Quantile Regression and the Distribution of House Prices in Japanese Cities, 1986 – 2015

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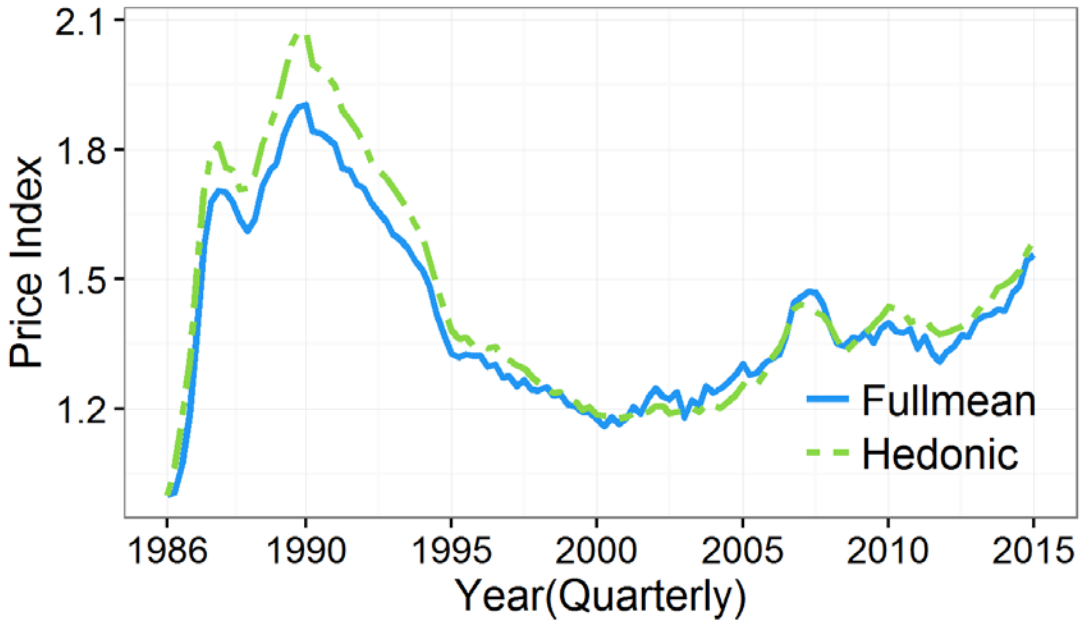
October 2016

Background

- Housing market cycle
  - Bubble in late 1980s
  - Long decline in 1990s
  - 2008 Global Financial Crisis

- Changes in the price distribution during the bubble, decline, rebound, and the 2008 crisis
  - Timing for different cities: Tokyo, Kawasaki, Kobe, Kyoto, Osaka, Yokohama
  - Changes in the distribution of prices for high-priced and low-priced homes



Condominium Prices in Tokyo

Motivation

- Objectives
  - Describe changes in the full distribution of house prices
  - Compare distributions across cities
  - Changes in the distributions at different stages of the housing cycle
  - Decomposition of the change in distributions: coefficients effect v. variables

Background – Conventional Price Indices

- Medians or Means
- "Quality – Controlled" Indices
  - Hedonic model with controls for structural characteristics
  - Repeat Sales – Sample size, sample selection. Do characteristics or coefficients change over time?
  - Hybrid – Combines repeat sales with hedonic

All focus on a central tendency – mean or median.

Repeat Sales as a Matching Estimator

- Wang and Zorn, *Journal of Housing Economics* (1997): Repeat sales approach is identical to period by period means when the number of sales is the same for all periods in the repeat sales sample.

- McMillen, *Real Estate Economics* (2012)
  - Series of matched samples based on propensity scores for probability of sale in time t versus period.
  - Repeat sales approach is an extreme form of matching
  - Using a matching approach to trim sample of outliers produces a much larger sample than the repeat sales approach. Particularly useful when estimating price indices for relatively small geographic areas.

Quantile Price Indices

- $Q_{lnP}(q|X_{it}, D_{it}) = X_i\beta(q) + \sum_{t=2}^{T} D_{it}\delta_t(q)$

- q = .50 is comparable to hedonic estimation. Also directly comparable to repeat sales estimator if the sample is restricted to properties that have sold at least twice.

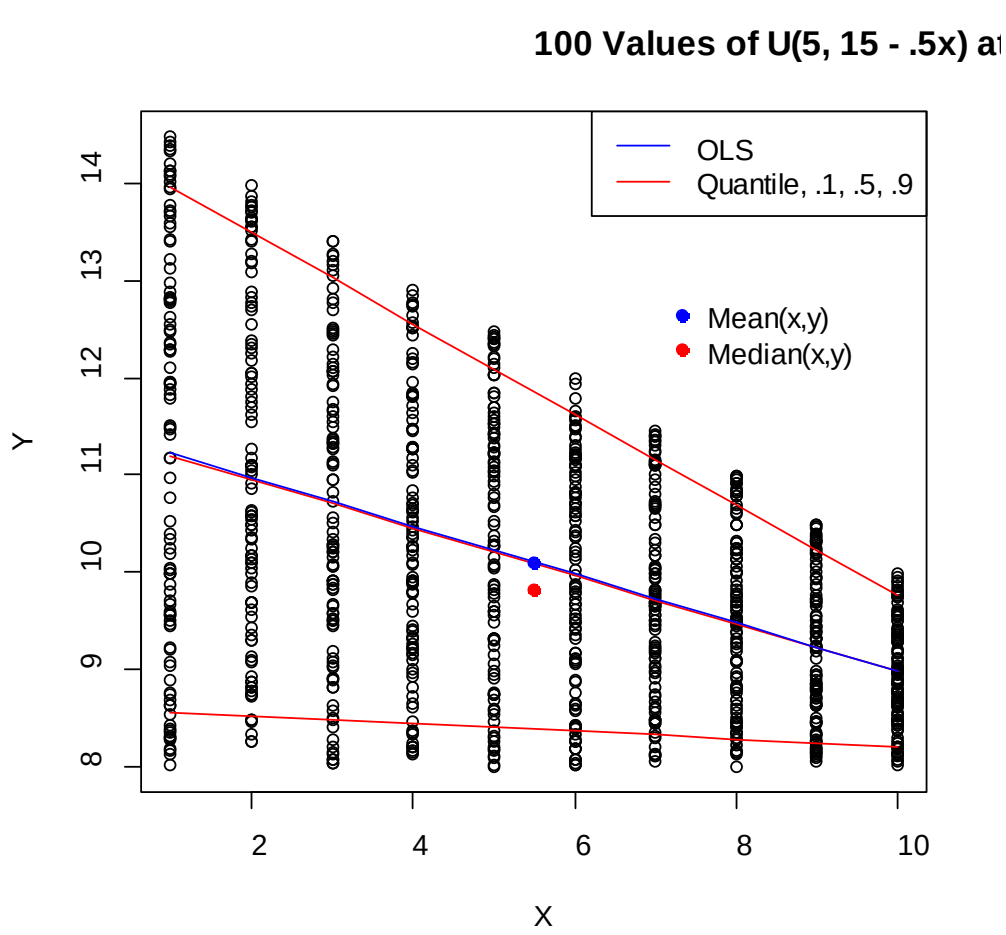
- Can trace out the full distribution by estimating across many quantiles.

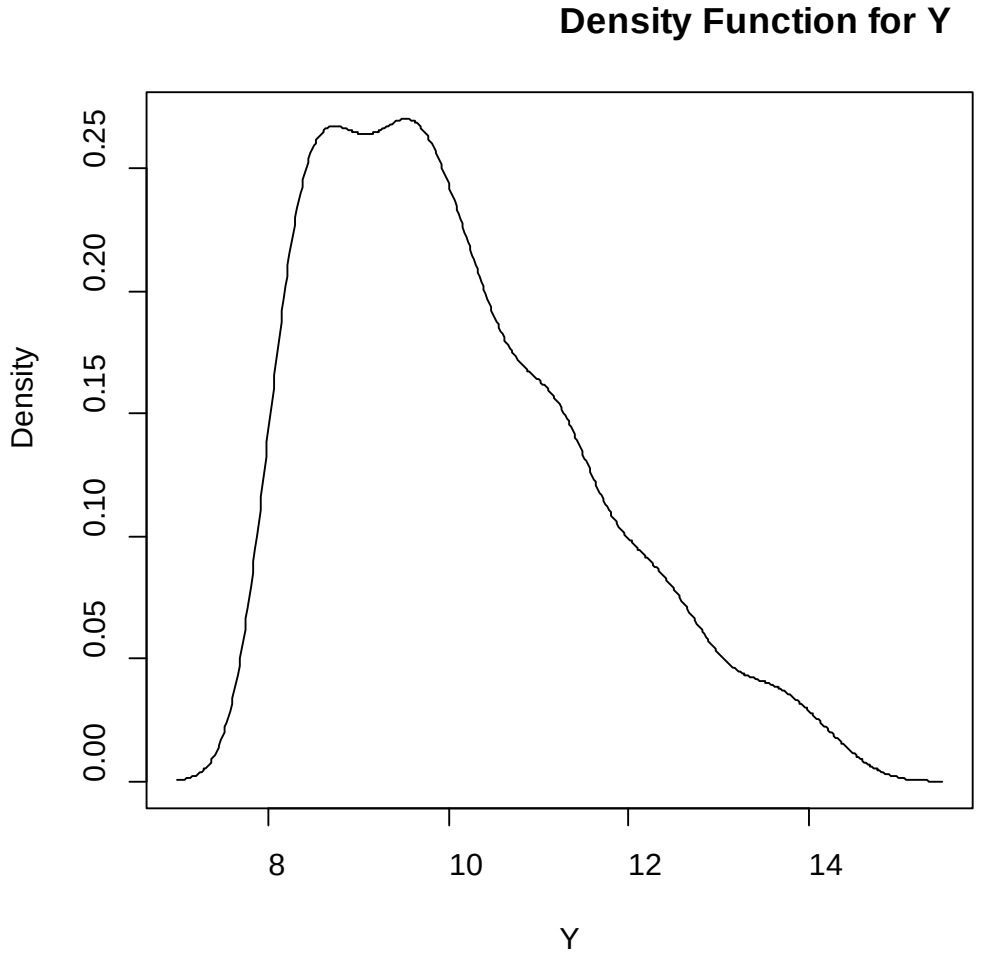
Predicted Densities

- $Q_Y(q|X_i) = \alpha(q) + \beta(q)X_i$
- At a given value of X = δ: $Q_Y(q|X = \delta) = \alpha(q) + \beta(q)\delta$
- Estimating at many values of q implies a distribution of values at $X = \delta$
- Example: Estimate for q = 0.02, .03, .., .98. (97 values of q)
- Calculate kernel density functions of predicted values at $X = \delta_1$ and $X = \delta_2$:
  - $\alpha(q) + \beta(q)\delta_1$ and $\alpha(q) + \beta(q)\delta_2$, where q = 0.02, .03, .., .98
- Key simplification for experiments is that X is discrete. Makes it possible to directly compare actual and predicted densities

