max
ln(dealprice)	natural log of the deal rent	11.3873	0.4339	9.4572	14.9469
ln(areaofhouse)	natural log of the area of the house	3.3983	0.4831	0.6931	6.5709
ln(popinstation)	natural log of number of people take off at the nearest station in a day	9.7948	0.8902	6.5653	13.0544
ln(dist2nursery)	natural log of the distance to the nearest nursery	5.7538	0.5790	-0.1000	7.2379
ln(dist2station)	natural log of the distance to the nearest station	6.0007	0.6440	2.6613	7.9077
ln(dist2agedcare)	natural log of the distance to the nearest aged-care center	5.7011	0.6402	-0.4552	7.9613
ln(dist2mall)	natural log of the distance to the nearest shopping mall	7.5147	0.7802	2.3474	8.9700
ln(dist2tokyo)	natural log of the distance from the nearest station to Tokyo station	9.0137	0.5312	6.2698	9.8966

Source: 126,293 samples from At Home Ltd. 2012

Table 13: Result of the Estimation for the Distribution of Tenants' Reservation Prices

Stoc. frontier normal/exponential model						Number of obs= 126293
						Wald $\chi^2(7)$ = 496867.40
Log likelihood = 28479.801						Prob > χ^2= 0.0000
ln(dealprice)	Coef.	Std. Err.	z	P>z	[95% Conf. Interval]	
ln(areaofhouse)	0.7628	0.0012	663.0500	0.0000	0.7605	0.7650
ln(popinstation)	0.0277	0.0006	43.8900	0.0000	0.0265	0.0290
ln(dist2nursery)	-0.0078	0.0009	-8.1700	0.0000	-0.0096	-0.0059
ln(dist2station)	-0.0590	0.0009	-66.4500	0.0000	-0.0607	-0.0572
ln(dist2agedcare)	-0.0155	0.0009	-18.1300	0.0000	-0.0172	-0.0139
ln(dist2mall)	-0.0769	0.0008	-95.7100	0.0000	-0.0784	-0.0753
ln(dist2tokyo)	-0.0981	0.0012	-82.1900	0.0000	-0.1005	-0.0958
_cons	10.5148	0.0141	744.7400	0.0000	10.4871	10.5424
$\ln(\sigma_v^2)$	-3.3387	0.0071	-471.5200	0.0000	-3.3526	-3.3249
$ln(\sigma_u^2)$	-6.3315	0.1165	-54.3600	0.0000	-6.5598	-6.1032
σ_v	0.1884	0.0007			0.1871	0.1897
σ_u	0.0422	0.0025			0.0376	0.0473
$\sigma_v^2 + \sigma_u^2$	0.0373	0.0001			0.0370	0.0376
Likelihood-ratio test of σ_u=0: $\bar{\chi}^2(01)$ = 31.64 Prob>=$\bar{\chi}^2$= 0.0000						

Table 14: Result of the Estimation for the Distribution of the Landlords' Reservation Prices

Stoc. frontier normal/exponential model					Number of obs = 126293	
					Wald $\chi^2(7)$ = 389909.84	
Log likelihood = 30732.98					Prob > χ^2 =0.0000	
ln(dealprice)	Coef.	Std. Err.	z	P>z	[95% Conf. Interval]	
ln(areaofhouse)	0.7326	0.0012	594.6500	0.0000	0.7302	0.7350
ln(popinstation)	0.0272	0.0006	44.1000	0.0000	0.0260	0.0284
ln(dist2nursery)	-0.0077	0.0009	-8.3800	0.0000	-0.0095	-0.0059
ln(dist2station)	-0.0591	0.0008	-70.0900	0.0000	-0.0607	-0.0574
ln(dist2agedcare)	-0.0161	0.0008	-19.5300	0.0000	-0.0177	-0.0145
ln(dist2mall)	-0.0732	0.0008	-96.1600	0.0000	-0.0747	-0.0717
ln(dist2tokyo)	-0.0931	0.0011	-81.6700	0.0000	-0.0954	-0.0909
_cons	10.4088	0.0133	781.0100	0.0000	10.3827	10.4349
$\ln(\sigma_v^2)$	-3.6523	0.0068	-539.8400	0.0000	-3.6655	-3.6390
$ln(\sigma_u^2)$	-4.5614	0.0183	-248.5900	0.0000	-4.5973	-4.5254
σ_v	0.1610	0.0005			0.1600	0.1621
σ_u	0.1022	0.0009			0.1004	0.1041
$\sigma_v^2 + \sigma_u^2$	0.0364	0.0002			0.0361	0.0367
Likelihood-ratio test of σ_u=0: $\bar{\chi}^2(01)$ = 4.5e+03 Prob>=$\bar{\chi}^2$= 0.0000						

4.1.2 Duration of Residence for the Tenant-occupied Houses

Similar to section 3.1.2, the duration of residence for the tenant-occupied houses are based on the information from land and housing survey. The samples are the cumulative probabilities for the duration of residence for the tenant-0ccupied houses as shown in Table 15.

Table 15: Samples for the Residence Duration for Tenant-occupied Houses

	cumulative frequency	cumulative probability
under 1year	330,000	0.0697
under 2 years	891,000	0.1883
under 3 years	1,718,500	0.3632
under 4 years	2,334,200	0.4933
under 5 years	2,772,300	0.5859
under 10 years	3,854,800	0.8146
under 15 years	4,297,400	0.9082
under 20 years	4,466,400	0.9439
total	4,731,900	1.0000

Source: Land and Housing Survey 1998

Cumulative function for Weibull distribution as shown in Expression 21 is used to fit the samples by Gauss–Newton method. The result of fitting is shown as Figure 17. In the estimation, R^2 is 0.9967, the cumulative function for the Weibull distribution is $1 - e^{-(\frac{x}{6.1066})^{1.1645}}$. Figure 18 shows the probability density distribution of the Weibull distribution. With the probability density function, the expectation of the residence duration for the tenants-occupied houses is 5.7823 years.

