Change in the Distribution of Sale/Rental Prices:

Comparison of Beijing and Tokyo

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Abstract

This paper examines the change in the distribution of sale and rental prices in Beijing and Tokyo. Differ from previous cross-country comparison studies, we focus on the determinants of changes in the full distribution of prices, rents, and price-to-rent ratios. The quantile decomposition approaches have been proven to offer relevant insights into the evolution of price distribution. Using decomposition methods, we disentangle the distributional price, rent and price-to-rent ratio differentials into a composition effect attributable to the coefficient effect and variable effect of two housing markets. The changes of distributions of price, rent, and price-to-rent ratio of Beijing housing market between 2005 and 2010 are compared with Tokyo housing market in the same period and in bubble period between 1986 and 1991. The results show the appreciations of all three indicators in Beijing housing market are larger than Tokyo housing market between 2005 and 2010, and are even larger than Tokyo housing market in bubble period of 1980s. We show that the contribution s of the variable effect and the coefficient effect to price gaps vary with the part of distribution and also differ between sale market and rental market.

Key Words: Housing market; quantile decomposition; price distribution; asset bubble; Cross-country Comparison

JEL Classification: R21; R31; C1

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1 Introduction

Cross-country comparison is an important topic in many fields, such as corporate finance, macroeconomics, labor and health economics. However, in housing market, no such work has been done until Knoll, Schularick, and Steger (2017) using 14 advanced economics over 140 years to compare the global housing boom. Comparisons of the distributions, instead of mean, for different countries can help understanding the difference appreciation of house prices during the booms. In this study, unconditional quantile decomposition approach is applied for distributional comparisons of Beijing and Tokyo housing market.

Chinese housing boom in last decades attracts concerns of researchers and policy makers. As the second largest economy following the US, Chinese economy might be hurt by the collapse of housing market as the US subprime crisis and Japanese asset bubble. A large volume of studies tries to estimate the mean-based quality-adjusted house and land sale price in China (Deng, Gyourko and Wu, 2014; Wu, Deng and Liu, 2014; Fang et al, 2015). However, the distributional analysis for sale and rental price of Chinese housing market is limit. As such, decomposition approach, originally developed in labor economics, offers additional distributional insights into the evolvement of appreciation rates.

China and Japan are the second and third largest national economy in the world, after the US, in terms of nominal GDP. Japanese asset bubble that began around the mid-1980s has been called the greatest bubble of the twentieth century. In the aftermath of the bubble's collapse, the country faced a period of long-term economic stagnation dubbed the "lost decade." Many researchers compare the Japanese asset bubble to the housing boom in the China last decade. Deng et al. (2017) denotes that, after 2000, the Japanese housing market experienced a recovery and growth. How does change of distribution of China and differ from Japan? Does the distributional change of house prices in both markets simply is attributed to larger size and smaller age or alternatively due to changes in the underlying hedonic price functions?

To address these questions, the distributional decomposition approaches are the most commonly used method. Among several distributional decomposition approaches, the unconditional quantile regression version by Firpo, et al. (2007, 2009) is suitable for the cross-country comparison in the change of distributions. Unconditional quantile decomposition is focus below on the case of quantiles of the unconditional distribution, instead of conditional distribution, of the outcome variable (Fortin et al., 2011).

Using the unique micro-level datasets of condominium transaction in Beijing and Tokyo with similar characteristics, this study investigates the patterns, determinants and variations of the difference of change of distribution in house price between 2005 and 2010 in Beijing and Tokyo. Differ from previous studies, we consider both sale and rental housing markets. The spatial price-to-rent ratio for each unit in Beijing and Tokyo is also calculated based on the estimation proposed in the second study. The change of distribution in price-to-rent ratio could be better used to compare the potential expectation of appreciation, which is typically used to support the notion of house bubble. In this study, we decompose the house prices, rents, and price-to-rent ratios gaps between 2005 and 2010 into two components: a variable effect (attributable to the varying house characteristics, such as unitize and age, during 2005-2010) and a coefficient effect (due to changes in the underlying land price function). In addition, we also compare the change of house price market of Beijing between 2005 and 2010 to the market in Tokyo of in the bubble period between 1986 and 1991.

The remaining sections is organized as follows. In section 2, we will specify the empirical approach. The dataset and summary statistic are shown in section 3. Section 4 present the empirical results and section 5 concludes.

2 Unconditional Quantile Decomposition

The decomposition method was first proposed by Oaxaca (1973) and Blinder (1973), which names Oaxaca-Blinder decomposition. Oaxaca-Blinder decomposition, originally designed for decomposing differences in mean wage across two group, is now a standard tool in applied econometrics. The standard assumption used in this mean decomposition is the same with OLS linear model:

$$E(Y_g|X_g) = X_g'\beta_g \tag{1}$$

where Y is wage or house price for two groups g, 1 and 0. In housing markets, two groups are usually two years, for example 2005 and 2010 in this study. X is the vector of characteristics including constant term. The mean decomposition is estimated as:

$$\overline{\mathrm{Y}}_1 - \overline{\mathrm{Y}}_0 = \underbrace{(\overline{\mathrm{X}}_1 - \overline{\mathrm{X}}_0)\,\hat{\beta}_0}_{\text{Variable}} + \underbrace{\bar{X}_1(\hat{\beta}_1 - \hat{\beta}_0)}_{\text{Coefficient}} \tag{2}$$

where the first component is a variable effect, which also be called composition effect or "explained" effect, and the coefficient effect is the second term which is usually called the "wage structure" effect or "unexplained" effect in Oaxaca decomposition. In housing market, the coefficient effect can be treated as "price structure" effect. The variable and coefficient effects can be divided into the contribution of each covariate.

Many methodological papers aim at refining the Oaxaca-Blinder decomposition, and expanding it to the case of distributional parameters besides the mean over the last three decades. Going beyond the mean is important but Fortin et al. (2011) pointed that "until recently, no comprehensive approach was available for computing a detailed decomposition of the effect of single covariates for a distributional statistic other than the mean". Three major distributional decomposition are developed, which are conditional quantile regression (Machado and Mata, 2005), distributional regression (Chernozhukov et al., 2013), and recentered influence function (RIF) regression, also called unconditional quantile regression (Firpo et al., 2007, 2009).

Machado and Mata (2005) constructed a decomposition approach based on quantile regressions. This quantile approach is more general than the conventional Oaxaca decomposition. The conditional quantiles approach was provided by Koenker and Bassett (1978). Following Koenker (2005), the standard quantile regression approach is to find the values for $\hat{\beta}(\tau)$ that minimize $\sum_i \rho_\tau(y_i - x_i'\beta)$ where $\rho_\tau(u) = u(\tau - I(u < 0))$. Machado and Mata (2005) used conditional quantile regression estimators to decompose wages with coefficient change and covariance change. A four-step replacement procedure is proposed to construct the counterfactual densities. It is a natural way of performing an overall and detailed coefficient decomposition. However, as mentioned in Fortin (2011 et al.), MM decomposition does not provide a way of performing the detail decomposition and path dependent, which means that the decomposition results depend on the order in which the decomposition is performed. Chernozhukov et al. (2013) proposed a more directly way to decompose the detail variable effect on conditional distribution by distributional regression models. However, the path dependent problem is still not solved in this distributional regression approach.[4]

The unconditional quantile regression (RIF-regression) are developed by Firpo et al. (2009) to investigate the effect of changes in the explanatory variables on the marginal distribution of the dependent variable, instead of holding all other variables at their actual value. In housing context, the unconditional quantile approach answers the question such as "what happens to 10% quantile of the sale price of housing when a subway station constructed

[4] Comprehensive survey of decomposition methods could be find in Fortin et al. (2011) in *Handbook of Labor Economics.*

nearby". Unlike conditional quantile regression, their answer is not conditional on the covariates such as floor space and age of the building. The unconditional quantile regression builds upon the concept of the influence function (IF), a widely used tool in robust estimation of statistical or econometric models. The IF represents the influence of an individual observation on the distributional statistic. The recentered influence function (RIF) is obtained by adding back the statistic to the influence function. For the quantile, the RIF is simply $q_\tau + IF(Y, q_\tau)$, where $q_\tau = Q_\tau[Y]$ is the population τ-quantile of the unconditional distribution of Y, and $IF(Y, q_\tau)$ is its influence function, known to be equal to $(\tau - 1(\mathrm{Y} \leq \mathrm{q}_\tau))/f_Y(q_\tau)$; $f_Y(\cdot)$ is the density of the marginal distribution of Y. As a result, the estimated of RIF can be rewritten as

$$\widehat{RIF}(Y, \widehat{q_\tau}) = \widehat{q_\tau} + \frac{\tau - 1(y \leq \widehat{q_t})}{f_Y(q_\tau)} \quad (3)$$

where $\widehat{q_\tau}$ is the τ-th quantile on the marginal distribution of Y, which can be estimated by Koenker and Bassett (1978) approach: $\hat{q}_\tau = \arg\min_q \sum_{i=1}^{N} (\tau - 1(Y_i \leq q)) \cdot (Y_i - q)$. The estimation of the density of Y is $\widehat{f_Y}(\cdot)$, the kernel density estimator. Following Firpo et al. (2009), we use the Gaussian kernel with bandwidth in the empirical section: $\widehat{f_Y}(y) = \frac{1}{N \cdot b_Y} \cdot \sum_{i=1}^{N} K_Y(\frac{Y_i - y}{b_Y})$.