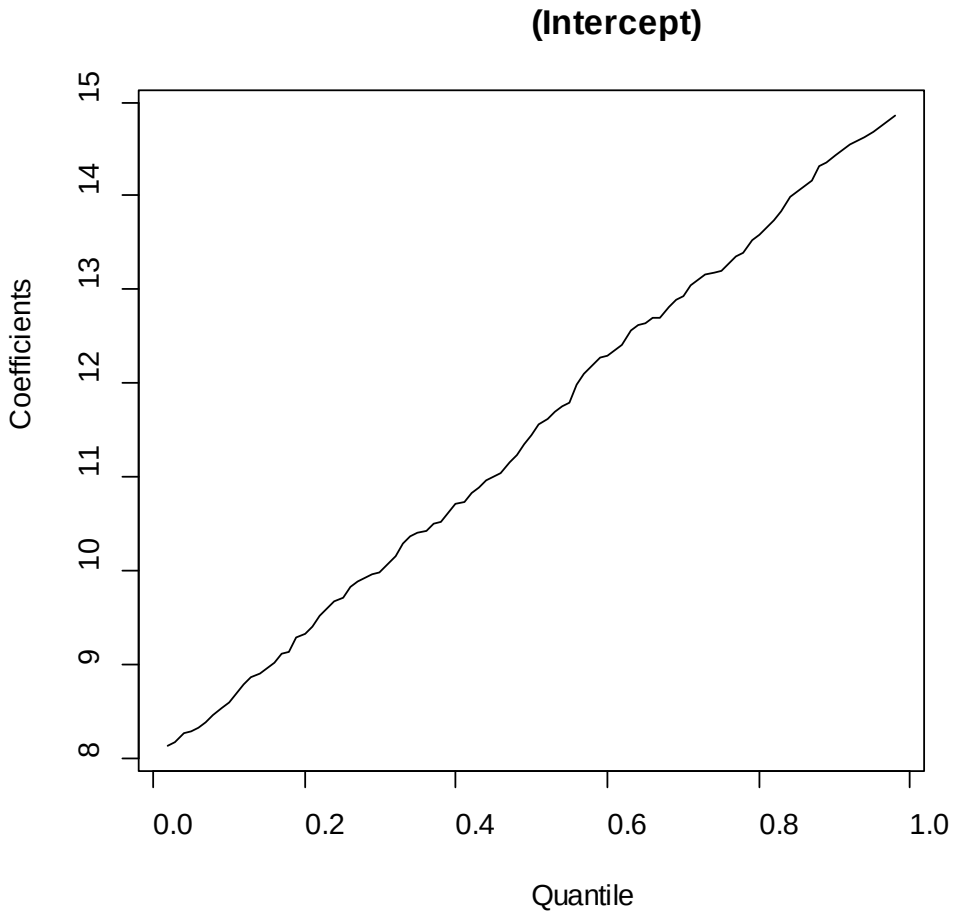
Illustration for a Single Explanatory Variable:

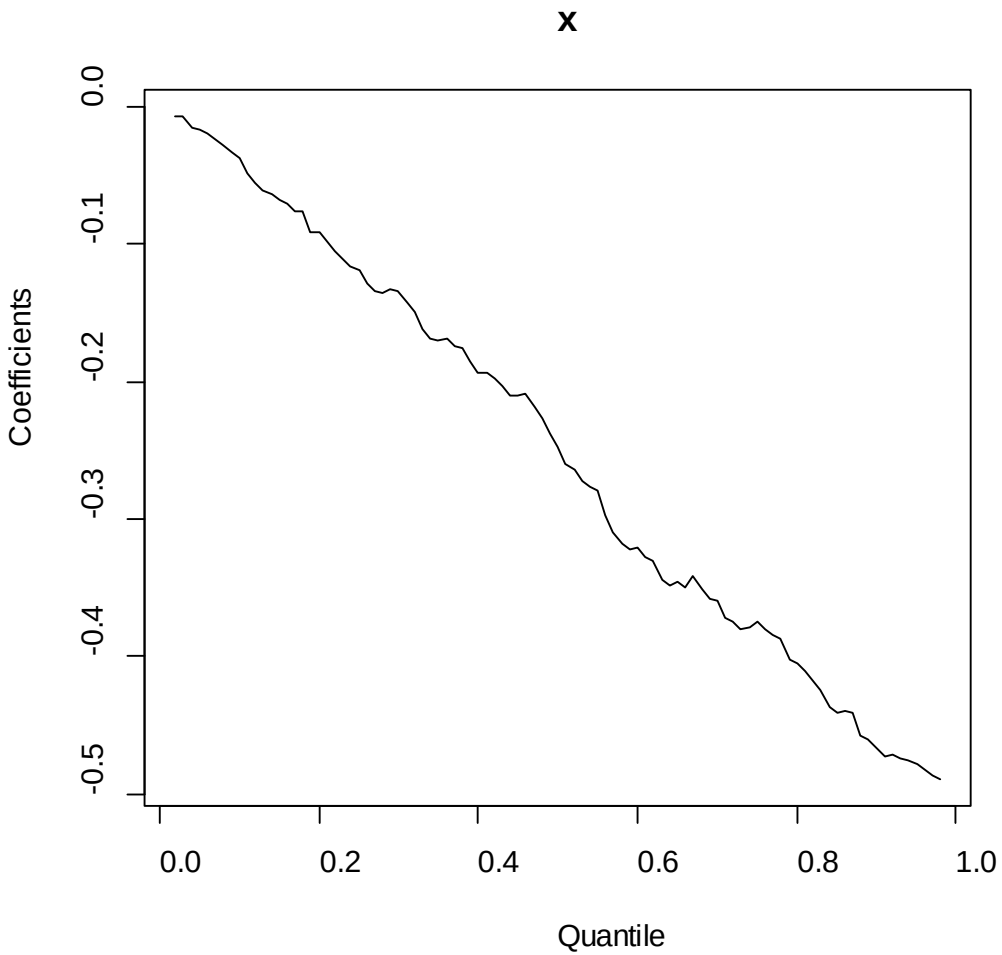
$$Q_Y(q|X_i) = \alpha(q) + \beta(q)X_i$$