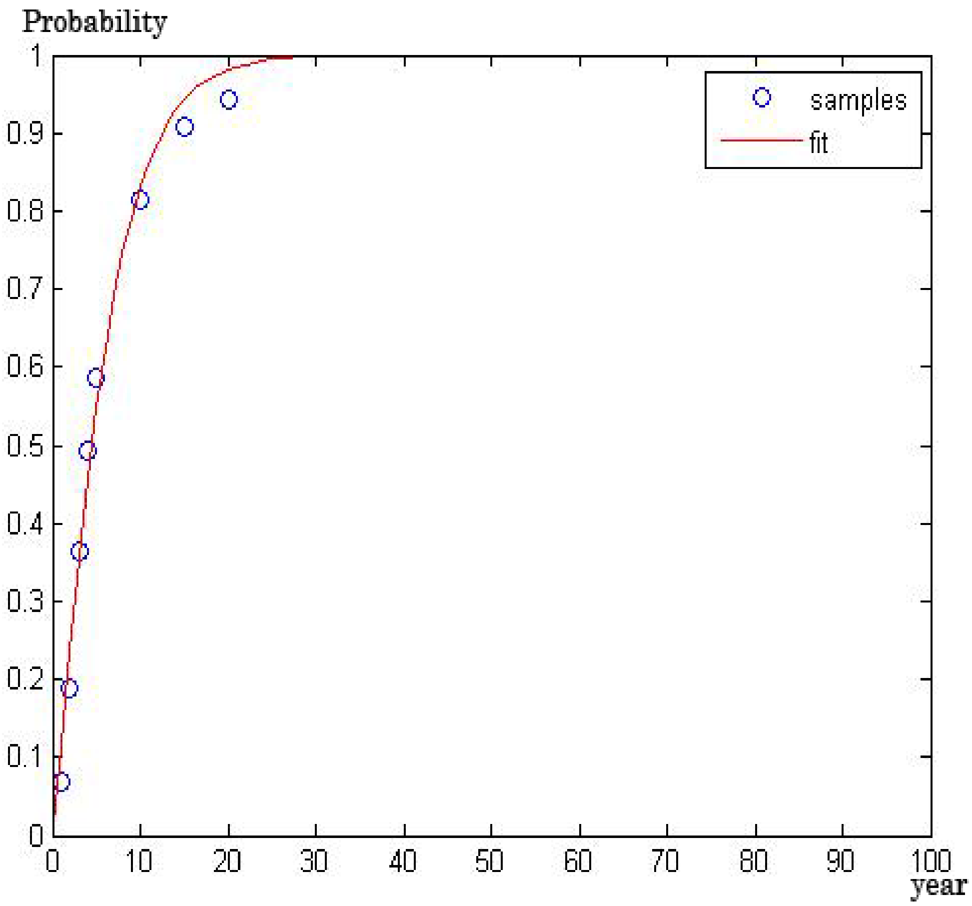

Figure 17: Cumulative Probability of Weibull Distribution for Housing Rental Market

Source: samples are from land and housing survey 1998

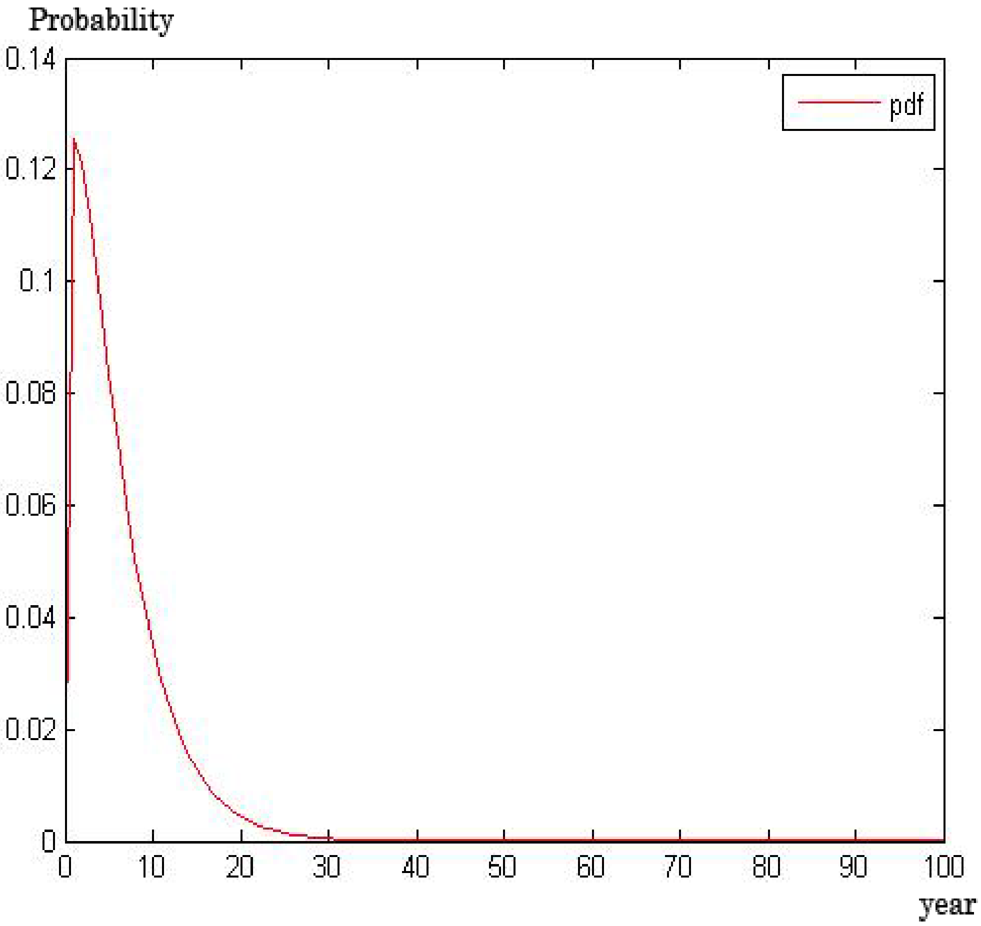

Figure 18: Probability Density for Weibull Distribution for Housing Rental Market

4.1.3 Tenants' search and time discount rate

For the search of the potential tenants, the information is based on the survey on the users for the websites of real estate agencies in 2014 (RSC, 2014) shown in Figure 19 and Figure 20. From Figure 19, the tenants will averagely visit 4.7 houses before rent a house. From Figure 20, the tenants will averagely spend 1.3198 months for the search process before rent a house. Hence, averagely the interval duration for one potential tenant to visit a house is about 8 days.

For the maximum number of the potential tenants, the number should be big enough. Assume the maximum number of the potential tenants is 10, because in the simulation, after the visits from 10 potential tenants, the probability of remain unrented is less than 1%.

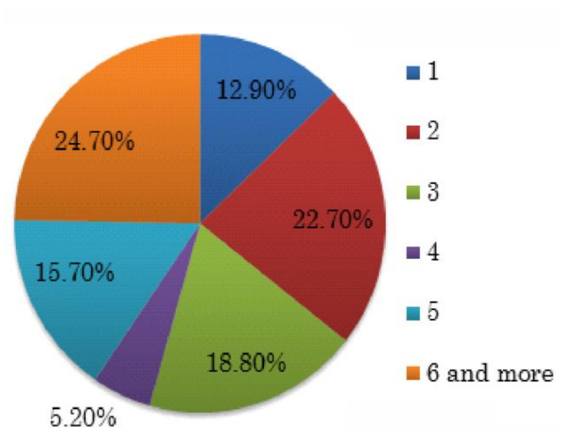

Figure 19: Number of Houses Visited Before Tenants Rent a House

Source: RCS 2014

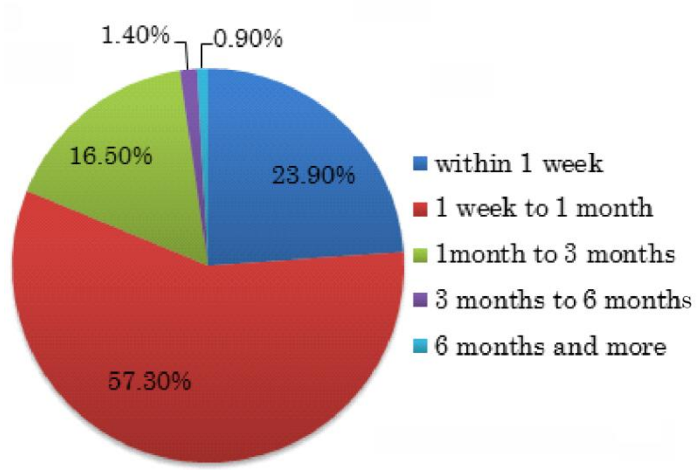

Figure 20: Duration of Search of the Tenants

Source: RCS 2014

The savings interest rate will be used for the time discount rate for the simulation. The average saving interest rate per year in Kanto area is 0.025% (Yahoo Finance, 2015). Since there is only 8 days for the time discount between every stage, the time discount rate is almost 0, the time discount factor is 1 in this case.