The coefficients of the unconditional quantile regression for each group $g = 1{,}0$ can be presented as:

$$\hat{\gamma}_{g,\tau} = (\sum_{i \in G} X_i \cdot X_i^T)^{-1} \cdot \sum_{i \in G} \widehat{RIF}\left(Y_{gi}, q_{g,\tau}\right) \cdot X_i \quad (4)$$

Similar with Oaxaca-Blinder decomposition, the unconditional quantile decomposition for any τ-th quantile is

$$\hat{q}_1^{\tau} - \hat{q}_0^{\tau} = \underbrace{(\overline{X}_1 - \overline{X}_0)\hat{\gamma}_{0,\tau}}_{\text{Variable}} + \underbrace{\bar{X}_1(\hat{\gamma}_{1,\tau} - \hat{\gamma}_{0,\tau})}_{\text{Coefficient}} \quad (5)$$

This unconditional decomposition disentangles the unconditional wage of house price gap at τ-th quantile into variable effect and coefficient effect, which can be further divided into the contribution of each explanatory variable. RIF approach is path independent and straightforward to unconditional marginal distribution.

In housing market, decomposition is a useful tool to analyze the difference of sale prices between two periods, such as before the boom and after the bust but was rarely used. The shift of distribution of prices can be split into portions caused by changes the explanatory variables and by the changes of the coefficients. McMillen (2008) was the first to connect the decomposition approach to housing market. He used MM approach to decompose change from 1995 to 2005 in the distribution of house prices in Chicago. Subsequently the MM decomposition are applied in several studies: Nicodemo and Raya (2012) showed the decomposition of Spanish housing markets in 2004 and 2007 and Fesselmeyer, Le and Seah (2013) provided evidence of differing housing prices for Caucasians and African Americans in the US market. Thomschke (2015) applied Chernozhukov et al. (2013) distributional regression approach to decompose the change of distribution in rental price from 2007 to 2012 in Berlin. Qin et al. (2016) firstly applied unconditional quantile approach to decompose the change of distribution in land price from 2007 to 2012 in China.

This study is the first study to compare the distributional changes of house sale and rental housing market in different countries. As the value of explanatory variables differs across market, the unconditional quantile regression is more suitable to present the effect of changes in the explanatory variable on the marginal distribution of the house price. In the next section, the data and empirical model specification are introduced.

3 Data and Model Specification

The datasets used in this study contain condominium of sale and rent in Beijing and Tokyo. The dataset of Beijing is from two large brokerage company, Beijing Woaiwojia Real Estate Agency Co., Ltd. and Century 21 China Real Estate. The dataset of Tokyo is provided by Suumo (Residential Information Website), which is owned by Recruit Co., Ltd., one of the largest vendors of residential lettings information in Japan. This study uses the house transaction and rent records in 2005 and 2010 of two markets for major analysis. In addition, the Tokyo sample in Japanese bubble period 1986 and 1991 is also used to make comparison with Beijing housing boom. The structural characteristics include floor space and building age; the amenity characteristics include distance to the subway station and CBD[5]; the location characteristics include district code, address, latitude, and longitude.

Summary statistics are presented in Table 1. Sale and rental price are

[5] The CBD of Beijing is used Tiananmen Square in the center of Beijing. Tokyo Station is used for CBD of Tokyo.

converted to USD under the exchange rate in 2010 to enhance comparability. The appreciation rate of average sale price per square meter in Beijing is 265% from 2005 to 2010, while that in Tokyo is only 12%. Although inflation rate from 2005 to 2010 measured by CPI[6] is 15% for China and -1% for Japan, the high appreciation rate in Beijing cannot be explained. The appreciation rate of Japanese from the start of the boom 1986 to the peak of bubble 1991 is 99%, and the inflation rate in this period is 9%. The rental price in Beijing and Tokyo increase 49% and 7% from 2005 to 2010 and that in Tokyo bubble period is 27%. The average unit age and commuting cost increases over time. The floor space increases with time in Beijing in 2000s and Tokyo 1980s, while the average floor space in Tokyo 2005 is larger than 2010. The average floor space in Beijing is bigger than Tokyo, while the age in Beijing is smaller than Tokyo. The rental sample have smaller unit size, commuting cost and larger age than sale sample in Beijing. While the rental sample have smaller unit size and age than sale sample in Tokyo.

The average spatial price-to-rent ratio are also included in Table 1, which is calculated by the method proposed in the second study, we simply introduce the steps of the estimations:

6 CPI data is from OECD: *https://data.oecd.org/price/inflation-cpi.htm*

Table 1 Summary Statistics

	Sale Data					
	Beijing		Tokyo		Tokyo	
	2005	2010	2005	2010	1986	1991
Total price	70286.7	256394.7	353012.9	378929.3	304559.3	649487.8
(US dollar in 2010)	(44523.8)	(171247.2)	(197159.9)	(179531.7)	(209790.9)	(326679.0)
Price per m^2	886.2	3231.9	5611.7	6258.8	6581.0	13098.8
(US dollar in 2010)	(263.9)	(1142.3)	(1985.8)	(2108.7)	(3707.4)	(5150.5)
Log price per m^2	6.743	7.997	8.573	8.687	8.680	9.412
	(0.306)	(0.460)	(0.347)	(0.333)	(0.445)	(0.362)
Price-to-rent Ratio	18.70	46.54	15.94	18.51	14.81	28.93
	(3.717)	(9.353)	(2.460)	(5.855)	(4.425)	(2.501)
Floor Space (m^2)	79.42	81.23	61.98	60.75	48.28	51.45
	(37.32)	(40.29)	(18.76)	(17.47)	(17.94)	(17.96)
Age (year)	10.17	11.14	15.90	17.05	8.022	11.27
	(6.046)	(6.963)	(9.822)	(9.931)	(4.572)	(5.757)
Distance to Station	1.684	1.801	0.574	0.593	0.564	0.570
(km)	(1.972)	(1.563)	(0.327)	(0.342)	(0.329)	(0.329)
Distance to CBD	13.35	14.74	8.782	9.138	8.642	9.068
(km)	(7.478)	(7.794)	(3.888)	(3.954)	(3.753)	(3.680)
Observation	2512	19294	4666	3982	4835	9584
	Rent Data					
	Beijing		Tokyo		Tokyo	
	2005	2010	2005	2010	1986	1991
Total annual rent	3233.9	5159.3	13999.6	14644.7	15747.7	20967.9
(US dollar in 2010)	(2440.7)	(3385.5)	(6465.7)	(6867.0)	(9019.6)	(11007.6)
Annual rent per m^2	54.90	81.97	407.4	438.5	411.7	524.1
(US dollar in 2010)	(25.78)	(37.53)	(100.5)	(100.2)	(140.0)	(168.9)
Log rent per m^2	3.933	4.317	5.979	6.056	5.966	6.214
	(0.375)	(0.433)	(0.251)	(0.240)	(0.331)	(0.305)
Floor Space (m^2)	60.77	68.64	36.27	34.88	40.79	41.55
	(24.65)	(33.01)	(16.96)	(16.68)	(20.82)	(19.25)
Age (year)	11.66	13.04	15.64	11.73	3.413	6.066
	(6.429)	(7.134)	(8.662)	(9.439)	(3.401)	(5.823)
Distance to Station	1.382	1.589	0.593	0.547	0.527	0.583
(km)	(1.059)	(1.307)	(0.336)	(0.322)	(0.303)	(0.327)
Distance to CBD	10.76	12.71	9.566	8.413	9.149	9.287
(km)	(5.655)	(6.974)	(3.600)	(3.868)	(4.038)	(3.551)
Observation	20965	82278	11088	271448	706	4517

Note: Means are presented as coefficients and Standard deviations are reported in parentheses. Prices and rents are shown in US dollar used the exchange rate in 2010 (The exchange rate of RMB to USD is 6.77; JPY to USD is 87.779 in 2010). Price-to-rent ratio are shown the results of spatial price-to-rent ratio estimated by my locally weighted quantile approach.

1. Estimate locally weighted quantile regressions in each observation in the set of target points of sale and rental datasets separately[7], $x(z)$, for each quantile range of $\tau = 0.02, 0.04, \ldots, 0.98$, in increments of 0.02, implies a number of quantile $B = 48$: $\arg\min_{\beta \in \mathbb{R}} \sum_i w_i(z)\rho_\tau(y_i - (x_i - x)'\beta)$, where z is longitude and latitude and $w_i(\cdot)$ is the kernel weight function. The estimate of target point in each τ-th quantile is $\hat{\beta}(\tau, z)$.
2. Interpolate the quantile regression estimates $\hat{\beta}(\tau, z)$ of the set of target points to the full set of locations represented in the data set. Then, we get n_p coefficient estimates $\hat{\beta}_p(\tau, z_p)$ and n_r coefficient estimates $\hat{\beta}_r(\tau, z_r)$ for each value of τ, one for each observation in sale sample and rental sample, where n_p and n_r are the numbers of observations in sale and rental datasets.
3. Interpolate the coefficients in τ-th quantile of rental models, $n_r \times k$ matrix $\hat{\beta}_r(\tau, z_r)$, to the location of sales sample, $n_p \times 1$ vector z_p, and get the $n_p \times k$ counterfactual coefficients matrix: $\hat{\beta}_r^C(\tau, z_p)$.
4. Calculate the spatial price-to-rent ratios in τth quantile for each observation in sale dataset $x_p(z_p)$: $ptr(\tau, z_p) = \exp(X_p\hat{\beta}_p(\tau, z_p) - X_p\hat{\beta}_r^C(\tau, z_p))$. The kernel density of $ptr(z_p)$ for each observation in sale dataset is estimated and median of $ptr(z_p)$ represent the spatial price-to-rent ratio.