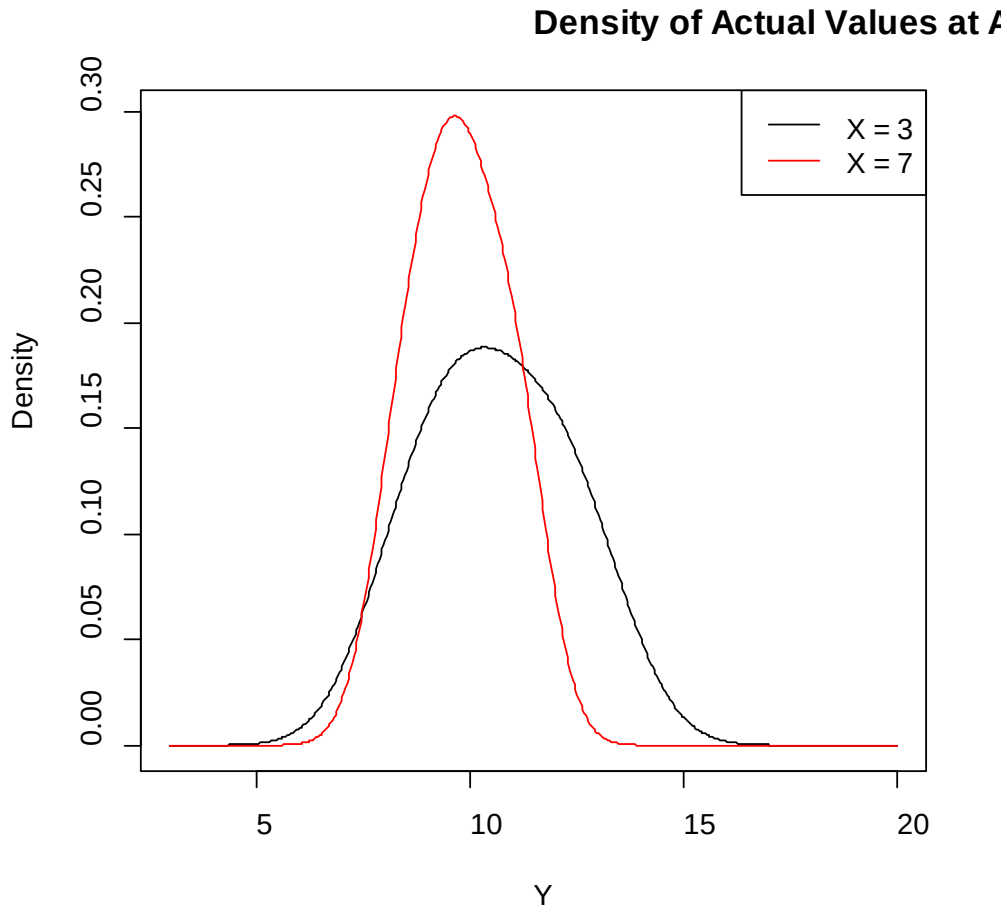


Estimated Coefficients across Quantiles

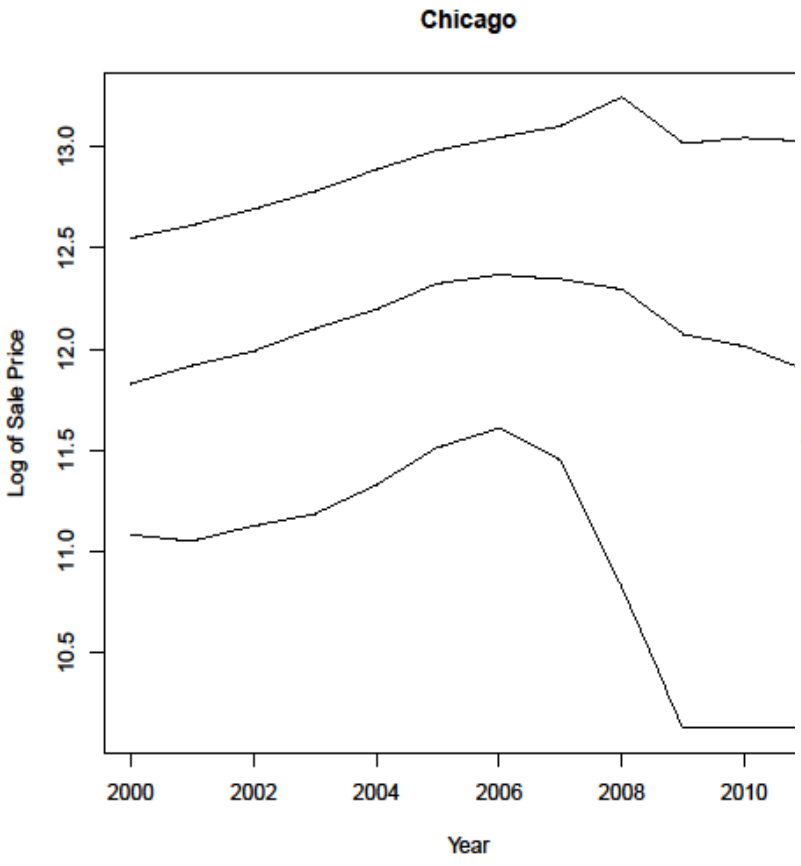


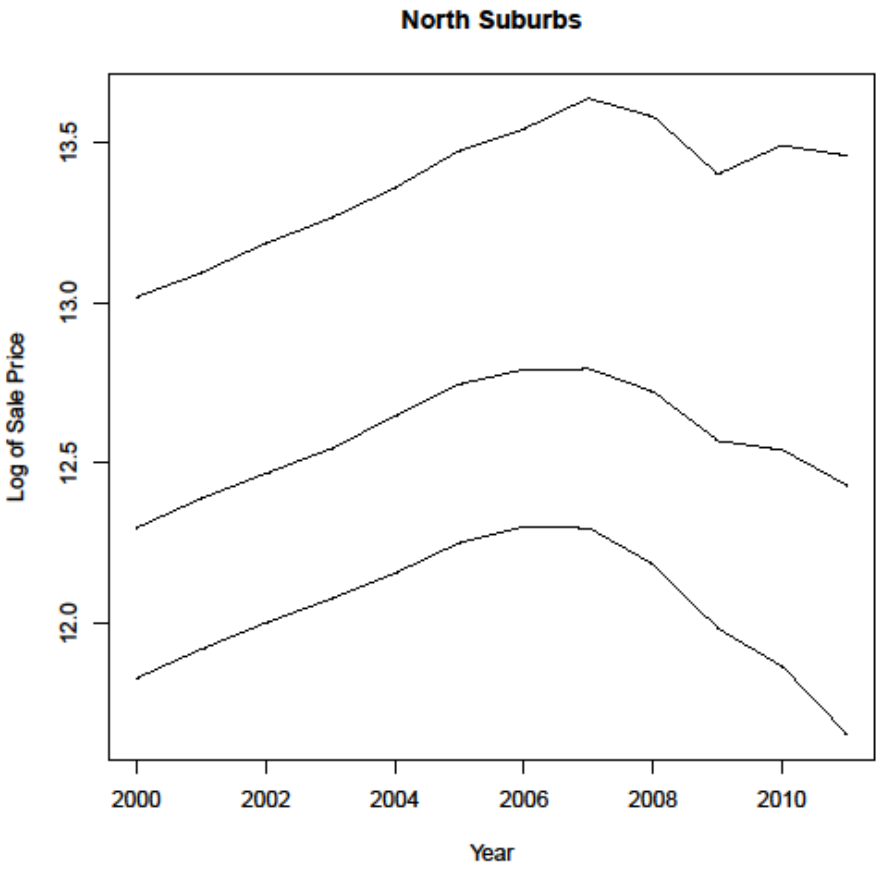


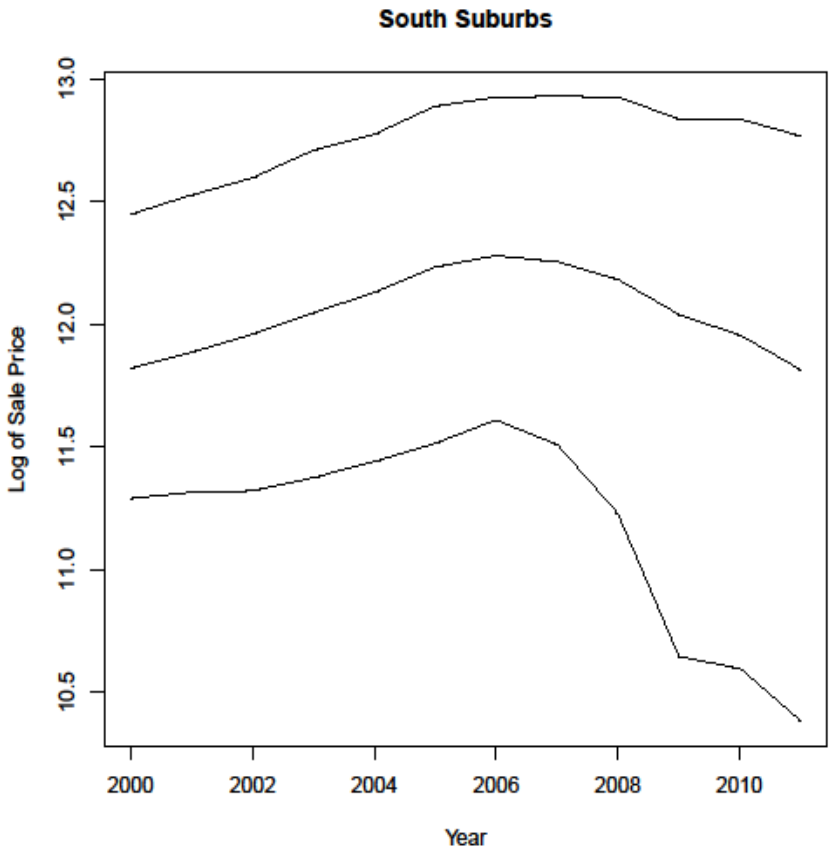
Actual and Predicted Densities at X = 3 and X = 7



Sale Price Densities by Year, 10%, 50%, 90%: Chicago



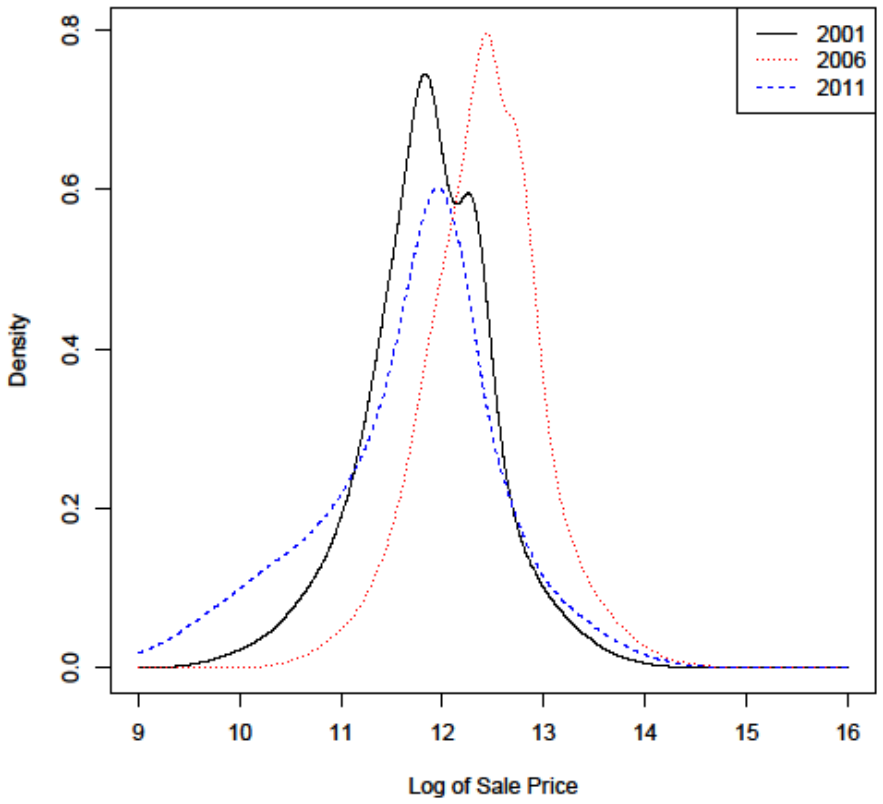




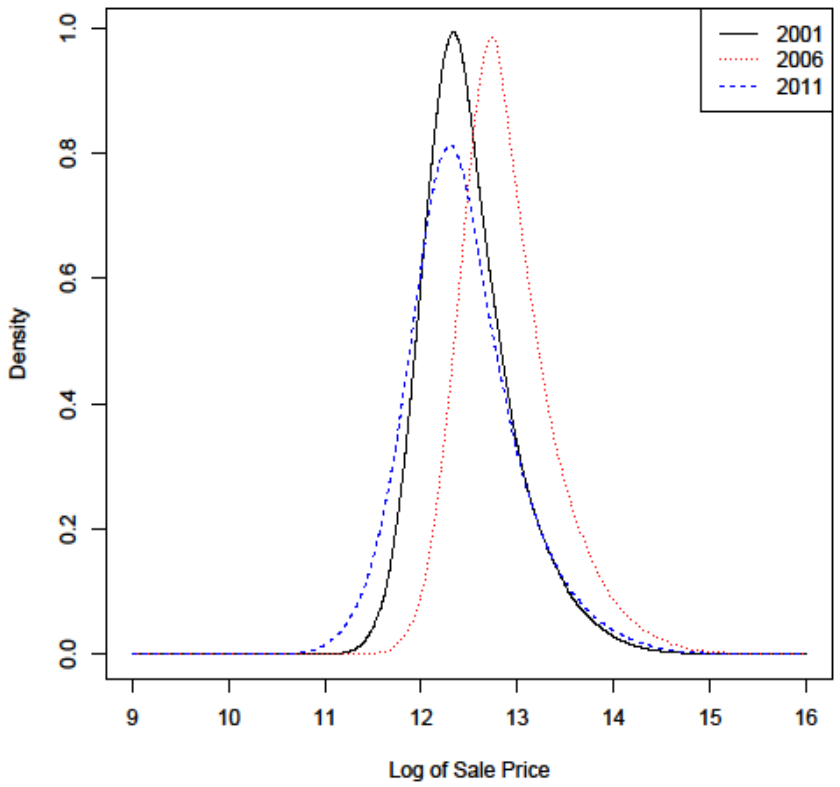
Sale Price Densities

Kernel density estimates from quantile regressions, q=.03, .05, …, .97 (B = 48). Pooled data from 2000, 2006, 2011. Predictions using actual data with dummy variables set to counterfactual values.