4.1.4 Landlords' prior knowledge calibration and model validation

Since there is no direct information on the landlords' prior knowledge, the information of the list rent in actual housing rental market in Tokyo (23 wards) is used to calibrate the parameters for the landlords prior knowledge. Figure 21 shows the actual list rent discounts in the housing rental market. The expectation of the list rental price discount is -7.51% in the actual housing rental market in Tokyo (23 wards).

Since the landlords may consult the real estate agencies for the information of the market before they issue their advertisements for rent, they may acquire relatively accurate information on the reservation rents of the potential tenants. So assume that the average value of the landlords' observations equals to the mean value for the distribution of the tenants' reservation prices, which means $\frac{\sum_{j=1}^{k} x_j}{k}$=11.4294. But the landlords are not certain about the value.

For the number of the observations before listing the rent (k), simulation experiments made with different values are shown in Figure 22. The value for k bigger, the discount rates are larger. Table 16 shows expectations of the list price discount rates with various values for k. When k=100, the expectation of the discount rate is -7.87%, which is very close to the expectation of the actual list rent discounts in the housing rental market in Tokyo (23 wards). Hence, the landlord observes 100 samples of the reservation prices of the tenants before he lists the rent on the advertisement in the housing rental market in 23 wards area of Tokyo.

Table 17 shows the summary of the parameters specified for the housing rental market in Tokyo 23 wards. The parameters will used for the simulation of the theoretical model described in Chapter 2 to achieve the results in the following section.

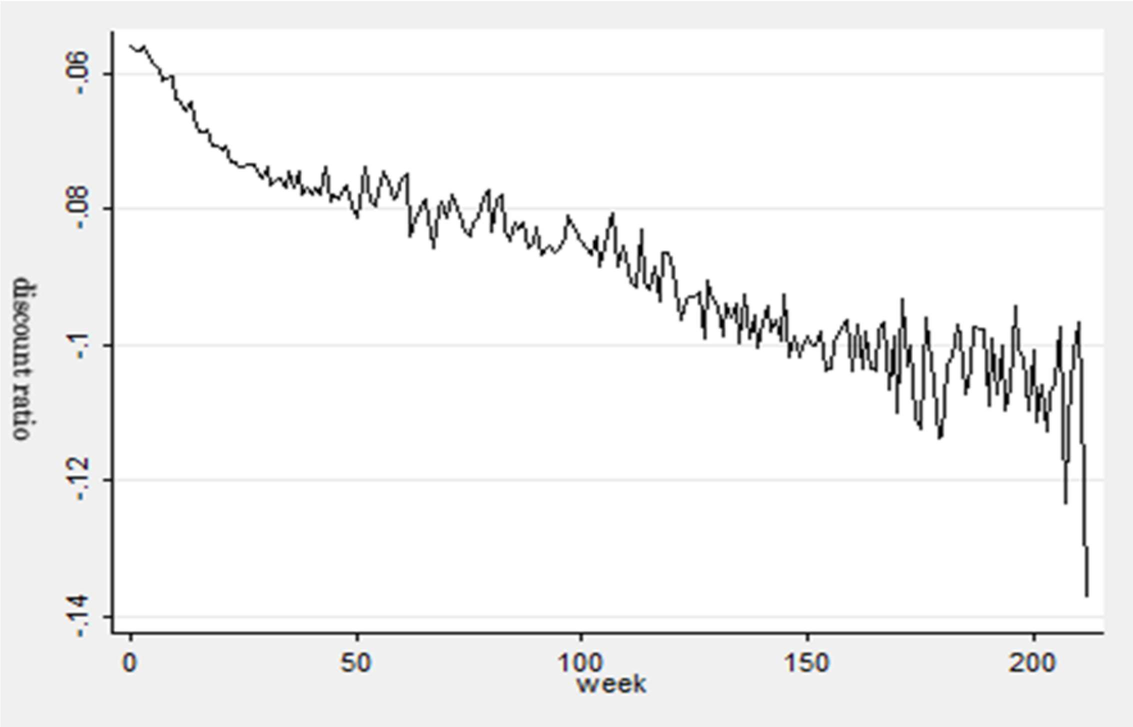

Figure 21: List Rent Discount in Actual Housing Rental Market in Tokyo

Source: Rental samples from At Home Co. Ltd. 2012

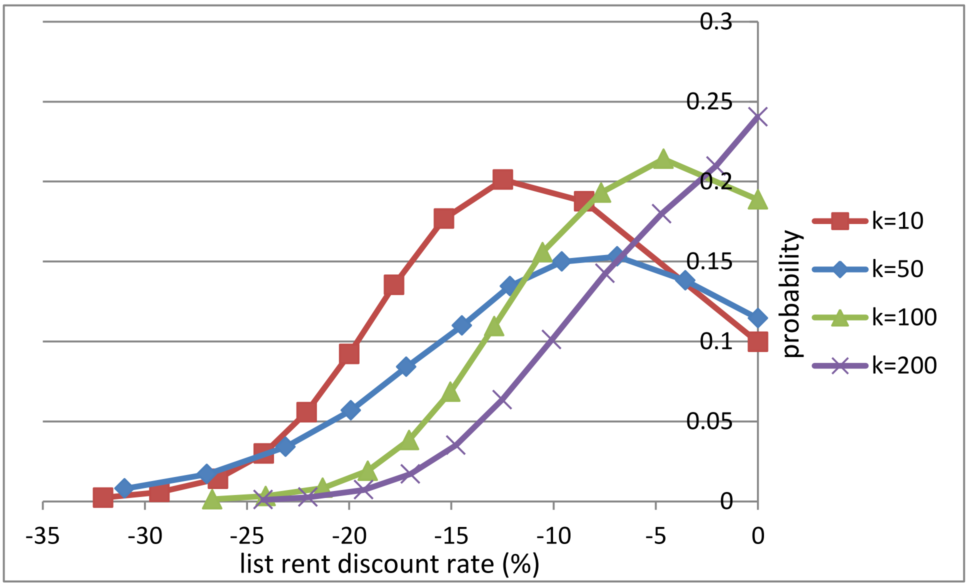

Figure 22: Experiments for Number of the Observations before List Rent for Housing Rental Market

Table 16: Expectation of the List Rent Discount Rate for Housing Rental Market

Value of k	10	50	100	200
Expectation of list price discount rate (%)	-13.63	-10.27	-7.87	-4.50

Table 17: Summary of the Parameters for the Housing Rental Market

Parameters	Values	references
σ	0.1884	Estimation
m^*	11.4294	Estimation
t_0	8.4 days	RCS 2014
r	11.2851	Estimation
c	0	Websites of real estate agencies
N	10	Assumption
δ	1	Yahoo Finance
k	100	Model calibration
$\frac{\sum_{j=1}^{k} x_j}{k}$	11.4294	Assumption
Duration of residence	5.7823 years	Estimation

4.2 Result for List Price Strategy and Natural Vacancy Rate in the Housing Rental Market

With the parameters specified for the housing rental market in Tokyo (23 wards) in Table 17, numerical simulation of the theoretical model described in Chapter 2 have been made to achieve the result for the list price strategy and natural vacancy rate for the housing rental market in Tokyo.