[7] The target point is selected by an adaptive tree approach proposed by (Loader, 1999)

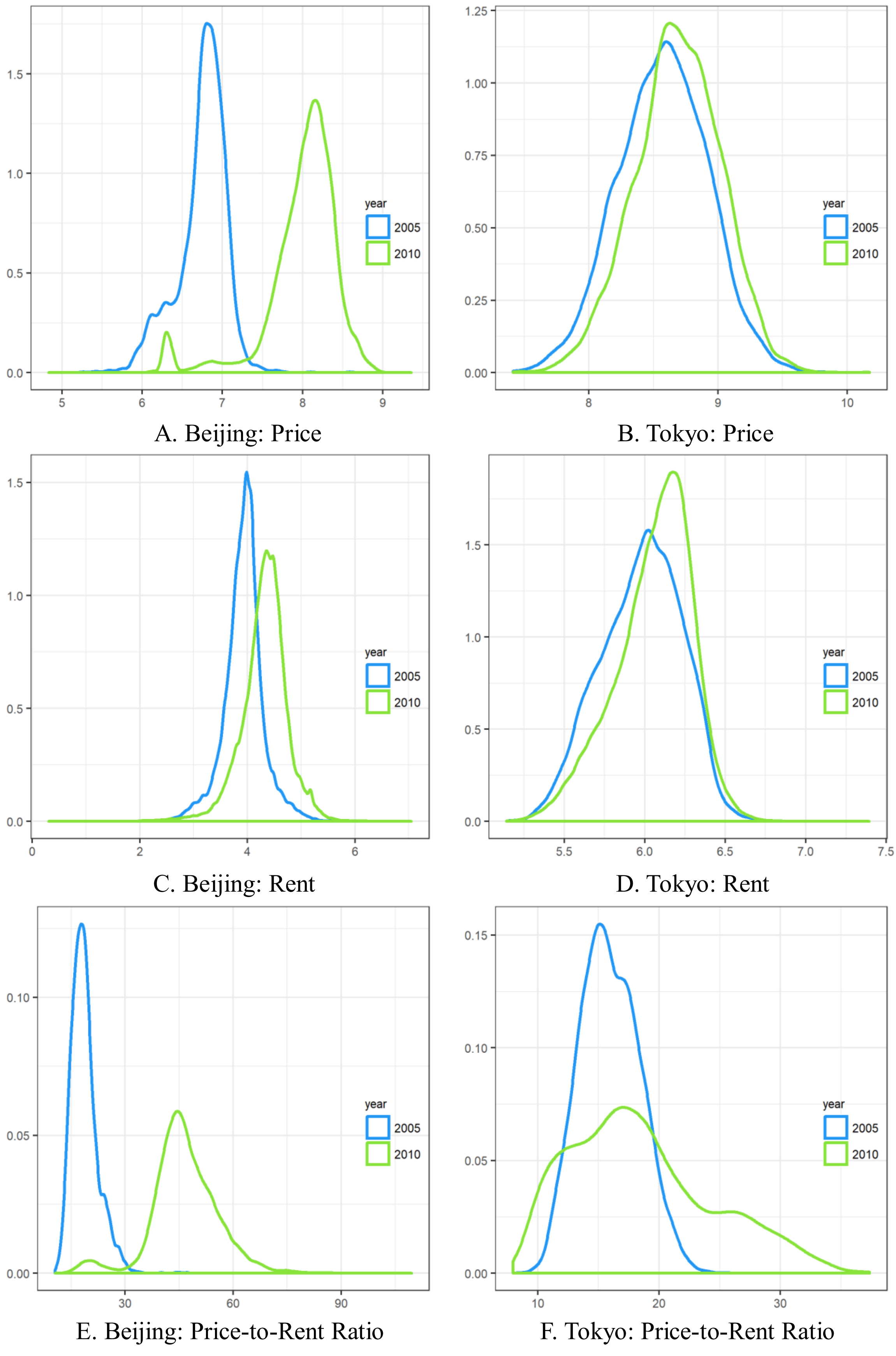


Figure 1 Kernel Density Estimates of Price, Rent and Price-to-Rent Ratio of Beijing and Tokyo in 2005 and 2010

Spatial price-to-rent ratios estimated by above procedures can be used as dependent variable in OLS and unconditional quantile regression. Average price-to-rent ratio of Beijing market increases from 18.70 in 2005 to 46.54 in 2010, with 148% appreciation rate, whereas that of Tokyo market only increases 16% from 15.94 to 18.51 in the same period. In Japanese bubble period from 1986 to 1991, the price to rent ratio roses 95% from 14.81 to 28.93 with.

Figure 1 shows the kernel densities of prices, rents and spatial price-to-rent ratios of Beijing and Tokyo in 2005 and 2010. The changes of distributions vary over markets and are different among prices, rents and price-to-rent ratios. The price distributional gap between 2005 and 2010 of Beijing market is larger than that of Tokyo market. The variance of rents distribution of Beijing market is smaller than Tokyo market in each year. Distributions of spatial price-to-rent ratios of Beijing and Tokyo market have smaller variance in 2005 than 2010.

In the empirical models, the main explanatory variables of regression models are floor space, age, distance to subway station and distance to CBD. The latitude, longitude, district dummies, and quarter dummies are also included as control variables. Dependent variables of OLS regressions are Prices, rents and price-to-rent ratios. The RIF is used as dependent variable for each unconditional quantile regression. The OLS and unconditional quantile regressions are estimated for each separately year of Beijing and Tokyo markets. The unconditional quantile decomposition approach is applied to three measures of Beijing and Tokyo housing markets.

4 Empirical Results

4.1 OLS Estimation

This study examines the determination of house sale price, rental price and price-to-rent ratio for different housing markets using OLS estimation. The regressions are separately estimated for price and price-to-rent ratio used sale dataset and rent used rental dataset. Table 2 presents the OLS estimation results of Beijing market in 2005 and 2010. The results show that average prices

Table 2 OLS Estimation Results: Beijing 2005, 2010

	(1)	(2)	(3)	(4)	(5)	(6)
	Price		Rent		Price-to-Rent Ratio	
	2005	2010	2005	2010	2005	2010
Log of Floor Space	-0.00521	-0.116***	-0.305***	-0.373***	3.637***	14.24***
(m^2)	(0.0220)	(0.00745)	(0.00680)	(0.00264)	(0.155)	(0.115)
Age (year)	-0.00782***	-0.00895***	-0.0122***	-0.0126***	-0.102***	-0.0386***
	(0.000956)	(0.000358)	(0.000377)	(0.000164)	(0.0111)	(0.00547)
Distance to Station	-0.0205***	-0.0144***	-0.0293***	-0.0315***	0.924***	0.927***
(km)	(0.00368)	(0.00191)	(0.00256)	(0.000959)	(0.0577)	(0.0400)
Distance to CBD	-0.0338***	-0.0267***	-0.0364***	-0.0324***	-0.0836***	-0.127***
(km)	(0.00140)	(0.000749)	(0.000936)	(0.000407)	(0.0169)	(0.0130)
Geographic Coordinates	Y	Y	Y	Y	Y	Y
District Dummies	Y	Y	Y	Y	Y	Y
Quarterly Dummies	Y	Y	Y	Y	Y	Y
Constant	39.87***	36.26***	2.803	35.64***	-13.76	486.5***
	(11.44)	(7.157)	(7.564)	(3.593)	(164.4)	(141.1)
Observations	2512	19294	20965	82278	2512	19294
R^2	0.723	0.456	0.456	0.536	0.635	0.658

Note: Dependent variable is log of sale price per square meter in (1) (2), log of rent per square meter in (3) (4), and spatial price-to-rent ratio in (5) (6). *** means 1% significance level. Standard deviations are in parentheses.

and rents per square meter decrease with floor space, except no significant effect of floor space on price in 2005. The negative effects are larger in rental markets than sale market and increase over time. In addition, the average price-to-rent ratio increases with unit size, and the coefficient of log of floor space rose from 3.63 to 14.24. Prices, rents and price-to-rent ratios decline with the age of unit and distance to CBD. Prices and rents are lower for houses farther from subway station. It is interesting that price-to-rent ratios increase with distance to subway station. One possible explanation is that sale prices are less sensitive to distance to station than rental prices.