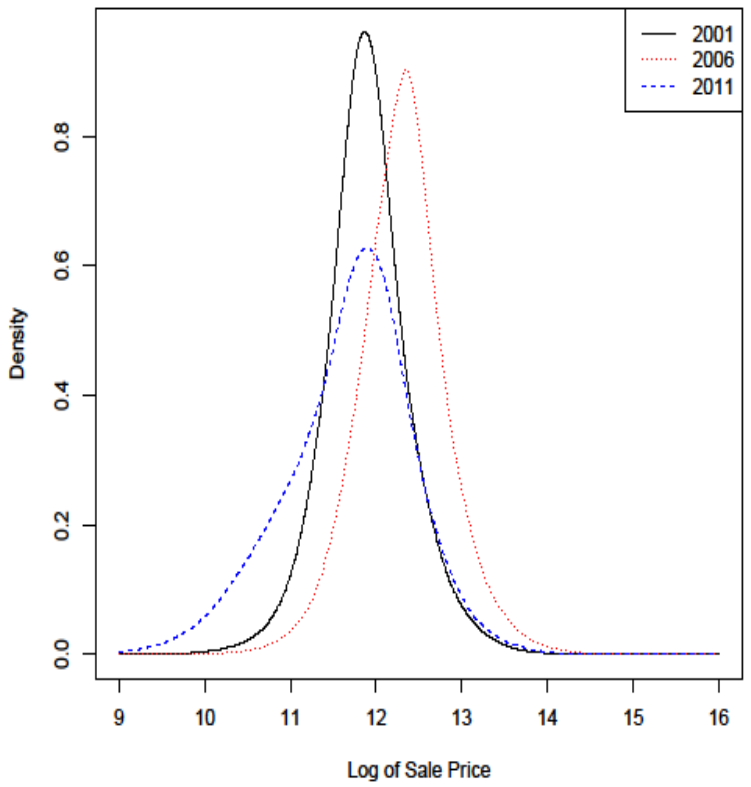
Chicago



North Suburbs

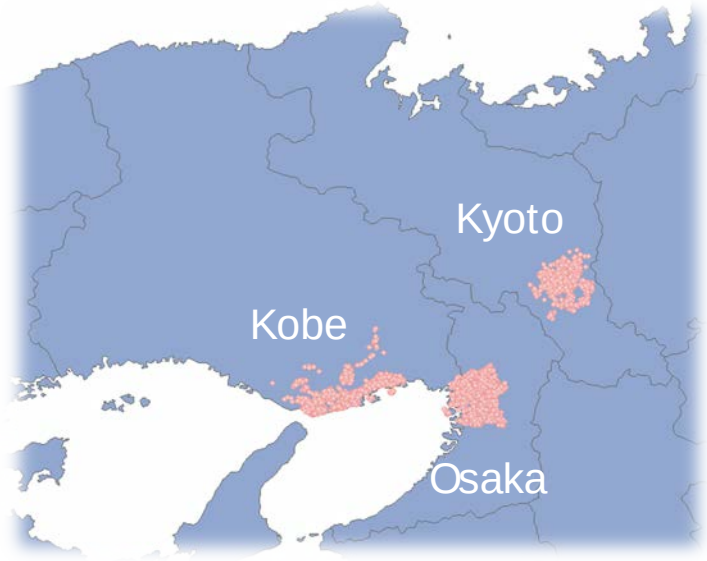


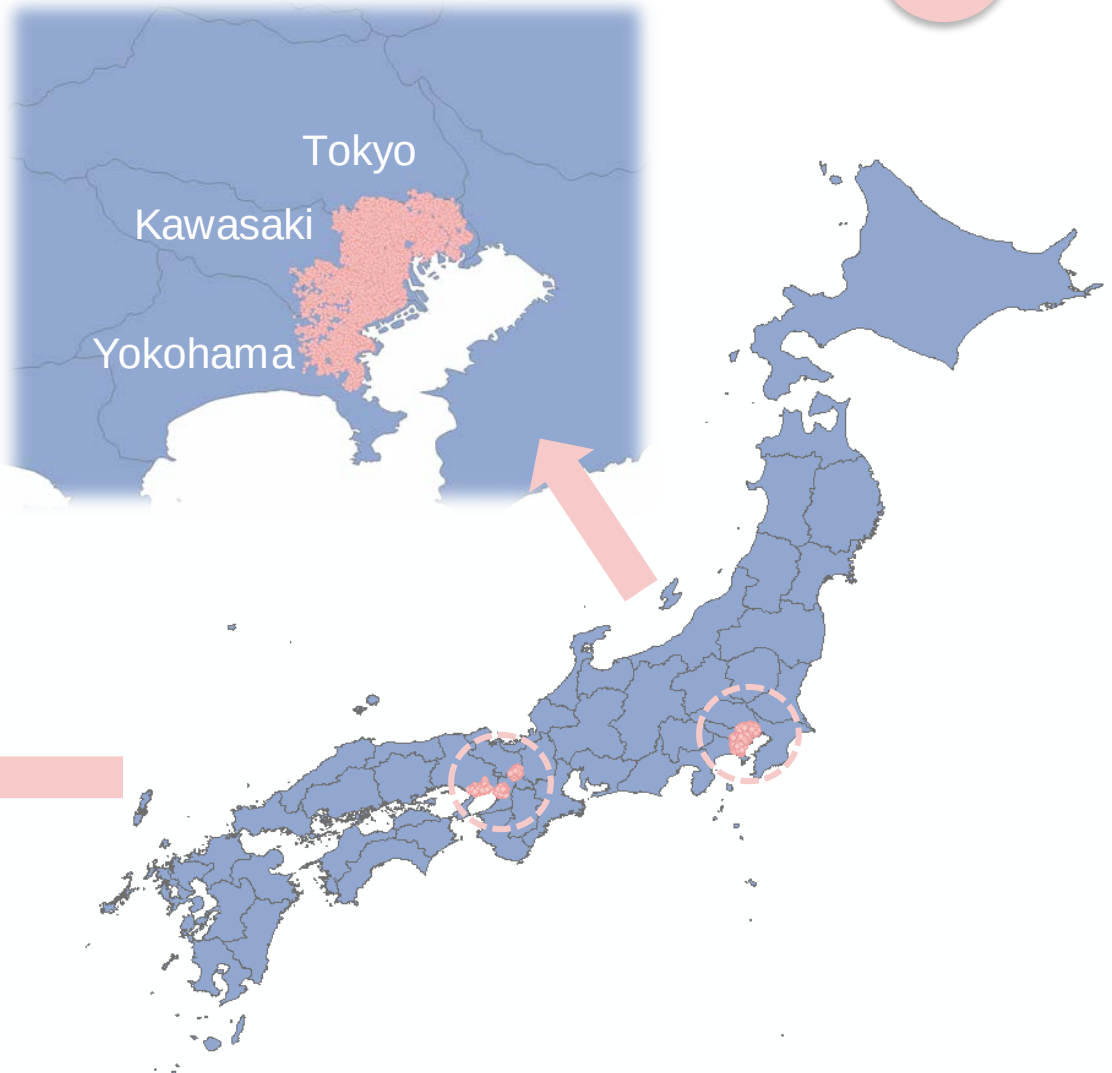
South Suburbs



Data

- Japan Condominium Listing Data
  - From 1986 to 2015
  - Provided by Recruit Co., Ltd.
  - Tokyo 241,702 observations
  - Six cities 482,677 observations