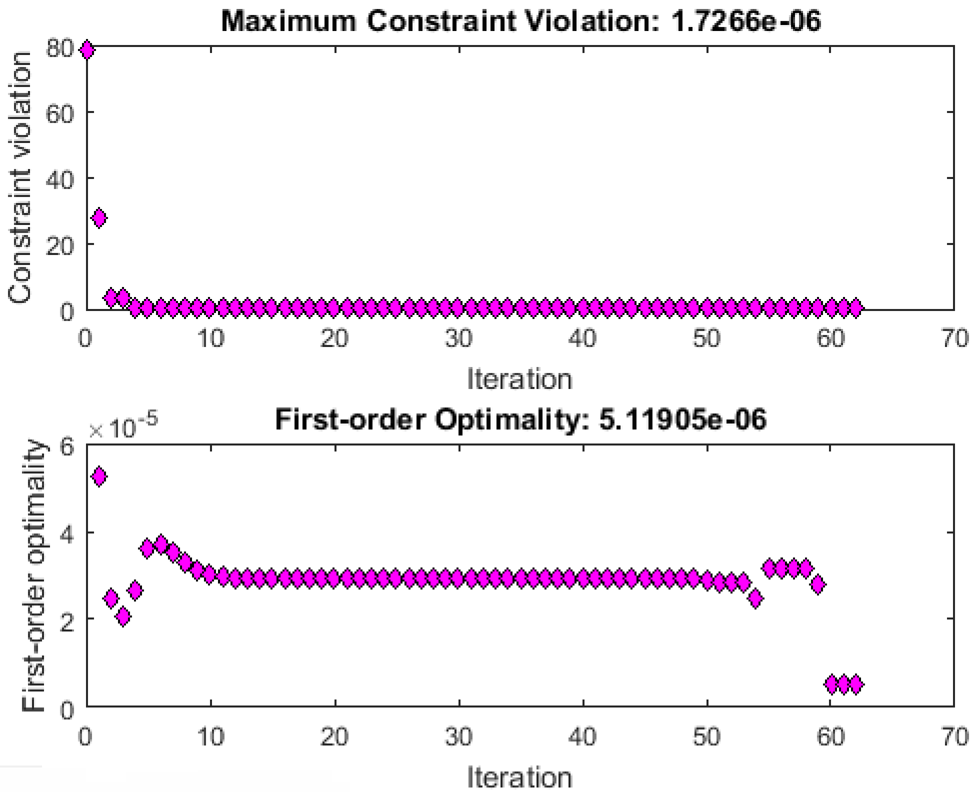

Figure 23: Iterative Processes for Numerical Simulation for the Housing Rental Market

Figure 23 shows the iterative processes for numerical simulation, the tolerance values for the maximum constraint violation and first-order optimality are small enough to guarantee the accuracy of the solution achieved by the numerical simulation.

Figure 24 shows the result of the list price strategy for the housing rental market in Tokyo. The landlord' expectation on the quality of the house decreases as receiving the fact that potential tenants visited but didn't rent the house. The landlord takes 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.

As shown in Table 18, the simulation result indicates that the landlord can receive 5,467 JPY more than he directly lists his reservation price during the search process. The expected rental price is 100,800 JPY, which is slightly higher but close to the average rental price in the actual market. During the process for search, the landlord is expected to discount about -7.87% of the initial list price, which is also consistent with the actual situation. The fact that the expectation of the rental price and the range of the list rent discount is close to the actual situation indicates that the model has the good simulation power for the actual housing rental market in Tokyo (23 wards).

The expected duration for searching the tenants with the optimal list rent strategy is 0.9327months, while in the actual rental market, while the expectation of duration on the market is 1.6942 months. There is potential for the landlord to shorten the time on the market while increase the return of rent by improving the list price strategy.

For the vacancy rate, the natural vacancy rate is 1.33% for the rental housing market, while in actual rental market the vacancy rate is 15.7%. There is a big difference between the natural vacancy rate and the actual vacancy rate in the housing rental market. Since the difference in the duration for search is not so large as the difference in vacancy rate, which implies that in the housing rental market in Tokyo, large part of the housing 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 chapter of introduction.

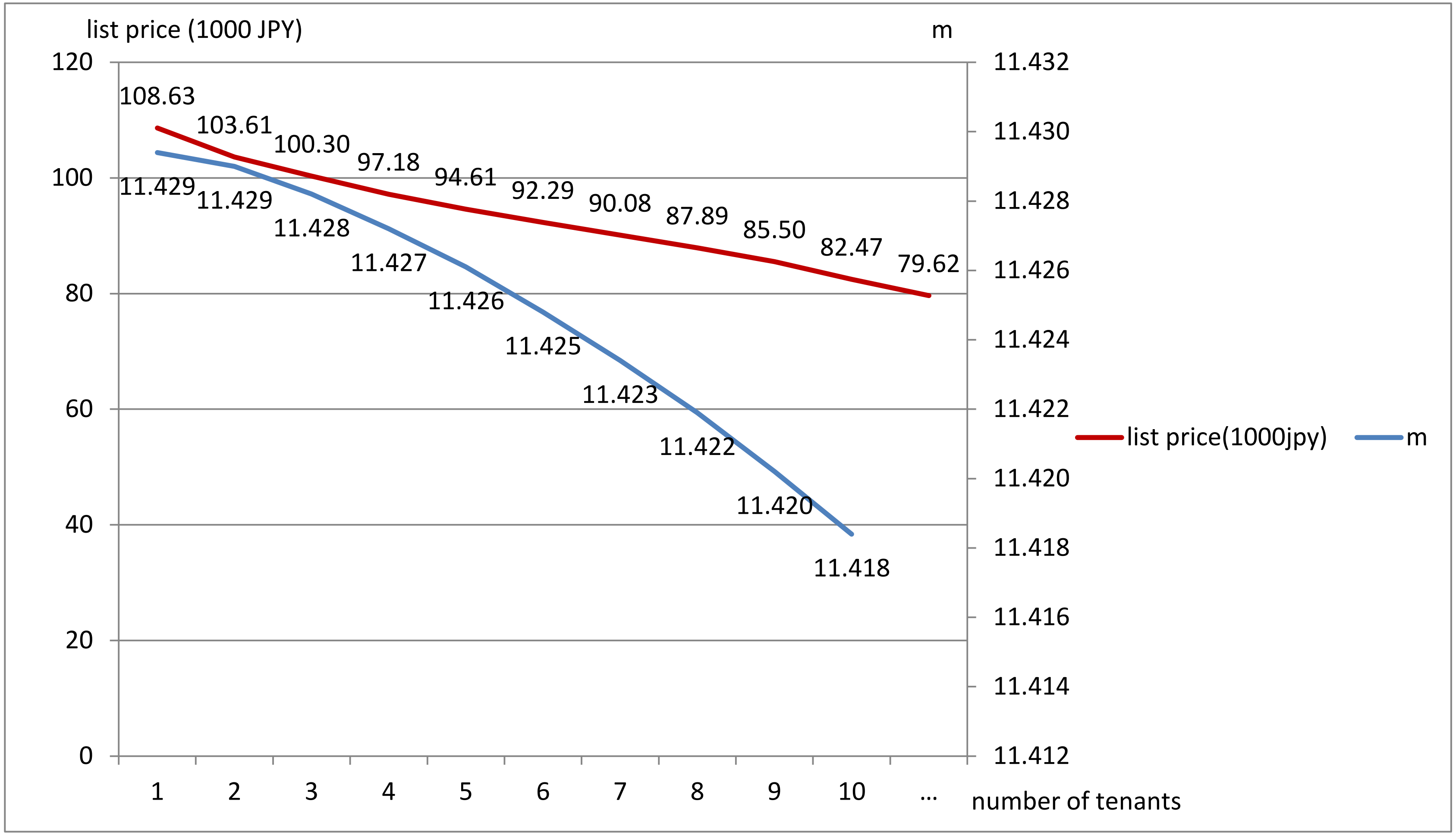

Figure 24: Result of the List Price Strategy for the Housing Rental Market

Table 18: Comparison between the Situation Result and Actual Rental Market

	Simulation	Actual market situation	reference
Expected extra return than list reservation price (1000JPY)	5.467		
rent (1000JPY)	100.800	99.044	average of rental samples from At Home co. Ltd. in 2012
Rent change (%)	-7.87	-7.51	Expectation of rental samples from At Home co. Ltd in 2012
Time on the market (months)	0.9327	1.6942	Expectation of rental samples from At Home co. Ltd in 2012
Vacancy rate (%)	1.3264	15.7	land and housing survey 2013

Source: the values for the actual rental market are calculate from At Home co. Ltd 2008-2012 and land and housing survey in 2013

4.3 Scenarios Analysis for Housing Rental Market

Scenarios with the variances in parameters will be discussed in the section to identify the dynamic variances in natural vacancy rate according to the changes in the cost of price, volatility of tenants' reservation price as well as landlords' prior knowledge.