Table 3 OLS Estimation Results: Tokyo 2005, 2010

	(1)	(2)	(3)	(4)	(5)	(6)
	Price		Rent		Price-to-Rent Ratio	
	2005	2010	2005	2010	2005	2010
Log of Floor Space	0.0633***	0.0223**	-0.289***	-0.235***	4.655***	3.881***
(m^2)	(0.00883)	(0.0108)	(0.00349)	(0.000670)	(0.0398)	(0.234)
Age (year)	-0.0176***	-0.0157***	-0.00869***	-0.00842***	-0.139***	-0.143***
	(0.000245)	(0.000252)	(0.000155)	(0.0000259)	(0.00102)	(0.00716)
Distance to Station	-0.110***	-0.126***	-0.0635***	-0.0678***	-0.809***	-0.571**
(km)	(0.00732)	(0.00844)	(0.00351)	(0.000751)	(0.0326)	(0.243)
Distance to CBD	-0.0423***	-0.0348***	-0.0232***	-0.0295***	-0.132***	0.147***
(km)	(0.00163)	(0.00178)	(0.000887)	(0.000179)	(0.00671)	(0.0537)
Geographic Coordinates	Y	Y	Y	Y	Y	Y
District Dummies	Y	Y	Y	Y	Y	Y
Quarterly Dummies	Y	Y	Y	Y	Y	Y
Constant	320.7***	173.4***	65.59***	109.5***	1681.1***	-4048.8***
	(21.40)	(21.36)	(10.96)	(2.397)	(93.64)	(683.5)
Observations	4666	3982	11088	271448	4666	3982
R^2	0.814	0.798	0.749	0.751	0.932	0.430

Note: Dependent variable is log of sale price per square meter in (1) (2), log of rent per square meter in (3) (4), and spatial price-to-rent ratio in (5) (6). *** means 1% significance level. Standard deviations are in parentheses.

Table 3 shows the OLS estimation results of housing market of Tokyo in 2005 and 2010. Similar with Beijing, rents and price-to-rent ratios are lower in larger houses. However, prices per square meter increase with the unit size. Prices, rents and price-to-rent ratios decline with age, distance to station, and distance to CBD. One exception is price-to-rent ratio increase with distance to CBD, Tokyo Station.

4.2 Unconditional Quantile Regression

Table 4 and Table 5 present unconditional regression results at 10th, 50th and 90th quantile estimates for the price, rent and price-to-rent ratio of Beijing and Tokyo market in 2005 and 2010. The RIF regressions are explained as the marginal effect of change explanatory variables on the unconditional quantiles of dependent variable.

Table 4 Unconditional Quantile Regression Results: Beijing 2005, 2010

Panel A: Price						
	2005			2010		
	10th	50th	90th	10th	50th	90th
Log of Floor Space	-0.107***	0.00555	0.0802***	-0.338***	-0.0290***	0.0508***
(m^2)	(0.0352)	(0.0143)	(0.0235)	(0.0189)	(0.00563)	(0.00823)
Age (year)	-0.0106***	-0.00180**	-0.0136***	-0.0135***	-0.00469***	-0.0111***
	(0.00185)	(0.000904)	(0.00146)	(0.000966)	(0.000347)	(0.000522)
Distance to Station	-0.0772***	-0.00192	-0.0110***	-0.0521***	-0.00760***	-0.00636***
(km)	(0.0156)	(0.00348)	(0.00398)	(0.00691)	(0.00177)	(0.00152)
Distance to CBD	-0.0413***	-0.0320***	-0.0196***	-0.0207***	-0.0328***	-0.0216***
(km)	(0.00670)	(0.00134)	(0.00177)	(0.00287)	(0.000743)	(0.000846)
Constant	52.50	55.25***	8.946	-21.00	59.12***	40.27***
	(57.92)	(13.60)	(15.19)	(26.46)	(6.554)	(6.360)
Observations	2512	2512	2512	19294	19294	19294
R^2	0.597	0.465	0.188	0.216	0.428	0.215

Panel B: Rent						
		2005			2010	
	10th	50th	90th	10th	50th	90th
Log of Floor Space	-0.228***	-0.194***	-0.628***	-0.267***	-0.263***	-0.640***
(m^2)	(0.0106)	(0.00432)	(0.0206)	(0.00464)	(0.00208)	(0.00683)
Age (year)	-0.00219***	-0.00791***	-0.0362***	-0.00750***	-0.00993***	-0.0260***
	(0.000699)	(0.000347)	(0.00110)	(0.000364)	(0.000182)	(0.000419)
Distance to Station	-0.0202***	-0.0247***	-0.0246***	-0.0557***	-0.0241***	-0.0203***
(km)	(0.00761)	(0.00229)	(0.00523)	(0.00318)	(0.000935)	(0.00155)
Distance to CBD	-0.0746***	-0.0279***	-0.0257***	-0.0325***	-0.0340***	-0.0286***
(km)	(0.00305)	(0.000831)	(0.00208)	(0.00137)	(0.000397)	(0.000777)
Constant	-61.57***	21.95***	37.98**	14.57	31.46***	49.60***
	(22.50)	(7.443)	(16.62)	(11.80)	(3.766)	(6.077)
Observations	20965	20965	20965	82278	82278	82278
R^2	0.401	0.283	0.151	0.274	0.398	0.273

Panel C: Price-to-Rent Ratio						
		2005			2010	
	10th	50th	90th	10th	50th	90th
Log of Floor Space	2.867***	3.388***	5.747***	8.876***	13.00***	20.50***
(m^2)	(0.236)	(0.182)	(0.657)	(0.276)	(0.107)	(0.347)
Age (year)	-0.0444***	-0.104***	-0.159***	0.226***	-0.101***	-0.114***
	(0.0161)	(0.0127)	(0.0403)	(0.0160)	(0.00749)	(0.0132)
Distance to Station	0.289***	0.571***	2.548***	0.438***	0.517***	1.634***
(km)	(0.0540)	(0.0596)	(0.224)	(0.0592)	(0.0365)	(0.102)
Distance to CBD	-0.0129	-0.0433*	-0.255***	-0.114***	-0.0791***	-0.148***
(km)	(0.0226)	(0.0223)	(0.0734)	(0.0259)	(0.0160)	(0.0376)
Constant	251.9	-136.2	-338.8	1742.4***	108.8	243.4
	(189.9)	(198.9)	(746.9)	(231.0)	(148.6)	(355.2)
Observations	2512	2512	2512	19294	19294	19294
R^2	0.219	0.426	0.309	0.302	0.506	0.336

Note: Dependent variable is RIF calculated by log of sale price per square meter for panel A, log of rent per square meter for panel B, and spatial price-to-rent ratio for Panel C. *** p<0.01; ** p<0.05; *p<0.1. Standard deviations are in parentheses.

The unconditional quantile regression results show the effect of explanatory variables vary over different quantiles on the marginal unconditional distribution of the dependent variable. Different from OLS results that floor space have no effect in 2005, as shown in panel A of Table 4, the price effect of floor space is negative and significant with 10.7% in 10th quantile, which means that the increasing of 1% floor space reduce the price per square meter 0.1%, while the effect is not significant in 50th quantile and positive significant with 8% in 90th quantile. In this case, the advantage of unconditional quantile regression is obvious. The effect of floor space on sale price is negative 33.8%, 2.9% and 5.1% at 10th, 50th, and 90th quantile in 2010. The sale prices of all quantiles in each year decline with age of units. The negative effects of age are larger in 10th and 90th quantiles than in 50th quantile for each year. Prices decrease with higher commuting cost to station and city center for each year on all quantiles and the effects is smaller in higher quantiles. Panel B shows the unconditional quantile regression results for rent sample of Beijing. Rents are lower for larger houses. These negative effects are around 20-25% at 10th and 50th quantile and around 60% in 90th quantile for each year. Different from sales market, the rents effects of floor space are larger in high-priced houses. The rents decrease also with age, distance to station, and distance to CBD at 10th, 50th and 90th quantile in each year. The negative rents effect is also higher in magnitude at 90th quantile, which suggests that the variability of per-meter sales rents is lower for old houses. Panel C presents the unconditional quantile estimates of spatial price-to-rent ratio. Bigger units have larger price-to-rent ratio, and magnitude of this positive effect increase with quantile. The effect of floor space on price-to-rent ratio is about 4 times in 2010 of that in 2005. Price-to-rent ratio decline with more age and distance to CBD. Different from the OLS estimation results, spatial price-to-rent ratio increase with more distance to subway station. The magnitudes of this effect are larger in higher quantiles, which suggest price of houses far from subway station are more over estimated than houses close to station.