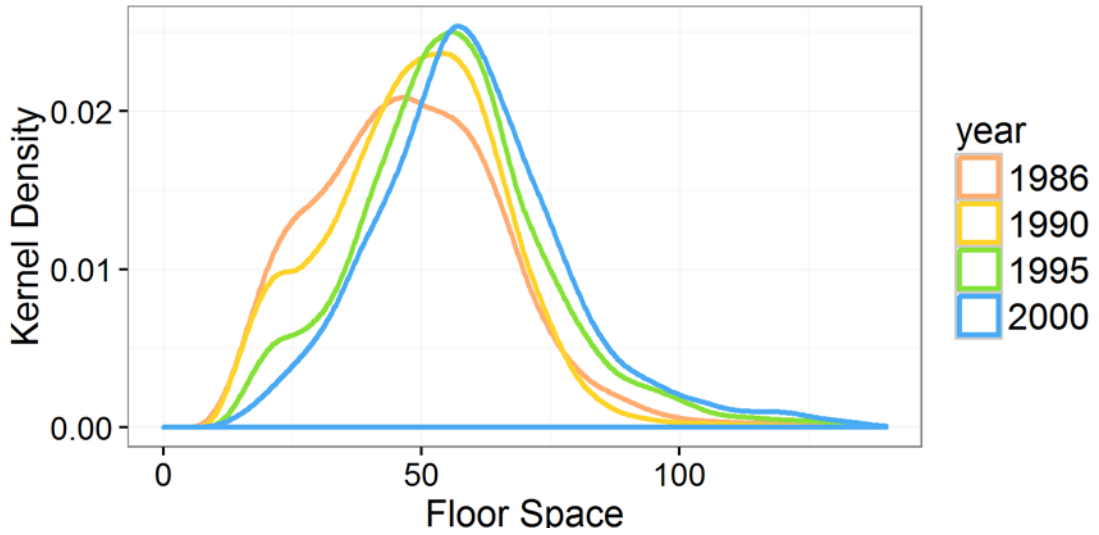


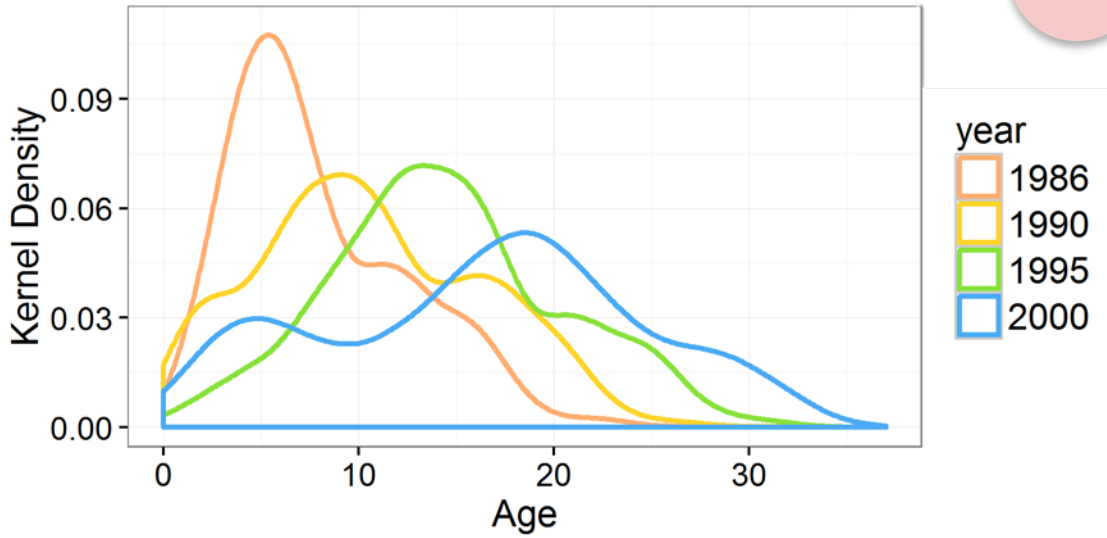
Summary Statistics: Tokyo

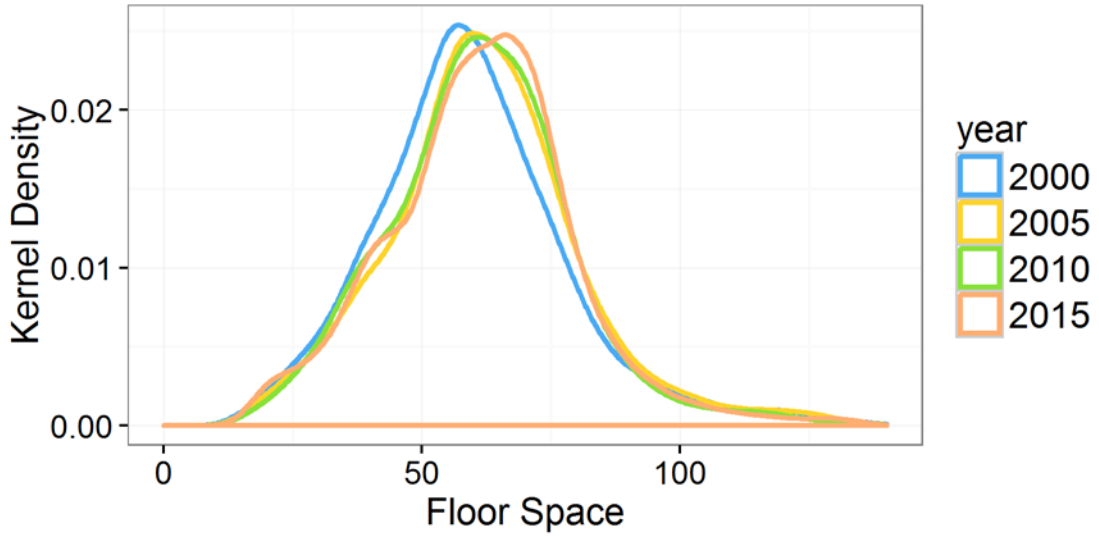
- Asset bubble
  - Boom: 1986-1990
  - Burst: 1990-2000
- Change in structures
  - Properties in 1986, 1990 are new and small
  - Age increases

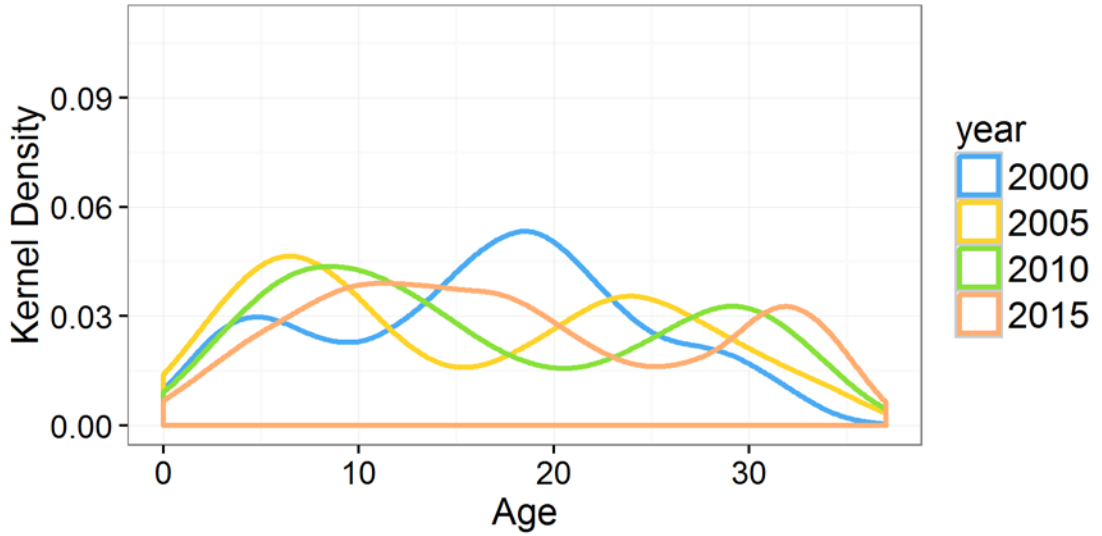
	(1) Full	(2) 1986	(3) 1990	(4) 1995	(5) 2000	(6) 2005	(7) 2010	(8) 2015
Listing Price (10,000 Yen)	3740.6 (1824.6)	2568.9 (1425.9)	5500.5 (1854.9)	3586.1 (1714.3)	2924.0 (1504.7)	3164.1 (1576.7)	3460.0 (1529.7)	3958.3 (1727.5)
Unitprice (Price/Area)	68.22 (31.67)	56.60 (28.78)	119.2 (40.22)	63.96 (18.02)	48.21 (14.30)	50.59 (16.21)	56.90 (18.16)	65.42 (22.05)
Floor Space (m^2)	56.82 (18.53)	47.93 (17.86)	48.89 (16.39)	55.92 (18.50)	59.67 (18.80)	62.01 (18.58)	61.13 (17.63)	61.39 (18.06)
Age of building (year)	14.74 (8.217)	7.995 (4.564)	10.60 (5.781)	14.46 (6.007)	16.24 (8.114)	15.69 (9.865)	16.67 (9.960)	17.80 (9.715)
Time to Nearest Station (minutes)	7.321 (4.191)	7.111 (4.155)	7.408 (4.206)	7.197 (4.134)	7.236 (4.126)	7.178 (4.089)	7.422 (4.289)	7.709 (4.266)
Time to Tokyo (minutes)	26.20 (8.414)	25.13 (8.339)	26.71 (8.023)	26.55 (8.480)	26.44 (8.517)	25.94 (8.380)	26.71 (8.577)	26.16 (8.601)
SRC (dummy)	0.489 (0.500)	0.579 (0.494)	0.540 (0.498)	0.531 (0.499)	0.508 (0.500)	0.443 (0.497)	0.387 (0.487)	0.310 (0.463)
Observations	241702	4942	8299	13859	4525	4721	3969	10918

Tokyo: Kernel Density of Floor Space and Age









Summary Statistics: Six Cities

	(1) Tokyo		(2) Yokohama		(3) Kawasaki		(4) Kyoto		(5) Osaka		(6) Kobe	
	1990	2015	1990	2015	1990	2015	1990	2015	1990	2015	1990	2015
Listing Price (10,000 Yen)	5500.5 (1854.9)	3958.3 (1727.5)	4721.1 (1484.2)	2951.6 (989.1)	5198.5 (1615.6)	3305.5 (1079.1)	4772.2 (1738.1)	2529.5 (1370.3)	5503.8 (1728.0)	2416.7 (907.6)	4705.8 (1682.6)	2322.1 (1072.8)
Unitprice (Price/Area)	119.2 (40.22)	65.42 (22.05)	83.05 (22.55)	42.33 (12.04)	90.28 (20.54)	47.52 (14.73)	84.46 (25.46)	39.28 (16.36)	97.62 (31.67)	35.68 (10.75)	75.29 (25.57)	31.33 (11.67)
Floor Space (m^2)	48.89 (16.39)	61.39 (18.06)	59.29 (17.90)	70.17 (14.78)	59.31 (17.10)	70.04 (13.03)	58.65 (17.05)	64.64 (18.83)	58.67 (15.24)	67.89 (14.50)	63.99 (14.11)	74.40 (16.16)
Age of building (year)	10.60 (5.781)	17.80 (9.715)	8.943 (5.832)	18.77 (8.289)	8.983 (5.604)	16.68 (8.526)	8.416 (5.073)	16.63 (9.096)	9.148 (4.764)	18.03 (9.750)	9.019 (5.702)	17.87 (8.056)
Time to Nearest Station (minutes)	7.408 (4.206)	7.709 (4.266)	10.38 (5.340)	10.01 (5.012)	9.701 (4.673)	9.977 (4.710)	8.552 (4.709)	8.074 (5.195)	6.752 (3.661)	6.150 (3.591)	9.040 (4.654)	7.359 (4.407)
Time to Terminal Station (minutes)	13.57 (6.352)	13.21 (6.506)	15.46 (7.918)	14.95 (8.174)	22.85 (7.447)	22.18 (7.617)	17.94 (8.855)	15.86 (8.965)	11.55 (6.428)	10.26 (6.108)	15.83 (6.909)	14.16 (7.901)
SRC (dummy)	0.540 (0.498)	0.310 (0.463)	0.227 (0.419)	0.150 (0.357)	0.308 (0.462)	0.156 (0.363)	0.394 (0.489)	0.178 (0.383)	0.797 (0.402)	0.513 (0.500)	0.334 (0.472)	0.308 (0.462)
Observations	8299	10918	4792	4069	1199	1377	558	815	3350	2692	1447	1430