Figure 25 and Table 19 compare the scenarios for different cost for the list rent revision.

According to the information on the websites of the real estate agencies, although currently there is no cost to revise the list rents, if the landlords want to issue the advertisement for rent, the average price is 10,000JPY. Assume that if the landlords want to revise the list rent, they need to issue a new advertisement. With the keeping the other parameters same with the baseline simulation, two scenarios are built based on the cost of the list rent revisions are 1,000 JPY and 10,000 JPY.

In Figure 25, 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 out 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 out 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.

In the scenarios, the landlords identify the best frequency for the list-rent revisions, best timings to revise the list rents, as well as the best sequence of values for the list rents. With the increase in the cost for the list-rent revisions, the landlord reduces the frequency for the list-rent revisions. With the consideration of higher cost for the list-rent revisions, there will be fewer chances to adjust the list rents so that the landlord intends to list a lower initial list rent. With the lower initial list rent, the landlord' expected return decreases because the landlord loses the opportunities to rent the house at higher rents. However, with the lower initial list rent, the duration on the market is smaller. Hence, in the housing rental market, with the higher cost for the list-rent revisions, the natural vacancy rate is smaller.

Figure 25: Scenarios for the Variances in Cost of Rent Revision in the Housing Rental Market

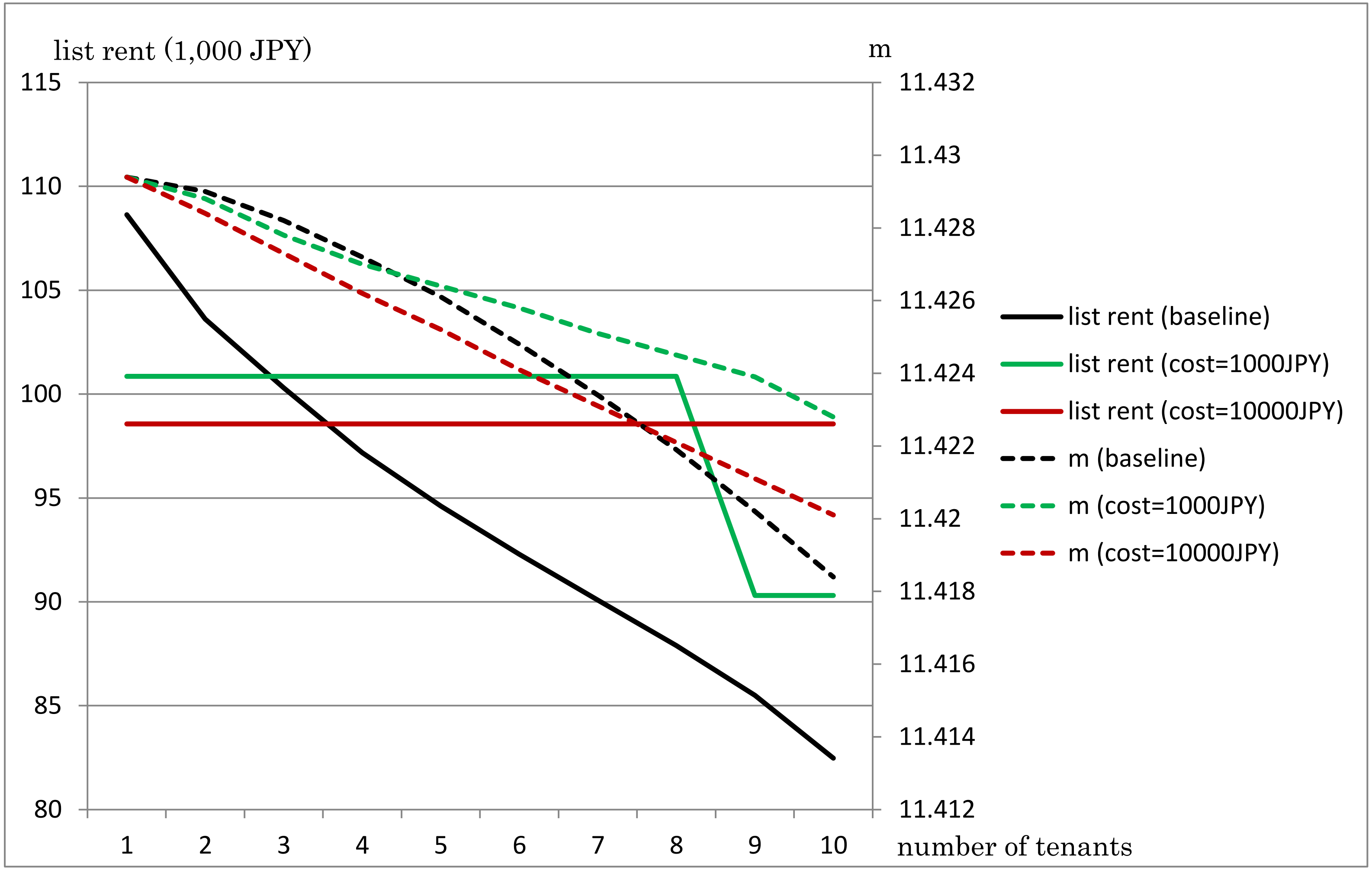

Table 19: Comparison of Scenarios for the Variances in Cost of Rent Revision in the Housing Rental Market

	baseline	cost=1,000JPY	cost=10,000JPY
Expectation of rental price (1,000 JPY)	100.8000	100.2200	98.3300
Time on the market (Month)	0.9327	0.8779	0.7811
Natural vacancy rate (%)	1.3264	1.2494	1.1131

Figure 26 and Table 20 compare the scenario for different landlords' prior expectations on the market. With the other parameters same with the baseline simulation, for the scenario with higher prior expectation, there is one standard deviation increase in the prior expectation of baseline, while for the scenario with lower prior expectation, there is one standard deviation decrease in the prior expectation of baseline.

The pattern is similar to the scenario in the housings sale market. In the scenario with higher prior expectation on the quality of the house, the adjustment process is prolonged than the baseline due to the higher prior expectation. 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 natural 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. For the housing rental market, where the rent is expected to decrease, there will be a lower natural vacancy rate.