Unconditional quantile results of Tokyo in 2005 and 2010 are shown in Table 5. Differ from sale market of Beijing in 2005, the positive price effects of floor space of Tokyo in 2005 are statistically significant for 10th, 50th and

Table 5 Unconditional Quantile Regression Results: Tokyo 2005, 2010

Panel A: Price						
	2005			2010		
	10th	50th	90th	10th	50th	90th
Log of Floor Space	0.0416***	0.0620***	0.0775***	0.0199	-0.00311	0.0323
(m^2)	(0.0146)	(0.0143)	(0.0285)	(0.0215)	(0.0159)	(0.0298)
Age (year)	-0.0136***	-0.0177***	-0.0178***	-0.0161***	-0.0147***	-0.0147***
	(0.000658)	(0.000439)	(0.000829)	(0.000822)	(0.000468)	(0.000767)
Distance to Station	-0.127***	-0.113***	-0.0713***	-0.138***	-0.114***	-0.0683***
(km)	(0.0240)	(0.0140)	(0.0190)	(0.0295)	(0.0146)	(0.0189)
Distance to CBD	-0.0482***	-0.0445***	-0.0294***	-0.0428***	-0.0310***	-0.0283***
(km)	(0.00581)	(0.00311)	(0.00383)	(0.00629)	(0.00324)	(0.00434)
Constant	586.6***	296.4***	38.59	325.3***	167.4***	-27.90
	(82.19)	(37.76)	(42.19)	(86.38)	(37.04)	(39.83)
Observations	4666	4666	4666	3982	3982	3982
R^2	0.347	0.580	0.300	0.342	0.578	0.290

Panel B: Rent						
	2005			2010		
	10th	50th	90th	10th	50th	90th
Log of Floor Space	-0.268***	-0.347***	-0.177***	-0.404***	-0.243***	-0.0761***
(m^2)	(0.00836)	(0.00532)	(0.00798)	(0.00241)	(0.000970)	(0.00123)
Age (year)	-0.00512***	-0.00992***	-0.00892***	-0.0111***	-0.00905***	-0.00472***
	(0.000365)	(0.000255)	(0.000375)	(0.000102)	(0.0000441)	(0.0000466)
Distance to Station	-0.134***	-0.0420***	-0.0313***	-0.152***	-0.0399***	-0.0370***
(km)	(0.0126)	(0.00629)	(0.00749)	(0.00323)	(0.00126)	(0.00140)
Distance to CBD	-0.0284***	-0.0202***	-0.0165***	-0.0450***	-0.0298***	-0.0193***
(km)	(0.00311)	(0.00153)	(0.00183)	(0.000795)	(0.000307)	(0.000323)
Constant	134.7***	51.95***	13.10	236.0***	104.7***	23.15***
	(45.42)	(18.76)	(19.28)	(11.53)	(3.937)	(3.716)
Observations	11088	11088	11088	271448	271448	271448
R^2	0.311	0.519	0.241	0.403	0.495	0.227

Panel C: Price-to-Rent Ratio						
	2005			2010		
	10th	50th	90th	10th	50th	90th
Log of Floor Space	4.363***	5.071***	4.501***	3.363***	3.583***	3.791***
(m^2)	(0.190)	(0.0965)	(0.193)	(0.378)	(0.337)	(0.411)
Age (year)	-0.101***	-0.175***	-0.116***	-0.146***	-0.153***	-0.227***
	(0.00488)	(0.00307)	(0.00549)	(0.00927)	(0.0102)	(0.0148)
Distance to Station	-0.613***	-0.934***	-0.575***	-1.578***	-0.199	0.724
(km)	(0.152)	(0.0993)	(0.163)	(0.259)	(0.314)	(0.605)
Distance to CBD	-0.142***	-0.186***	-0.115***	0.0835	0.143**	0.325**
(km)	(0.0370)	(0.0225)	(0.0325)	(0.0567)	(0.0691)	(0.141)
Constant	1269.4***	1855.0***	1588.6***	652.8	-3032.1***	-9342.4***
	(482.7)	(281.9)	(407.7)	(524.0)	(830.0)	(1904.7)
Observations	4666	4666	4666	3982	3982	3982
R^2	0.318	0.653	0.316	0.259	0.218	0.264

Note: Dependent variable is RIF calculated by log of sale price per square meter for panel A, log of rent per square meter for panel B, and spatial price-to-rent ratio for Panel C. *** p<0.01; ** p<0.05; *p<0.1. Standard deviations are in parentheses.

90th quantiles. The price effect of the floor space is 4.1% for 10th quantile, 6.2% for 50th quantile, and 7.7% for 90th quantile. Sale price in 2010 have no significant correlation with unit size. The sale prices of all quantiles in each year decline with age of units. Prices decrease with larger commuting cost to station and city center for each year on all quantiles and the effects is smaller in higher quantiles. The effect of distance to station is larger for Tokyo market in magnitude than Beijing market. Panel B shows that rents are lower in large houses in each year for all quantiles. The negative rents effect on floor space is 26.8% at 10th quantile, 34.7% at 50th quantile and 17.7% at 90th quantile in 2005, which means that house with expensive rent has small sensitive to the unit size. The negative rent effects in 2010 is 40.4%, 24.3%, and 7.6% at 10th, 50th, and 90th quantile, with the increase in 10th quantile and decrease in 50th and

90th quantile. Rents decline with distance to subway station and CBD at all quantiles in each year. The negative rent effect is larger in 10th percentile, which means that low-priced rental market has more sensitive to commuting cost. Panel C present the positive effects of floor space and negative effect of age and commuting cost on rental price of Tokyo market, consistent with the results of Beijing market. The positive effect of unit size is smaller in 2010 than 2005. The coefficients of distance to station in 50th and 90th quantile and distance to CBD in 10th quantile are not statistically significant.

4.3 Unconditional Quantile Decomposition

The changes of distributions in house prices, rents and price-to-rent ratios from 2005 to 2010 of Beijing and Tokyo markets are further explored by unconditional quantile approach described in 4.2. The distributional changes of the dependent variables for τ-th quantile are decomposed into a variable effect $(\overline{\mathrm{X}}_1 - \overline{\mathrm{X}}_0)\hat{\gamma}_{0,\tau}$ and a coefficient effect $\bar{X}_1(\hat{\gamma}_{1,\tau} - \hat{\gamma}_{0,\tau})$. Table 6 and Table 7 present the unconditional quantile decomposition results of Beijing and Tokyo housing market between 2005 and 2010. The results show that the differences (total effects) of prices, rents, and price-to-rent ratios in Beijing market monotonically increase with quantile over the distribution, while overall differences of prices and rents in Tokyo market decrease with quantile after 30th quantile. It suggests that the prices, rents and price-to-rent ratios rose more in

Table 6 Unconditional Quantile Decomposition: Beijing, 2005-2010

	(1) Price			(2) Rent			(3) Price-to-Rent Ratio		
	Total Difference	Variable Effect	Coefficient Effect	Total Difference	Variable Effect	Coefficient Effect	Total Difference	Variable Effect	Coefficient Effect
10th	1.275***	-0.119***	1.394***	0.291***	-0.176***	0.467***	22.87***	0.213	22.66***
	(0.0187)	(0.0104)	(0.0159)	(0.00655)	(0.00327)	(0.00579)	(0.123)	(0.141)	(0.161)
20th	1.237***	-0.116***	1.352***	0.337***	-0.186***	0.523***	24.81***	0.199*	24.61***
	(0.0142)	(0.00724)	(0.0104)	(0.00435)	(0.00292)	(0.00374)	(0.103)	(0.105)	(0.115)
30th	1.231***	-0.114***	1.345***	0.360***	-0.155***	0.514***	25.94***	0.154	25.79***
	(0.00895)	(0.00679)	(0.00652)	(0.00333)	(0.00232)	(0.00285)	(0.0987)	(0.105)	(0.108)
40th	1.261***	-0.101***	1.362***	0.395***	-0.139***	0.534***	26.89***	0.0892	26.80***
	(0.00685)	(0.00579)	(0.00534)	(0.00306)	(0.00204)	(0.00264)	(0.0985)	(0.111)	(0.106)
50th	1.290***	-0.0933***	1.383***	0.397***	-0.135***	0.532***	27.79***	0.00651	27.78***
	(0.00636)	(0.00518)	(0.00510)	(0.00276)	(0.00193)	(0.00246)	(0.102)	(0.125)	(0.112)
60th	1.304***	-0.0867***	1.390***	0.416***	-0.135***	0.551***	28.96***	0.0128	28.95***
	(0.00620)	(0.00477)	(0.00515)	(0.00269)	(0.00193)	(0.00248)	(0.111)	(0.152)	(0.132)
70th	1.323***	-0.0833***	1.406***	0.427***	-0.127***	0.553***	30.51***	-0.0104	30.52***
	(0.00614)	(0.00467)	(0.00532)	(0.00270)	(0.00183)	(0.00253)	(0.129)	(0.178)	(0.157)
80th	1.343***	-0.0790***	1.422***	0.452***	-0.135***	0.586***	32.19***	-0.0731	32.27***
	(0.00635)	(0.00466)	(0.00591)	(0.00342)	(0.00205)	(0.00325)	(0.166)	(0.184)	(0.181)
90th	1.365***	-0.0754***	1.440***	0.447***	-0.164***	0.610***	33.93***	-0.0280	33.96***
	(0.00705)	(0.00486)	(0.00709)	(0.00617)	(0.00288)	(0.00585)	(0.244)	(0.203)	(0.249)

Note: *** p<0.01; ** p<0.05; *p<0.1. Standard deviations are in parentheses. Total effect in each quantile is the difference of prices, rents, or price-to-rent ratios $(\hat{q}_1^{\tau} - \hat{q}_0^{\tau})$ between 2005 and 2010 in this unconditional quantile. Variable effect is $(\overline{X}_1 - \overline{X}_0)\hat{\gamma}_{0,\tau}$. Coefficient effect is $\bar{X}_1(\hat{\gamma}_{1,\tau} - \hat{\gamma}_{0,\tau})$.