Hedonic Regressions

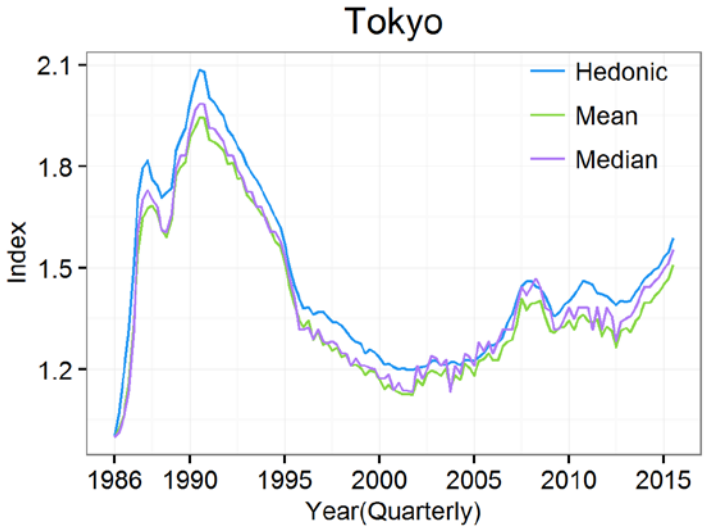
Hedonic regressions of six cities

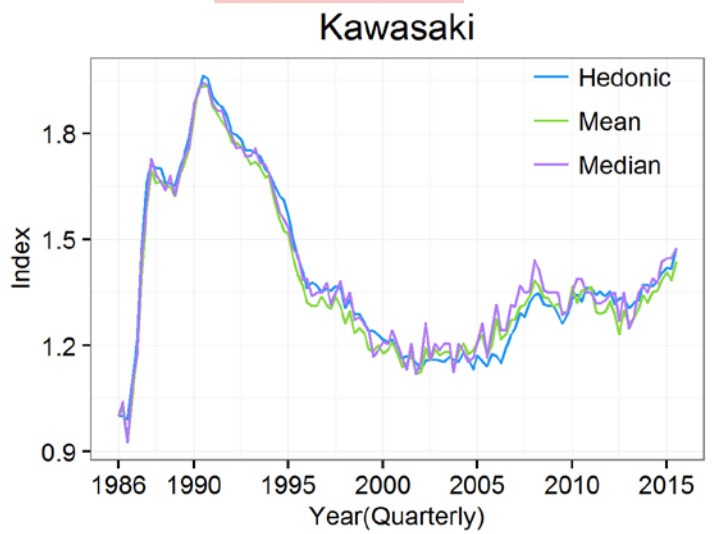
	(1) Tokyo		(2) Yokohama		(3) Kawasaki		(4) Kyoto		(5) Osaka		(6) Kobe	
	1990	2015	1990	2015	1990	2015	1990	2015	1990	2015	1990	2015
Floor Space (m^2)	0.0160*** (111.00)	0.0160*** (109.38)	0.0150*** (98.32)	0.0129*** (49.48)	0.0166*** (54.50)	0.0114*** (20.44)	0.0172*** (33.39)	0.0191*** (35.59)	0.0146*** (54.19)	0.0149*** (46.53)	0.0168*** (41.19)	0.0136*** (27.28)
Age (year)	-0.00937*** (-20.19)	-0.0154*** (-67.99)	-0.0128*** (-31.76)	-0.0152*** (-38.70)	-0.0136*** (-18.13)	-0.0178*** (-26.68)	-0.0184*** (-11.62)	-0.0245*** (-24.00)	-0.0148*** (-18.65)	-0.0223*** (-51.35)	-0.0126*** (-12.45)	-0.0221*** (-27.93)
Time to Nearest Station (minutes)	-0.0109*** (-20.14)	-0.0178*** (-36.82)	-0.0111*** (-26.00)	-0.0162*** (-23.89)	-0.0142*** (-14.46)	-0.0208*** (-17.34)	-0.00874*** (-4.47)	-0.0254*** (-15.91)	-0.0211*** (-20.10)	-0.0169*** (-18.01)	-0.00795*** (-6.51)	-0.0204*** (-13.12)
Time to Terminal Station (minutes)	-0.0182*** (-49.27)	-0.0181*** (-47.47)	-0.00146*** (-4.74)	-0.00432*** (-9.50)	-0.00394*** (-4.40)	-0.0129*** (-12.58)	-0.00141 (-1.43)	-0.00840*** (-8.75)	-0.0173*** (-28.24)	-0.0185*** (-32.64)	-0.0135*** (-12.70)	-0.0182*** (-17.90)
SRC (dummy)	0.0155*** (3.13)	0.0234*** (4.71)	0.0409*** (7.23)	0.0658*** (7.03)	0.0196** (2.09)	0.0465*** (2.97)	0.0394** (2.21)	0.0565** (2.08)	0.0669*** (7.52)	0.0483*** (6.09)	-0.00722 (-0.61)	-0.0887*** (-6.03)
x	-0.959*** (-35.18)	-0.906*** (-38.55)	0.497*** (10.44)	0.490*** (6.71)	-0.276* (-1.92)	0.465*** (2.86)	-0.0374 (-0.14)	0.188 (0.72)	0.891*** (8.74)	1.418*** (12.47)	2.248*** (19.55)	0.344*** (3.03)
y	-1.153*** (-30.00)	-1.853*** (-48.29)	0.932*** (27.98)	1.176*** (21.22)	0.722*** (2.94)	3.195*** (11.95)	3.814*** (15.63)	4.328*** (15.37)	-0.495*** (-5.23)	0.512*** (5.06)	-2.390*** (-8.36)	1.066*** (3.59)
Constant	183.3*** (47.54)	200.6*** (59.91)	-94.71*** (-14.22)	-102.6*** (-10.08)	20.75 (0.78)	-170.6*** (-5.67)	-120.7*** (-3.23)	-169.7*** (-4.53)	-95.42*** (-7.00)	-202.5*** (-13.22)	-213.2*** (-21.68)	-76.02*** (-6.62)
Observations	8299	10821	4792	4047	1199	1371	558	810	3350	2671	1447	1423
R^2	0.649	0.763	0.763	0.613	0.815	0.634	0.715	0.787	0.541	0.776	0.674	0.662

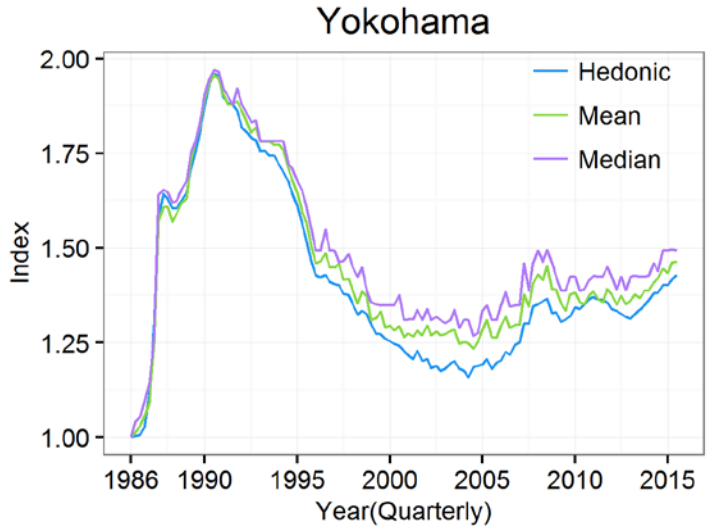
Note: Dependent variables is log(price); *t* statistics in parentheses; robust standard deviation are used

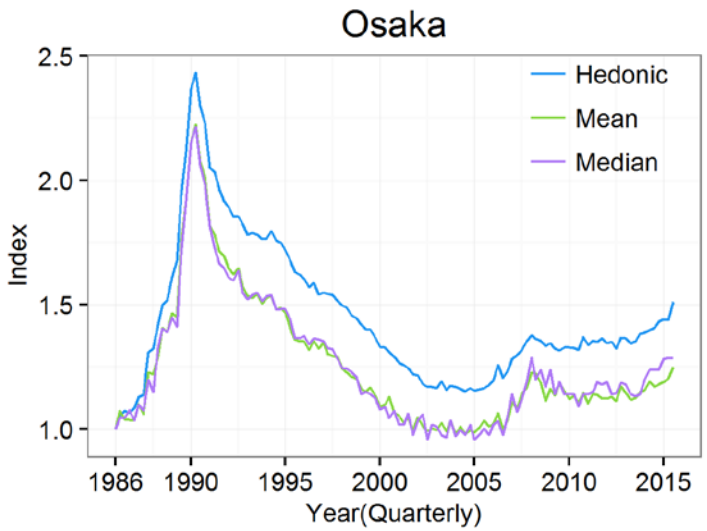
* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

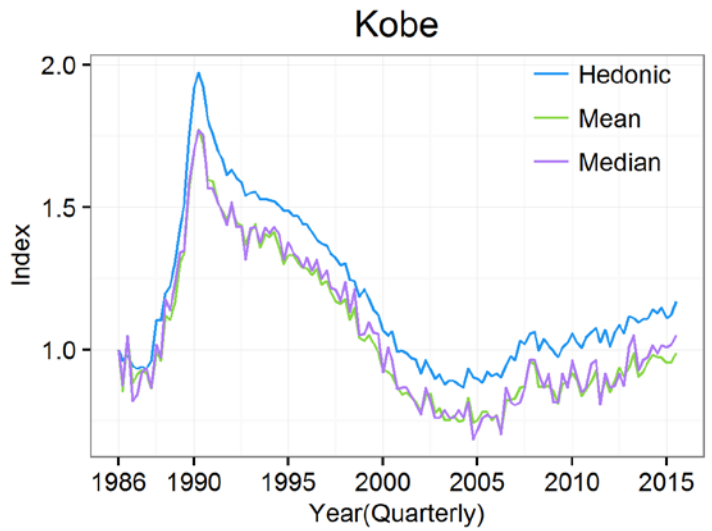
Hedonic, Mean and Median of Matched Sample