Figure 26: Scenarios for the Variances in Landlords' Prior Expectation in the Housing Rental Market

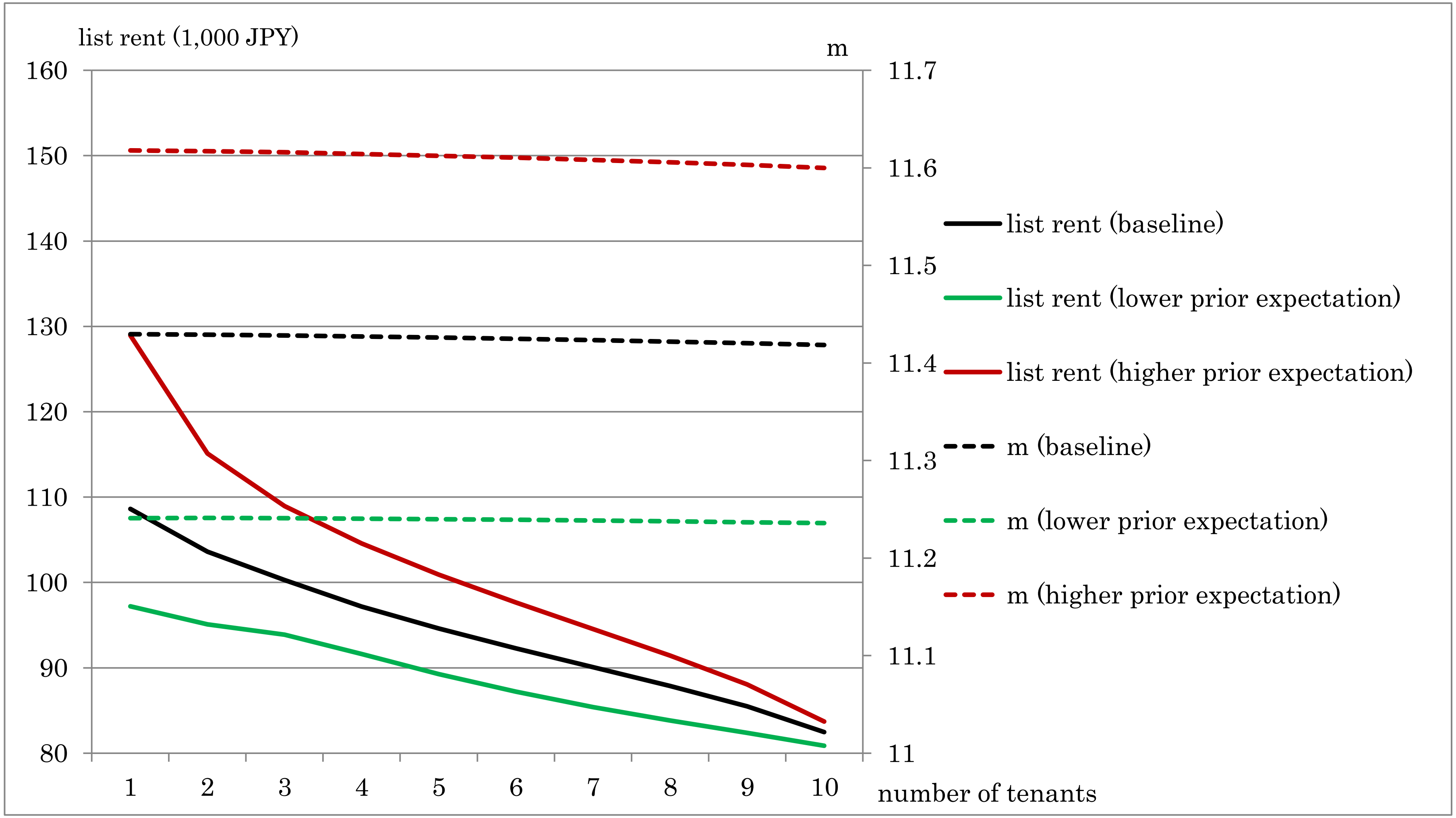

Table 20: Comparison of Scenarios for the Variances in Landlords' Prior Expectation in the Housing Rental Market

	baseline	half volatility	double volatility
Expectation of rental price (1,000 JPY)	100.8000	94.7040	102.8300
Time on the market (Month)	0.9327	0.6497	1.3573
Natural vacancy rate (%)	1.3264	0.9277	1.9186

The results for scenarios for the variances in the reliability of the landlord' prior knowledge in the housing rental market are displayed in Figure 27 and Table 21. Similar to the scenarios analysis for the housing sale market, with the other parameters same with the baseline simulation, for the scenario for the lower reliability of prior knowledge, the landlord observes 10 samples of tenants' reservation prices before he issues the advertisement, while for the scenario for the higher reliability of prior knowledge, the landlord observes 200 samples of tenants' reservation prices before he issues the advertisement.

With the lower reliability of prior knowledge, the landlord intends to adjust his mind more during the time on the market. The landlord initial lists a higher price, and adjust the list price more during the time on the market with the adjustment in his expectation for the market. Due to lack of the reliability of prior knowledge for the market, the landlord needs more time to learn and more time to adjust the list rents, hence the time on the market is larger.

On the other hand, if the landlord considers his prior knowledge is reliable, he barely changes his expectation for the market. With less adjustment in the expectation for the market in the scenario with higher reliability in the prior knowledge, the landlord initially lists a lower rent, and adjusts less in the list rents during the rental process, which leads to the shorter time on the market.

Hence, in the housing sale market, if in the housings sale market where the real estate information is less accessible, the natural vacancy rate is higher. On the other hand, if in the housings sale market where the real estate information is more accessible, the natural vacancy rate is lower.

Figure 27: Scenarios for the Variances in Reliability of the Landlord' Prior Knowledge in the Housing Rental Market