Table 7 Unconditional Quantile Decomposition: Tokyo, 2005-2010

	(1) Price			(2) Rent			(3) Price-to-Rent Ratio		
	Total Difference	Variable Effect	Coefficient Effect	Total Difference	Variable Effect	Coefficient Effect	Total Difference	Variable Effect	Coefficient Effect
10th	0.125***	-0.0967***	0.221***	0.0862***	0.109***	-0.0227***	-1.477***	0.230***	-1.707***
	(0.0122)	(0.00744)	(0.0104)	(0.00418)	(0.00360)	(0.00375)	(0.108)	(0.0736)	(0.108)
20th	0.132***	-0.104***	0.237***	0.107***	0.110***	-0.00276	-0.607***	0.389***	-0.997***
	(0.0118)	(0.00809)	(0.00905)	(0.00413)	(0.00318)	(0.00314)	(0.121)	(0.0859)	(0.122)
30th	0.136***	-0.0865***	0.222***	0.108***	0.0947***	0.0133***	0.386***	0.402***	-0.0166
	(0.00981)	(0.00676)	(0.00708)	(0.00389)	(0.00256)	(0.00280)	(0.125)	(0.0808)	(0.125)
40th	0.118***	-0.0810***	0.199***	0.0963***	0.0853***	0.0111***	1.245***	0.263***	0.982***
	(0.00943)	(0.00659)	(0.00658)	(0.00346)	(0.00221)	(0.00247)	(0.117)	(0.0750)	(0.115)
50th	0.110***	-0.0831***	0.193***	0.0915***	0.0743***	0.0172***	1.875***	0.283***	1.592***
	(0.00930)	(0.00695)	(0.00637)	(0.00311)	(0.00190)	(0.00226)	(0.120)	(0.0786)	(0.118)
60th	0.111***	-0.0819***	0.193***	0.0847***	0.0627***	0.0220***	2.506***	0.432***	2.074***
	(0.00952)	(0.00715)	(0.00669)	(0.00309)	(0.00161)	(0.00234)	(0.130)	(0.0868)	(0.128)
70th	0.104***	-0.0771***	0.181***	0.0650***	0.0518***	0.0133***	3.541***	0.692***	2.850***
	(0.00966)	(0.00690)	(0.00709)	(0.00310)	(0.00136)	(0.00246)	(0.163)	(0.118)	(0.166)
80th	0.100***	-0.0780***	0.178***	0.0497***	0.0447***	0.00498*	5.532***	0.855***	4.677***
	(0.0102)	(0.00709)	(0.00812)	(0.00316)	(0.00123)	(0.00269)	(0.231)	(0.177)	(0.237)
90th	0.0901***	-0.0682***	0.158***	0.0285***	0.0413***	-0.0128***	8.160***	0.458***	7.702***
	(0.0112)	(0.00656)	(0.00982)	(0.00333)	(0.00124)	(0.00301)	(0.200)	(0.143)	(0.202)

Note: *** $p<0.01$; ** $p<0.05$; *$p<0.1$. Standard deviations are in parentheses. Total effect in each quantile is the difference of prices, rents, or price-to-rent ratios $(\hat{q}_1^{\tau} - \hat{q}_0^{\tau})$ between 2005 and 2010 in this unconditional quantile. Variable effect is $(\overline{X}_1 - \overline{X}_0)\hat{\gamma}_{0,\tau}$. Coefficient effect is $\bar{X}_1(\hat{\gamma}_{1,\tau} - \hat{\gamma}_{0,\tau})$.

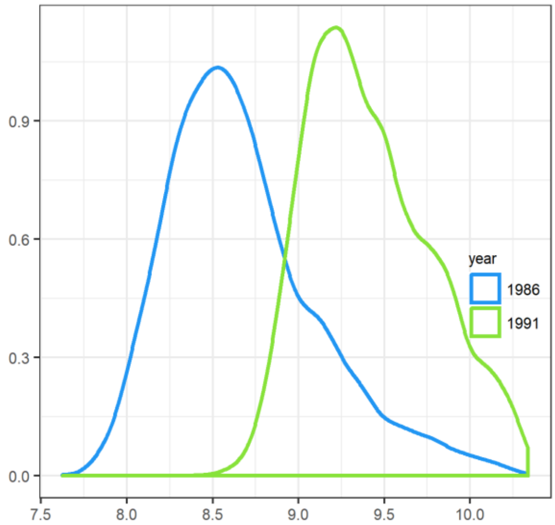
higher quantiles in Beijing market from 2005 to 2010, whereas prices and rents of lower-priced houses in Tokyo market increased more than higher-priced houses. Although, similar with Beijing market, price-to-rent ratio gaps in Tokyo monotony increase over distribution, the magnitude of the differences of price-to-rent ratios are lower in Tokyo markets than Beijing market. The differences of price-to-rent ratios are negative in 10th, 20th quantile and increase monotonically from 0.386 in 30th quantile to 8.16 in 90th quantile, which suggests price-to-rent ratios even decrease in low quantile of Tokyo market.

The coefficient effects fully contribute to the growth of prices, rents and price-to-rent ratios for each quantile of Beijing market, which is consistent with the results of Chicago housing markets shown in McMillen (2008). It is interesting that the variable effects are negative and significant in the prices and rents difference in Beijing market, which suggests if the explanatory variables are same in 2005 and 2010, the prices and rents rose more than what we observed. The changes of structural and locational characteristics slow the appreciation rate in price and rental markets of Beijing. The ratio of negative variable effects is about 10% in sale market and about 80% in rental market of Beijing. The changes of variables have no impact on the change of price-to-rent ratios in Beijing market. However, the decomposition results in Tokyo are totally different. The variable effects of Tokyo sale market are negative and have larger ratio than Beijing market. Differ from Beijing rental market, the variable effects contributes over 90% to the rents change. The reason why the decompositions in two rental markets are different might be the rental price in Tokyo is more stable than Beijing market from 2005 to 2010. The portion of variables effect to the change of price-to-rent ratio is larger in low quantiles of Tokyo markets, while the ratio of coefficient effect contributes more in high quantiles. The detailed decomposition of variable effect and coefficient effect are also conducted, and we put it in the online appendices.

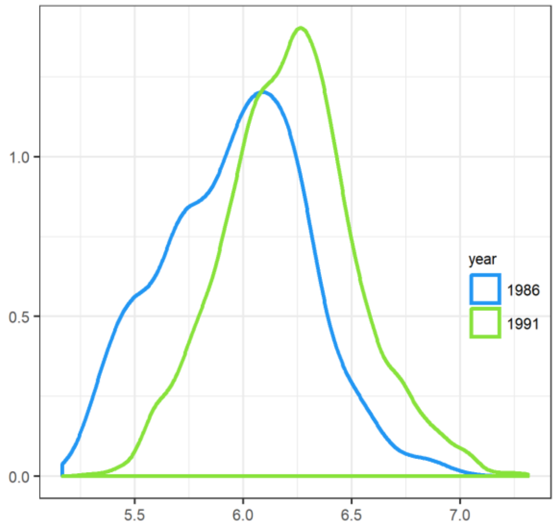
4.4 Comparison the booms in two housing markets

The difference of Beijing housing market and Tokyo housing market are shown above. Several studies debated that the housing boom in China 2000s is similar with the asset bubble in Japan 1980s. Fang et al. (2016) compared the mean-based land price index of Japanese and Chinese market and pointed several differences of macro economy in these markets. In this section, the empirical results for Tokyo market between 1986, the time beginning of the boom, and 1991, the peak time of the bubble, are shown as comparison with Beijing housing market in 2000s.

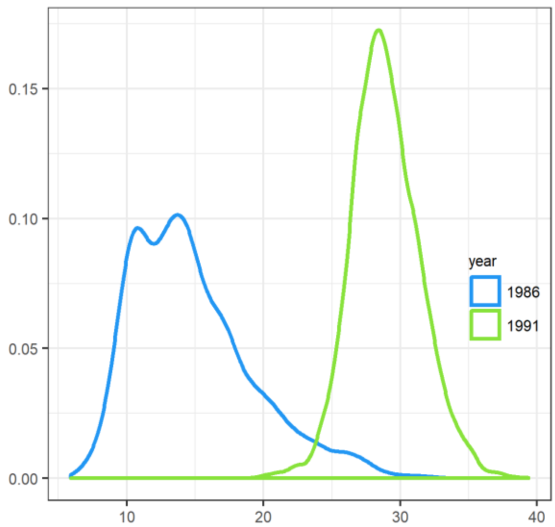
Figure 2 shows the kernel density of price, rent and spatial price-to-rent ratio of Tokyo in 1986 and 1991 for comparison. Although the growths of Beijing 2000s and Tokyo 1980s are similar in mean, the change of variance differ for two markets. Differ from Beijing 2000s, the variance of price-to-rent ratio decreased in Tokyo 1980s.