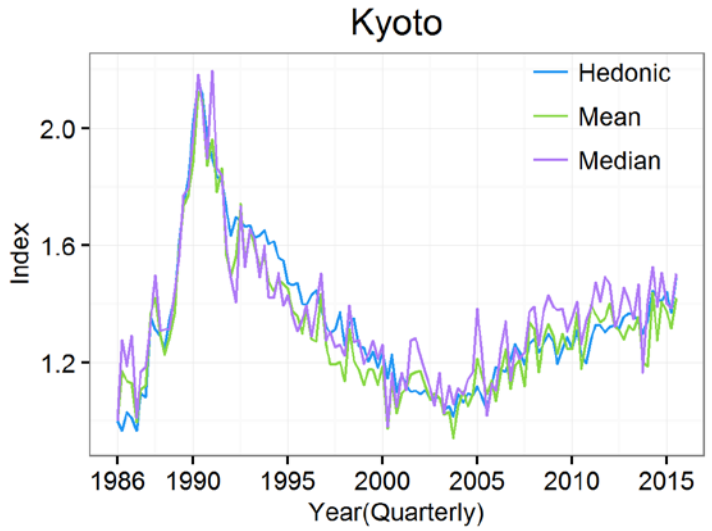




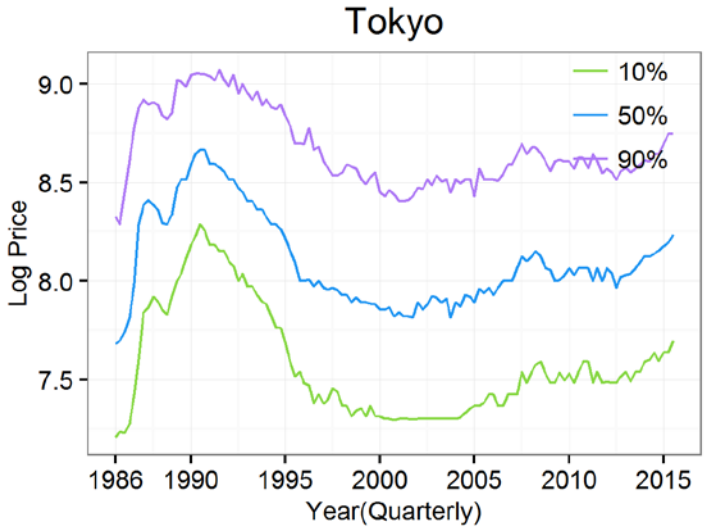


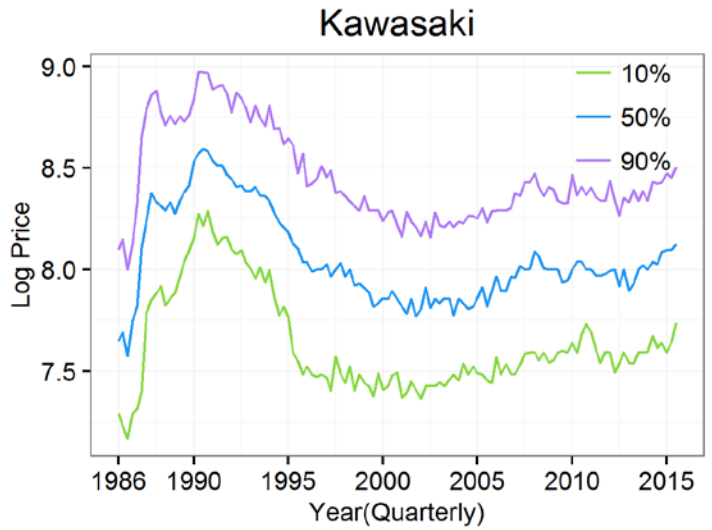


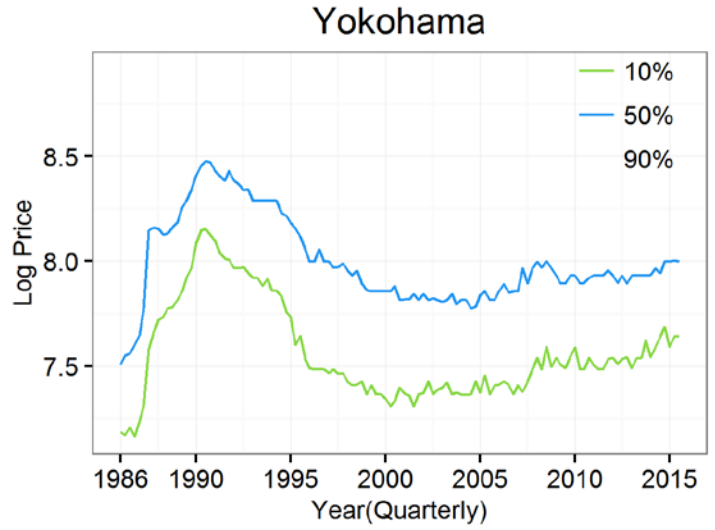


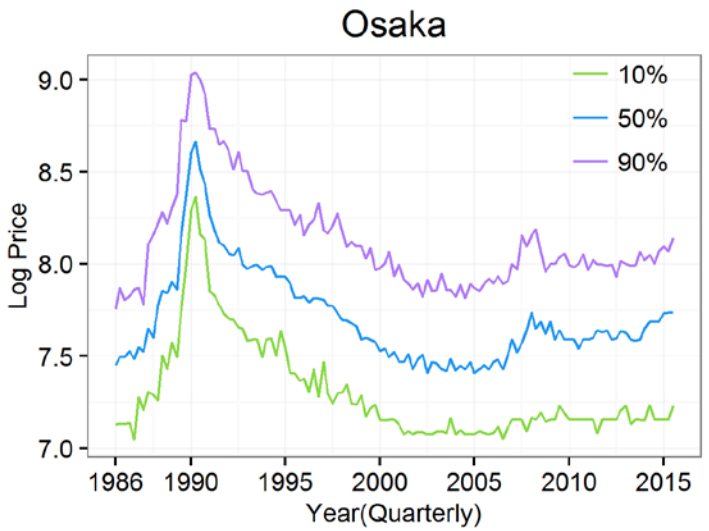


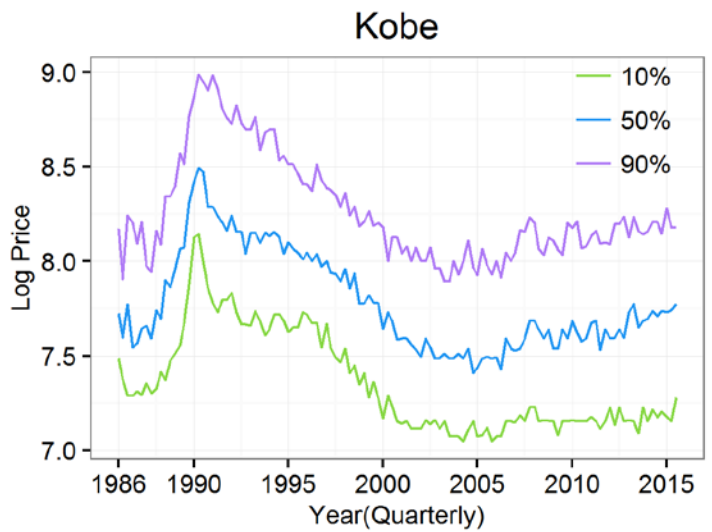
10%, 50% and 90% Percentile of Matched Sample