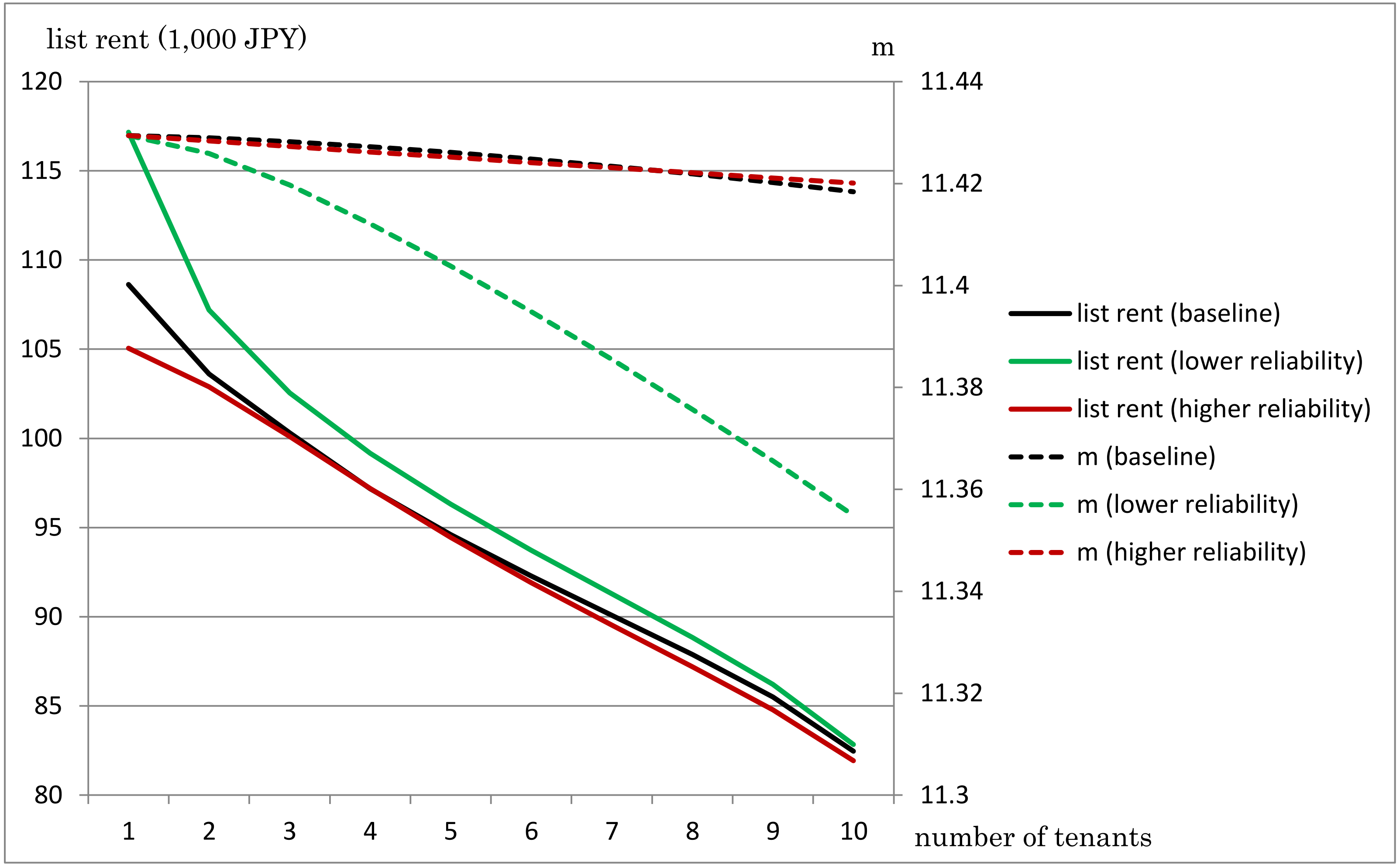

Table 21: Comparison of Scenarios for the Variances in Reliability of the Landlord' Prior Knowledge in the Housing Rental Market

	baseline	lower reliability	higher reliability
Expectation of rental price (1,000 JPY)	100.8000	101.1900	99.6020
Time on the market (Month)	0.9327	1.0821	0.8817
Natural vacancy rate (%)	1.3264	1.5355	1.2548

Figure 28 and Table 22 show the comparison of the scenarios for the variances in volatility of tenants' reservation price. With the other parameters same with the baseline simulation, for the scenario with double volatility, the standard deviation for the distribution of the tenants' reservation rent is doubled, while for scenario with half volatility, half value of the standard deviation is used for the simulation.

The pattern of change is similar to the pattern found in the housing sale market. In the scenario with double volatility, 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 natural vacancy rate.

On the other hand, in the scenario with half of the volatility in the market, the adjustments among the list rents are smaller than the baseline case because it is easier for the landlord the find the proper price to list. For a housing rental market, if there is less heterogeneity in tenants' preferences, the natural vacancy rate would be smaller.

Figure 28: Scenarios for the Variances in Volatility of Tenants' Reservation Prices in the Housing Rental Market

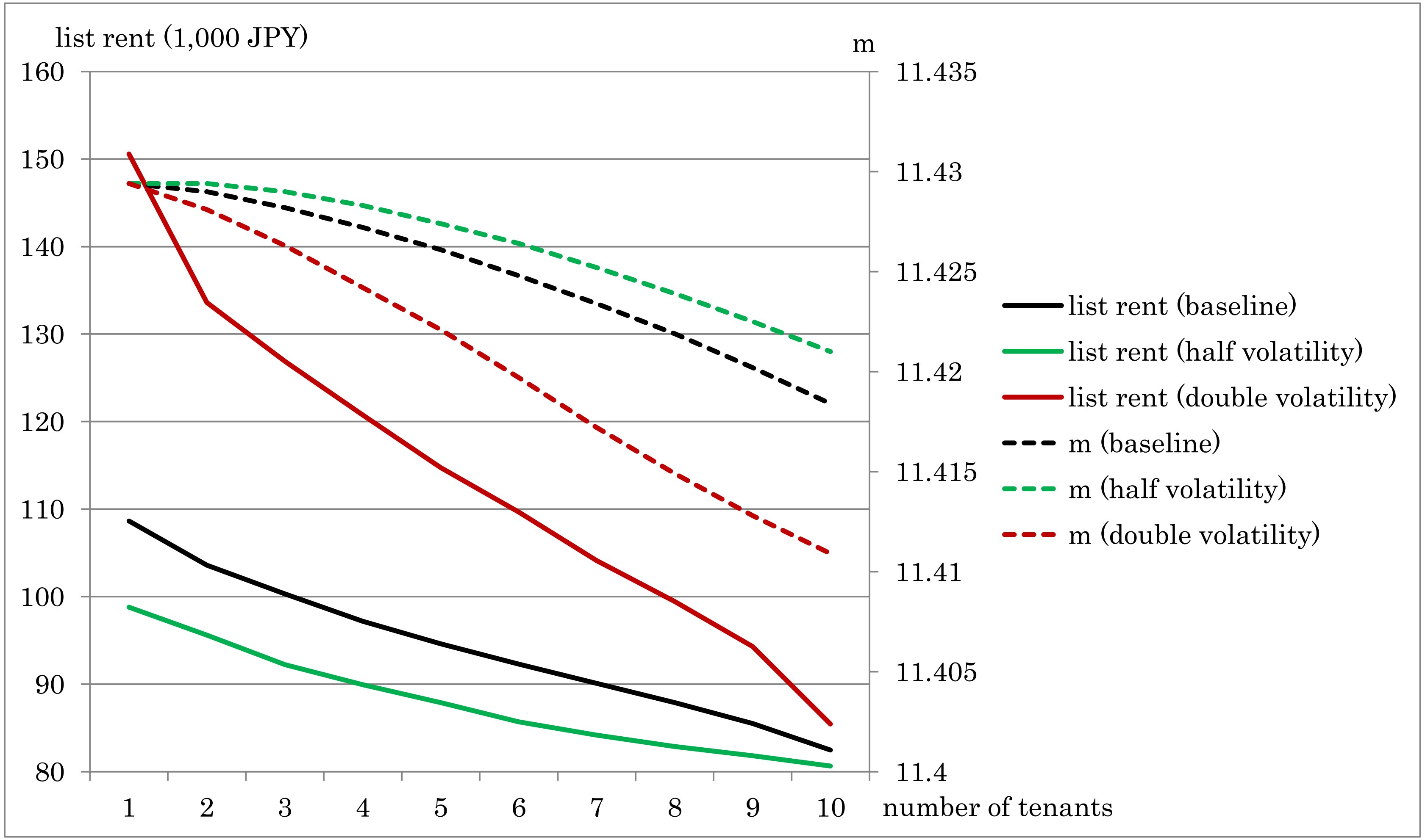

Table 22: Comparison of Scenarios for the Variances in Volatility of Tenants' Reservation Prices in the Housing Rental Market

	baseline	half volatility	double volatility
Expectation of rental price (1,000 JPY)	100.8000	93.6980	119.0100
Time on the market (Month)	0.9327	0.7573	1.2930
Natural vacancy rate (%)	1.3264	1.0796	1.8293

5. DISCUSSION

In the theoretical model, the landlords/home-sellers' expectation of the mean value for the potential tenants/home-buyers' reservation prices decreases with receiving the facts that the visited tenants/home-buyers haven't rented/bought the house. The reductions in the estimated mean vary to the when the information comes and what list price the information towards to. The landlords/home-sellers will initially list a high price, with the decrease in landlords/the home-sellers' confidence as the time pass on the market, the landlords/home-sellers will gradually reduce the list price. In addition, the home-sellers will identify the best frequency for the list price revision, best timings to revise the list prices, as well as the best sequence of values for the list prices.