A. Price



B. Rent



C. Price-to-Rent Ratio

Figure 2 Kernel Density Estimates of Price, Rent and Price-to-Rent Ratio of Tokyo in 1986 and 1991

Table 8 OLS Estimation Results: Tokyo 1986, 1991

	(1)	(2)	(3)	(4)	(5)	(6)
	Price		Rent		Price-to-Rent Ratio	
	1986	1991	1986	1991	1986	1991
Log of Floor Space	0.00780	-0.138***	-0.203***	-0.150***	1.700***	-0.0979**
(m^2)	(0.0106)	(0.00630)	(0.0174)	(0.00637)	(0.0967)	(0.0458)
Age (year)	-0.0170***	-0.0197***	-0.00575**	-0.00973***	-0.131***	-0.212***
	(0.000823)	(0.000398)	(0.00260)	(0.000599)	(0.00817)	(0.00297)
Distance to Station	-0.118***	-0.0792***	-0.132***	-0.0750***	0.749***	-0.521***
(km)	(0.00995)	(0.00670)	(0.0243)	(0.00889)	(0.125)	(0.0461)
Distance to CBD	-0.0583***	-0.0477***	-0.0357***	-0.0450***	0.250***	0.0465***
(km)	(0.00243)	(0.00149)	(0.00659)	(0.00225)	(0.0326)	(0.0102)
Geographic Coordinates	Y	Y	Y	Y	Y	Y
District Dummies	Y	Y	Y	Y	Y	Y
Quarterly Dummies	Y	Y	Y	Y	Y	Y
Constant	468.0***	194.0***	-2.823	131.3***	-3107.7***	-439.1***
	(32.73)	(17.94)	(81.77)	(30.69)	(484.8)	(124.4)
Observations	4835	9584	706	4517	4835	9584
R^2	0.751	0.717	0.725	0.634	0.682	0.706

Note: Dependent variable is log of sale price per square meter in (1) (2), log of rent per square meter in (3) (4), and spatial price-to-rent ratio in (5) (6). *** means 1% significance level. Standard deviations are in parentheses.

Table 8 presents the OLS estimation results of Tokyo market in 1986 and 1991. Prices and rents decline with age, distance to station, and distance to CBD, similar with Beijing market in 2000s. Prices and rents per square meter are lower in larger houses, except the prices in 1986. The OLS results of Price-to-rent ratios are more interesting. The effects are in different direction of floor space and distance to station on price-to-rent ratio in 1986 and 1991. Price-to-rent ratio are higher in houses with larger unit size and far from station in 1986, while the price-to-rent ratio are lower in those houses in 1991. Price-to-rent ratio of Tokyo market in bubble period also decrease with age and increase with distance to Tokyo Station.

Unconditional quantile regression results of Tokyo market in 1986 and 1991 are presented in Table 9. Dependent variables are the unconditional estimator RIF of prices, rents, and price-to-rent ratios in three panels. The results show

Table 9 Unconditional Quantile Regression Results: Tokyo, 1986 1991

Panel A: Price						
		1986			1991	
	10th	50th	90th	10th	50th	90th
Log of Floor Space	0.0435***	-0.0225*	0.160***	-0.0413***	-0.149***	-0.202***
(m^2)	(0.0108)	(0.0136)	(0.0435)	(0.00702)	(0.0102)	(0.0219)
Age (year)	-0.0158***	-0.0198***	-0.00631**	-0.0140***	-0.0221***	-0.0219***
	(0.00118)	(0.00115)	(0.00297)	(0.000651)	(0.000686)	(0.00129)
Distance to Station	-0.174***	-0.0808***	-0.188***	-0.0968***	-0.0798***	-0.0472***
(km)	(0.0200)	(0.0154)	(0.0378)	(0.0126)	(0.0121)	(0.0173)
Distance to CBD	-0.0501***	-0.0489***	-0.0654***	-0.0282***	-0.0572***	-0.0560***
(km)	(0.00579)	(0.00365)	(0.00734)	(0.00289)	(0.00265)	(0.00351)
Constant	670.7***	293.3***	419.8***	290.1***	245.8***	670.7***
	(86.52)	(47.67)	(94.34)	(41.24)	(32.43)	(86.52)
Observations	4835	4835	4835	9584	9584	4835
R^2	0.414	0.567	0.382	0.322	0.534	0.414

Panel B: Rent						
		1986			1991	
	10th	50th	90th	10th	50th	90th
Log of Floor Space	-0.0963***	-0.303***	-0.0754*	-0.196***	-0.179***	-0.0811***
(m^2)	(0.0352)	(0.0280)	(0.0386)	(0.0139)	(0.0100)	(0.0190)
Age (year)	-0.0171***	-0.0107***	0.0101*	-0.0145***	-0.0118***	-0.000743
	(0.00589)	(0.00388)	(0.00537)	(0.00133)	(0.000807)	(0.00172)
Distance to Station	-0.323***	-0.0676*	-0.126***	-0.170***	-0.0363***	-0.0699***
(km)	(0.0713)	(0.0398)	(0.0478)	(0.0244)	(0.0129)	(0.0262)
Distance to CBD	-0.0378**	-0.0492***	-0.0397***	-0.0223***	-0.0463***	-0.0521***
(km)	(0.0179)	(0.0119)	(0.0117)	(0.00748)	(0.00328)	(0.00420)
Constant	8.684	42.50	160.3	-27.75	111.5***	219.7***
	(260.5)	(145.7)	(112.9)	(108.9)	(42.42)	(51.24)
Observations	706	706	706	4517	4517	4517
R^2	0.346	0.555	0.338	0.352	0.428	0.299

Panel C: Price-to-Rent Ratio						
		1986			1991	
	10th	50th	90th	10th	50th	90th
Log of Floor Space	0.477***	2.023***	2.866***	0.00325	0.00373	-0.385***
(m^2)	(0.146)	(0.143)	(0.306)	(0.0910)	(0.0612)	(0.133)
Age (year)	-0.197***	-0.143***	-0.0720***	-0.206***	-0.188***	-0.242***
	(0.0127)	(0.0114)	(0.0254)	(0.00724)	(0.00400)	(0.00871)
Distance to Station	-0.163	0.0417	2.463***	-0.622***	-0.346***	-0.582***
(km)	(0.142)	(0.152)	(0.482)	(0.112)	(0.0728)	(0.137)
Distance to CBD	0.121***	0.180***	0.426***	0.167***	0.00827	-0.0462
(km)	(0.0282)	(0.0342)	(0.140)	(0.0239)	(0.0161)	(0.0281)
Constant	58.05	-1245.3***	-7218.2***	-2405.9***	144.9	58.05
	(296.6)	(417.5)	(2138.5)	(304.7)	(196.9)	(296.6)
Observations	4835	4835	4835	9584	9584	4835
R^2	0.281	0.552	0.317	0.285	0.488	0.281

Note: Dependent variable is RIF calculated by log of sale price per square meter for panel A, log of rent per square meter for panel B, and spatial price-to-rent ratio for Panel C. *** p<0.01; ** p<0.05; *p<0.1. Standard deviations are in parentheses.

much variation of coefficients over 10th, 90th and 90th quantiles. Floor space has no significant effect on price in 1986 on average as indicated by OLS, while unconditional quantile regression results indicate that the marginal effect of floor space on sale price is 4.35% on 10th quantile, -2.25% on 50th quantile, 16% on 90th quantile in 1986. The effect of floor space on sale price in -4.13%, -14.9%, and -20.2% for 10th, 50th, and 90th quantile in 1991. Rents decline with increasing of unit size of all quantiles in 1986 and 1991. Price-to-rent ratios are higher in larger units in 1986, and the magnitude of the effect increase with quantile. Price-to-rent ratios in 1991 have no significant correlation with floor space in 10th and 50th quantile, and decline with increasing of floor space in 90th quantiles. The effects of other variables on price, rents, and price-to-rent ratios vary with quantiles and change with time.

Table 10 Unconditional Quantile Decomposition: Tokyo, 1986-1991

	(1) Price			(2) Rent			(3) Price-to-Rent Ratio		
	Total Difference	Variable Effect	Coefficient Effect	Total Difference	Variable Effect	Coefficient Effect	Total Difference	Variable Effect	Coefficient Effect
10th	0.804***	-0.108***	0.912***	0.324***	-0.0415***	0.365***	16.03***	-0.736***	16.77***
	(0.00828)	(0.00461)	(0.00745)	(0.0220)	(0.0142)	(0.0198)	(0.0653)	(0.0455)	(0.0670)
20th	0.779***	-0.116***	0.895***	0.283***	-0.0409***	0.324***	16.03***	-0.820***	16.85***
	(0.00764)	(0.00479)	(0.00627)	(0.0212)	(0.0133)	(0.0168)	(0.0672)	(0.0366)	(0.0689)
30th	0.765***	-0.133***	0.898***	0.277***	-0.0449***	0.322***	15.60***	-0.933***	16.53***
	(0.00789)	(0.00546)	(0.00609)	(0.0212)	(0.0123)	(0.0158)	(0.0792)	(0.0373)	(0.0823)
40th	0.753***	-0.151***	0.903***	0.234***	-0.0484***	0.283***	15.09***	-0.983***	16.08***
	(0.00817)	(0.00614)	(0.00617)	(0.0201)	(0.0125)	(0.0145)	(0.0775)	(0.0375)	(0.0828)
50th	0.753***	-0.180***	0.932***	0.219***	-0.0423***	0.261***	14.72***	-1.055***	15.77***
	(0.00881)	(0.00729)	(0.00680)	(0.0176)	(0.0114)	(0.0133)	(0.0778)	(0.0397)	(0.0861)
60th	0.759***	-0.199***	0.957***	0.214***	-0.0382***	0.252***	14.34***	-1.158***	15.50***
	(0.00963)	(0.00806)	(0.00767)	(0.0164)	(0.0106)	(0.0129)	(0.0881)	(0.0433)	(0.0980)
70th	0.753***	-0.232***	0.985***	0.203***	-0.0347***	0.238***	13.65***	-1.258***	14.91***
	(0.0116)	(0.00943)	(0.00955)	(0.0160)	(0.0108)	(0.0129)	(0.106)	(0.0478)	(0.118)
80th	0.724***	-0.222***	0.946***	0.208***	-0.0275**	0.236***	12.84***	-1.285***	14.13***
	(0.0149)	(0.00967)	(0.0126)	(0.0165)	(0.0122)	(0.0138)	(0.129)	(0.0504)	(0.142)
90th	0.635***	-0.187***	0.822***	0.250***	-0.0408**	0.290***	11.13***	-1.380***	12.51***
	(0.0177)	(0.00953)	(0.0161)	(0.0210)	(0.0172)	(0.0194)	(0.172)	(0.0567)	(0.186)