In the housing sale market in Tokyo, with the same sale return, it is wasteful to prolong the duration for search and cause a higher vacancy rate. Base on the natural vacancy rate, the housing sale market in Tokyo only needs 14984 vacant houses for sale, however currently there are 40700 vacant houses for sale on the market. If consider the opportunity cost, which is calculated by implicit rent multiplies the time on the market, for those excessive house in housing sale market in Tokyo (23 wards), there would be a social cost which is 2.56 billion JPY per month in the housing sale market in Tokyo. The problem is caused by the slow price discount process that prolonged the search duration. It is recommended to promote home-seller to discount the list price faster in current housing sale market in Tokyo. In addition, according to the scenarios analysis for the housing sale market, there are potentials to shorten the time on the market and reduce the vacancy rate by improving the information in the housing sale market.

The problem is more serious in the housing rental market in Tokyo (23 wards) because large part of the vacant houses has become structural vacancies that cause the negative chain effects on the environment and society. Base on the natural vacancy rate for the housing rental market in Tokyo (23 wards) from the simulation, only 35,931 vacant houses are needed for the housing rental market. However, currently, there are 425,300 houses for rent in the market. There are 389,369 vacant houses in the rental market are excessive and wasteful houses. With the consideration of the opportunity cost for the excessive houses, there will be 38.56 billion social costs per month caused by the excessive vacant houses in housing rental market Tokyo. Although the number for social cost is large, only opportunity cost of those excessive houses is calculated, and there are still costs in society and environment caused by the chain-effects of the long-term vacant houses can't be calculated. 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. According to the scenarios analyses for the housing rental market, polices that increase the cost of list rent revision and improve the information in the housing rental market will shorten the search process of the landlords to improve the social efficiency.

The natural vacancy rate varies according to the variances in the economic situations, the landlords/home-sellers' behaviors as well as the tenants/buyers' behaviors. In Tokyo, the population peak will be reached in 2020, and peak for the number of households will be in 2030. The Olympic Games will be held in Tokyo in 2020, which will attract large amount of visitors. In the short-term, the population and number of households will still increase in Tokyo, and the landlords/home-sellers would expect that the rent/price 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 market, the volatility of the rent/sale price will increase in the short-term. Hence, with the increase in landlords/home-sellers' expectation and volatility of the rent/price, the natural vacancy rate would in increase in the housing market in Tokyo in the short-term.

In the long-term, there will be a long-term population decline in Tokyo, while the economy will be stagnant or stably decline. The landlords/home-sellers may expect that the rent/sale price will decrease in the housing market, and then they would have a lower expectation on their houses and try to rent/sell them fast. Hence, the natural vacancy rate for the housing market in Tokyo is expected to decline in the long-term.

6. CONCLUSIONS

By incorporating the information learning process into the structure of the multi-stage search-theoretical models, the dissertation develops an original theoretical model to directly explain the process of list price revision with an information updating process. In the face of uncertainties in the housing market, the landlords/home-sellers will use the list price to receive the feedbacks from the market to update market information so that they can adjust their evaluation for the market as well as the list price strategy promptly, which is one of the major academic contributions of the research for enriching the search theory. In the model, the landlords/home-sellers are considered rational so that they will make optimal decisions for list price strategy that is including the optimal decisions for the sequence of values for the list prices as well as the timings and frequencies for the list price revisions to maximize the expected present value of return. One major pattern of the list price strategy generated by the theoretical model is that the landlords/home-sellers will initial list a higher price, gradually reduce the list prices as the change in the evaluation for the market and time pass on the market, which is consist with actual situation in the housing market.　The list price strategy for search varies according to the variances in the economic and housing market situations, behavior patterns of the landlords/home-sellers as well tenants/home-buyers, so as the natural vacancy rate that is generated in the process of search.

With the list price strategy, the theoretical model produces the natural vacancy rate to compensate the trading friction caused by the imperfect information in the housing market, which is the rate of vacancy that are in need for the functioning of the housing market in the market equilibrium. Since with the natural vacancy rate, the vacant houses will flow in the market and will be efficiently allocated to satisfy the needs for residence and there will be no long-term vacant houses to generate the problems for sustainability, the natural vacancy rate is a reasonable benchmark for the housing market as well as the management of the issue of vacant houses.

By applying the theoretical model to the housing sale market as well as the housing rental market in Tokyo (23 wards), the research provides an original empirical perspective for the issue of the vacant houses by defining natural vacancy rate as the benchmark to divide vacant houses into the necessary amount of the vacant houses for the functioning of the market and wasteful amount of vacant houses that impose a vicious cycle for sustainability.

With the optimal list price strategy, the natural vacant rate for the housing sale market is 0.73%, while the natural rate for the housing rental market is 1.33% in Tokyo 23 wards.

Comparing the return and time on the market with optimal list price strategy to the actual market situation, there are still potentials in Tokyo for the landlords/home-sellers to save the time for search without losing the return by improving the list price strategy. The difference between the natural vacancy rates and the actual vacant rates in the housing market implies that there are many excessive housing vacancies in the housing market, especially there are large part of the vacant houses in housing rental market are the structure vacancies which can be barely rented out and cause the negative economic, social and environmental effects. There is 2.56 billion social cost per month in sale market while 38.56 billion social costs per month in rental market caused by the excessive housing vacancies.

For the housing sale market in Tokyo, it is recommended to motivate the home-sellers to discount the list price faster and improve the information in the market to shorten the time on the market and improve the social efficiency.

For the housing rental market, polices that increase the cost of list rent revision and improve the information in the market will reduce the vacancy rate and improve the social efficiency. However, concerning with the large amount of structural vacancies in housing rental, other responding policies to reconcile the negative influences caused by the structural vacancies are also in need.

The comparison between housing sale market and housing rental market are shown in Table 23. With the optimal list price strategy, the time on the market for housing sale market is longer than the time on the market for housing rental market. Because the residence duration for the owner-occupied houses is much longer than the residence duration for the tenant-occupied houses, the natural vacancy rate for the housing sale market is lower than the natural vacancy rate for the housing rental market. Comparing to the actual vacancy rate, the problem in the housing rental market is much more serious than the problem in the housing sale market. The major problem in the housing sale market is that the time on the market is largely extended, while in the housing rental market, although the time on the market is also slightly extended, the major problem is that there are large amount of structural vacancies in the market. For the differences in the recommendations, to motivate the home-sellers to discount the list price faster is efficient to reduce the vacancy rate in the housing sale market, while in the housing rental market to increase the cost for price revision is efficient to reduce the frictional vacancy, but there still needs other policies to deal with the structural vacancies.

Table 23 Differences between Housing Sale Market and Housing Rental Market

Items	Housing Sale Market	Housing Rental Market
Time on the market with optimal list price strategy	1.7562 Months	0.9327 Months
Natural Vacancy rate	0.73%	1.33%
Actual Vacancy rate	2.01%	15.70%
Problems	Time on the market is largely extended	Time on the market is extended; Large amount of structural vacancies
Recommendations	Motivate the home-sellers to discount the list price faster	Increase the cost of list rent revision; Other responding policies needed to deal with the structural vacancies

In the short-term, with the consideration of the peaks for the population and number of households in Tokyo, and Olympic Games in Tokyo as well, the natural vacancy rate for the housing market may increase due to the increase in volatility and the expectation of landlords/home-sellers. In the long-term, the natural vacancy rate for the housing market in Tokyo is expected to decrease.

For possible future extensions of the research, the natural vacant rate in the research is the vacancy rate that is focus on the landlords/home-sellers' search process to identify the trading frictional cost in the market equilibrium. The tenants/home-buyers' search process, as well as the environmental factors should be more dynamically involved into the model in the future research to achieve the vacancy rate that maximizes benefits of landlords/home-sellers, tenants/home-buyers as well as the environment. And in order to provide more practical solutions for the management of vacant houses, more heterogeneities should be considered in types of houses, regions, as well as types of landlords/home-sellers and tenants/home-buyers.

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