Note: *** p<0.01; ** p<0.05; *p<0.1. Standard deviations are in parentheses. Total effect in each quantile is the difference of prices, rents, or price-to-rent ratios $(\hat{q}_1^{\tau} - \hat{q}_0^{\tau})$ between 2005 and 2010 in this unconditional quantile. Variable effect is $(\overline{X}_1 - \overline{X}_0)\hat{\gamma}_{0,\tau}$. Coefficient effect is $\bar{X}_1(\hat{\gamma}_{1,\tau} - \hat{\gamma}_{0,\tau})$.

Table 10 shows the decomposition results of Tokyo market between 1986 and 1991. The results indicate that the differences of prices, rents, and price-to-rent ratios of Tokyo market in 1986-1991 monotonically decline with quantile over the distribution, different from the results of Beijing market in 2005-2010. It suggests prices, rents and price-to-rent ratios increasing more in lower quantiles. Similar with Beijing market, the coefficient effects fully contribute to the growth of prices, rents and price-to-rent ratios for each quantile of Tokyo market in 1980s. The negative variable effects are of prices, rents, and price-to-rent ratios difference are also be found, which suggests if the explanatory variables are same in 1986 and 1991, the prices, rents, and price-to-rent ratios rose more than what we observed. Those magnitude of negative variable effects are larger in higher quantiles, which suggests changes of structural and locational characteristics slow the appreciation rate of prices and rents more in higher quantiles. Variable effects are negative significant in the results, which differ from the case in Beijing market.

The changes of distributions in the boom of two markets contributes to coefficients effects more. The variable effects slow the appreciation rate in the booms for Beijing market in 2000s and Tokyo market in 1980s. The changes of distributions are larger in higher quantiles for Beijing market in 2000s, while the changes of distributions are smaller in higher quantiles for Tokyo in 1980s.

4.5 Appreciation Rate by unconditional quantile decomposition

In this section, we show the estimated appreciation rate of price, rent and price-to-rent ratio in 10th, 50th, and 90th quantile of unconditional quantile decomposition in Table 11. Differ from the appreciation rate of price mean of raw data summarized in section 3, the results shown in Table 11 are summarized by the total effect of unconditional quantile decomposition. The appreciation rates are unconditional predicted price, rent, and price-to-rent ratio. Median price appreciation rates are 263%, 11%, and 112% for Beijing 2005-2010, Tokyo 2005-2010, and Tokyo 1986-1991, which are similar with mean appreciation rate of raw data. Price of houses in Beijing have larger appreciation rate in the right side of the distribution (257% for 10th quantile, 263% for 50th quantile, and 291% for 90th quantile), while the appreciation rates of houses price in Tokyo housing market are larger in low-priced houses than high-priced houses.

Table 11. Appreciation Rate by Quantiles

Panel A. Beijing 2005-2010			
	10th quantile	50th quantile	90th quantile
Price	2.579	2.633	2.916
Rent	0.338	0.487	0.564
Price-to-rent ratio	1.565	1.527	1.423
Panel B. Tokyo 2005-2010			
	10th quantile	50th quantile	90th quantile
Price	0.133	0.116	0.094
Rent	0.090	0.096	0.029
Price-to-rent ratio	-0.115	0.119	0.425
Panel C. Tokyo 1986-1991			
	10th quantile	50th quantile	90th quantile
Price	1.234	1.123	0.887
Rent	0.383	0.245	0.284
Price-to-rent ratio	1.613	1.048	0.528

Note: Values in this table is the percentage of total appreciation rate of price, rent, and price-to-rent ratio estimated by unconditional quantile decomposition.

The appreciation rates of rents are much smaller than price for all markets. Appreciation rates of rents in Beijing are 33.8% for 10th quantile, 48.7% for 50th quantile, and 56.4% for 90th quantile. Similar with price, appreciation rates of rents in high quantile are larger than low quantile in Beijing. In Tokyo 2005-2010, appreciation rates of rents in are 9% and 9.6% 10th and 50th quantile and only 2.9% in 90th quantile. In Tokyo 1986-1991, the appreciation rates of rents are 38.3% for 10th quantile, and 24.5% and 28.4% for 50th and 90th quantile. Appreciation rates of price-to-rent ratios of Beijing (156%, 152%, and 143% for 10th, 50th, and 90th quantile) between 2005 and 2010 are larger than Tokyo (-11%, 11%, and 42.5%) in the same period. In Tokyo boom period over 1986 and 1991, the appreciation rates of price-to-rent ratio are 161%, 104%, and 52.8% for 10th, 50th, and 90th quantile. Overall, the affordability changes of two housing markets indicated by price-to-rent ratios are in similar level but the difference over the distribution is larger in Tokyo 1980s than Beijing 2000s.

5 Conclusion

This study differs from most previous work on comparing housing markets of different countries by focusing on the determinants of changes in the full distribution of prices, rents, and price-to-rent ratios. Using a unique and comprehensive sale and rental data in Beijing and Tokyo housing market, the changes of house price distributions are investigated. To better comparing the housing markets, three indicators, i.e., price, rents, and spatial price-to-rent ratios, are used. The spatial price-to-rent ratios are calculated by the locally weighted decomposition approach proposed in the second study of this thesis.

The average appreciation rates of median prices are 263% and 11.6% for Beijing and Tokyo housing markets between 2005 to 2010 and 112% for Tokyo market in asset bubble period from 1986 to 1991. The average appreciation rates of rents are 48.6% and 9.6% for Beijing and Tokyo housings markets between 2005 to 2010 and 24.5% for Tokyo market in asset bubble period from 1986 to 1991. The average appreciation rates of price-to-rent ratios are 152% and 11.9% for Beijing and Tokyo housing markets between 2005 to 2010 and 104% for Tokyo market in asset bubble period from 1986 to 1991. Appreciations of prices, rents and price-to-rent ratios are found not uniform throughout the distributions. Differences of prices and rents increase monotonically from lower quantiles to the higher quantiles in Beijing market from 2005 to 2010, while that decreases monotonically in Tokyo 1986 to 1991. The difference of these indicators is not monotonically over distribution in Tokyo 2005 to 2010.

Unconditional quantile regressions are applied for these housing markets, which is useful to estimate the effect of changes in the explanatory variable on marginal distribution of the dependent variable without condition on the values of other variables. As the condition of other variables totally different across housing markets, unconditional quantile regression is useful to compare for the housing markets of different countries. The results show that prices, rents and price-to-rent ratios across markets share some similar marginal effects on explanatory variables, for example they decline with increasing of age, distance to station, and distance to CBD. The magnitude of these effects varies among different quantiles and different across markets. The effect of a explanatory variable on prices per square meter are even in opposite direction for different quantiles, for example the effect of floor space on prices per square meter is -10% in 10th quantile and 8% in 90th quantile. Rents marginal effects on floor space are negative in most quantiles of those markets, while price-to-rent ratio marginal effect son floor space are positive.

Unconditional quantile decomposition results show that the price changes contribute to coefficient effects most, and the variable effects are in opposite direction of total difference and in those housing markets. The negative variable effects suggest that if the explanatory variables are same in two years, the prices may rose more than what we observed. The coefficient effects of Beijing market from 2005-2010 and Tokyo market from 1986-1991 contributes almost fully total difference of rents, and the variable effects are negative. On the contrary, variable effect of rents in Tokyo market 2005-2010 contributes more than 80% of total difference of all quantiles. The change of price-to-rent ratios are contributed by coefficient effects fully in Beijing market 2005-2010, and Tokyo market 1986-1991. The change of price-to-rent ratio at high quantile in Tokyo 2005-2010 are contributed by variable effect more but at low quantile are contributed by coefficient effect.

To sum up, the unconditional quantile approach is ideal for cross-country compassion analysis of housing markets. In addition, spatial price-to-rent ratio makes the markets with different house price level comparable. Distributional analysis shows more heterogeneity of changes within distribution and supports that focusing on the mean is inadequate for comparison.

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