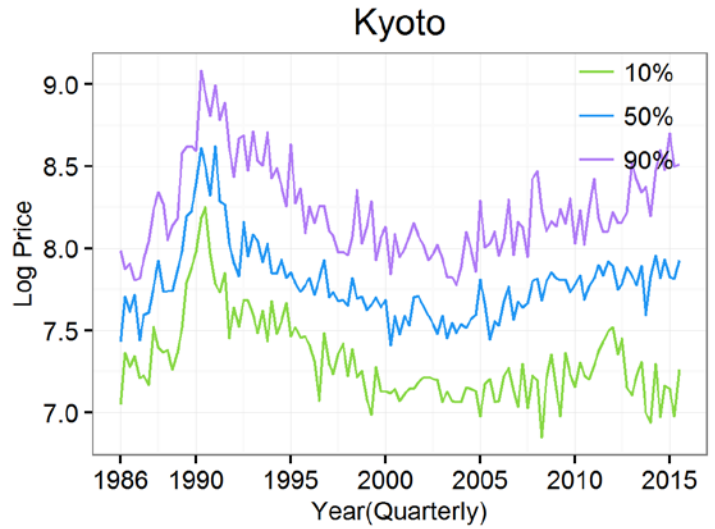




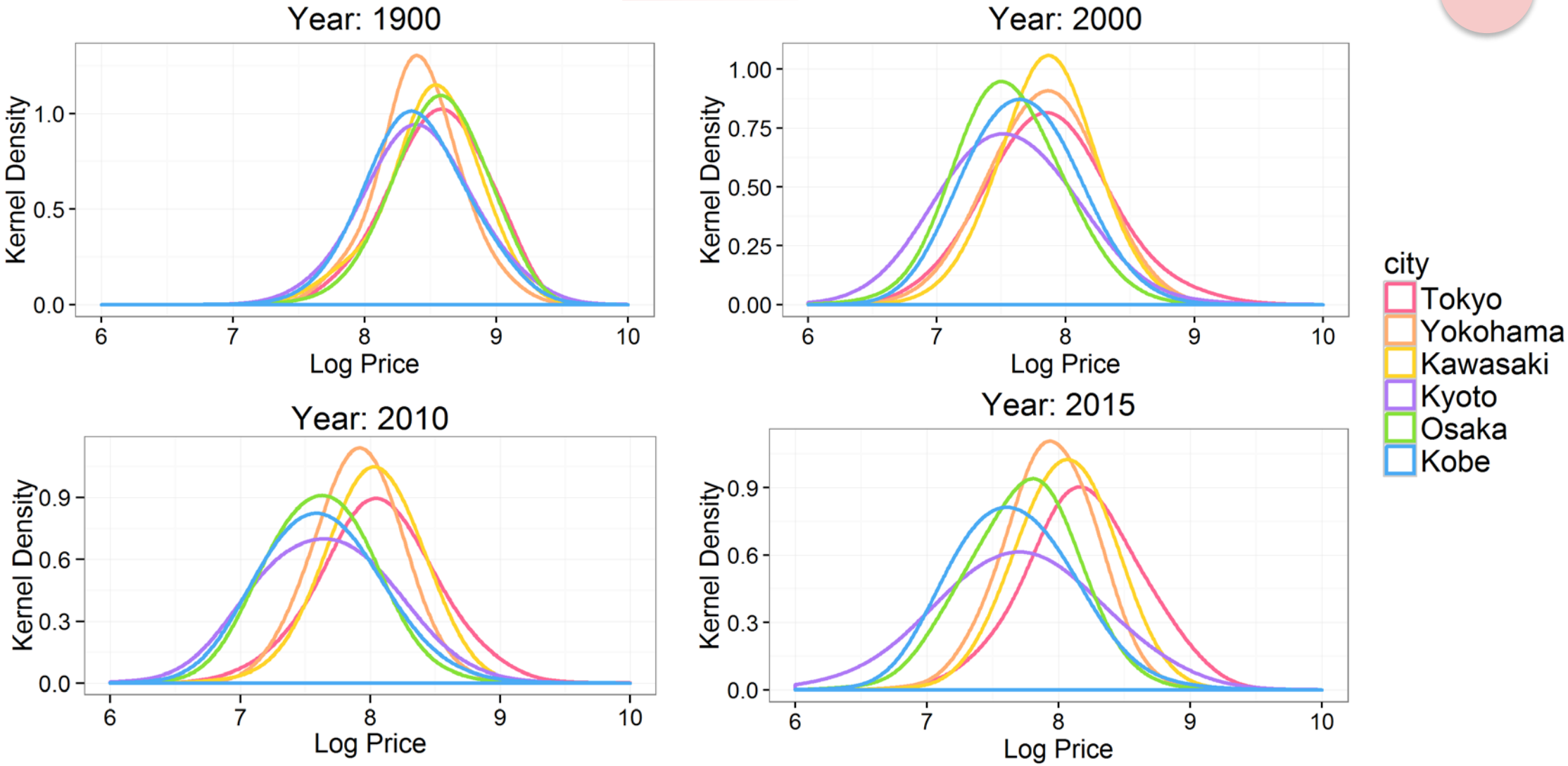




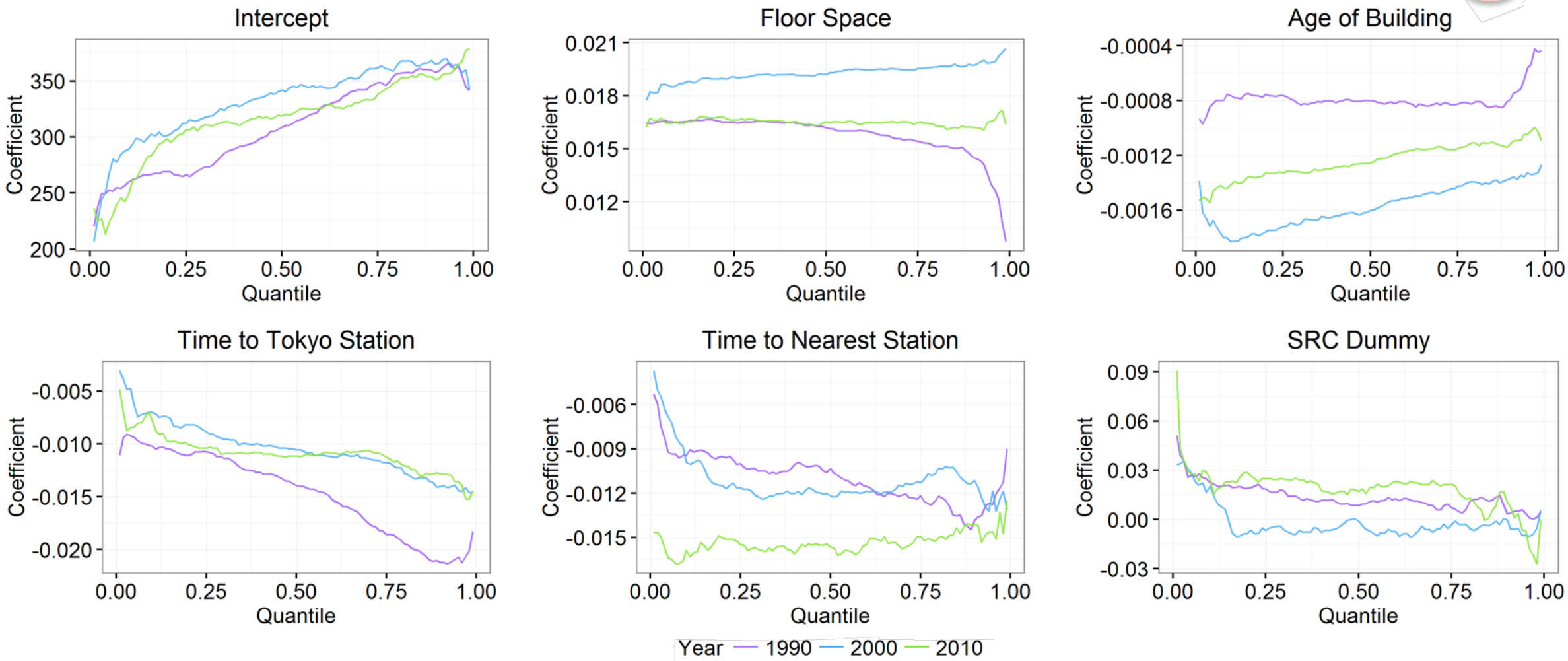




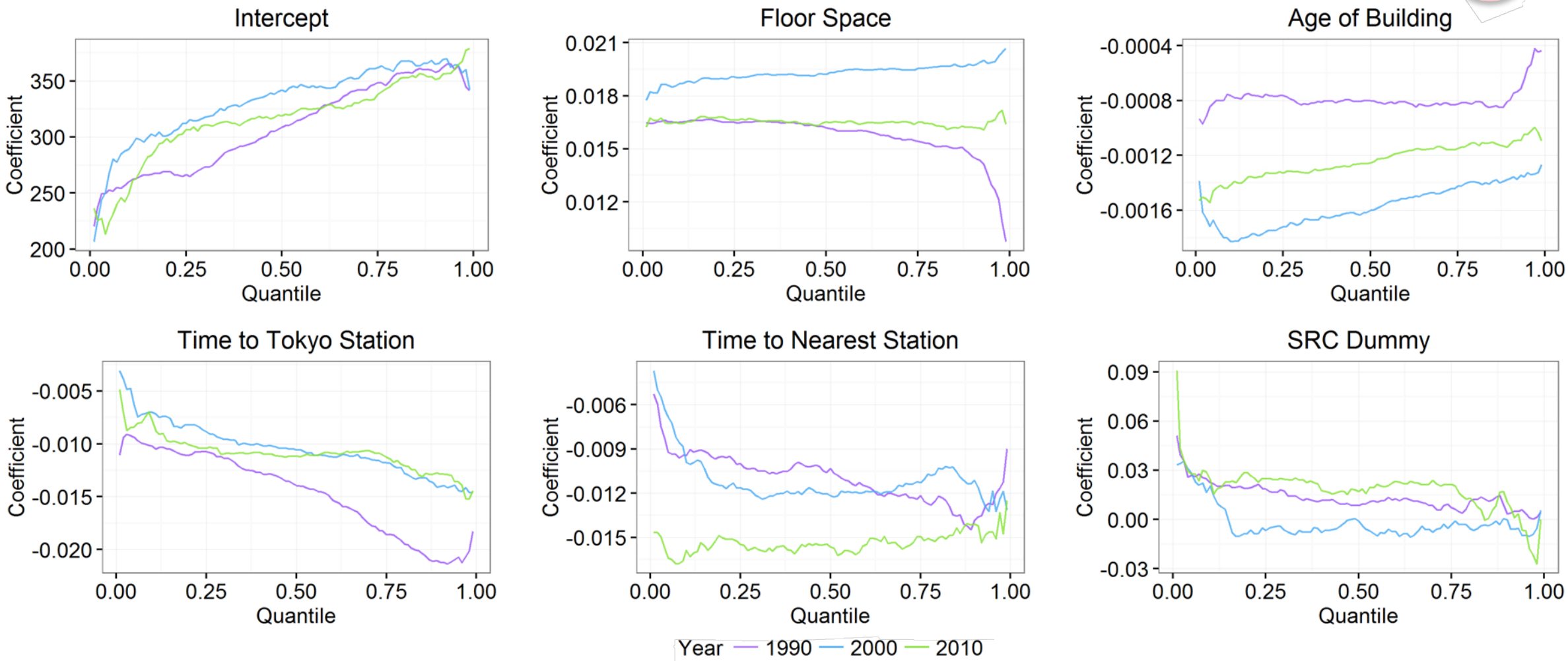
Cities: Kernel Density of Price



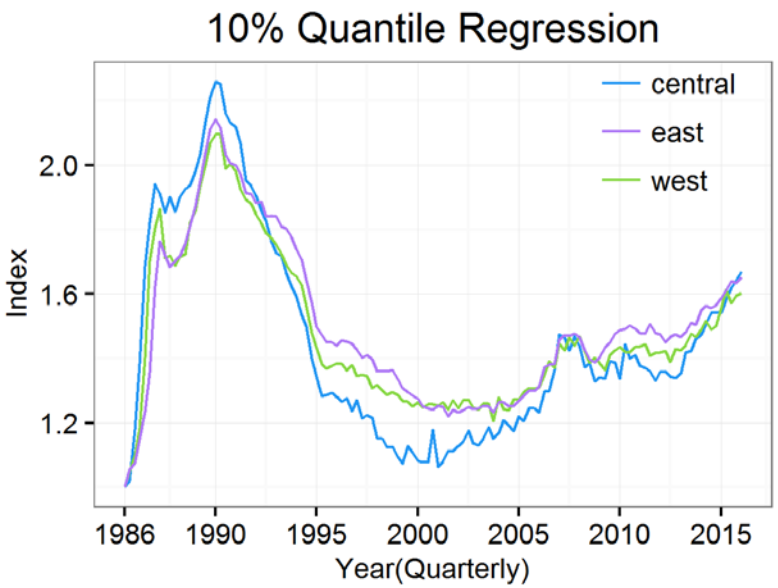
Tokyo: Quantile Regressions

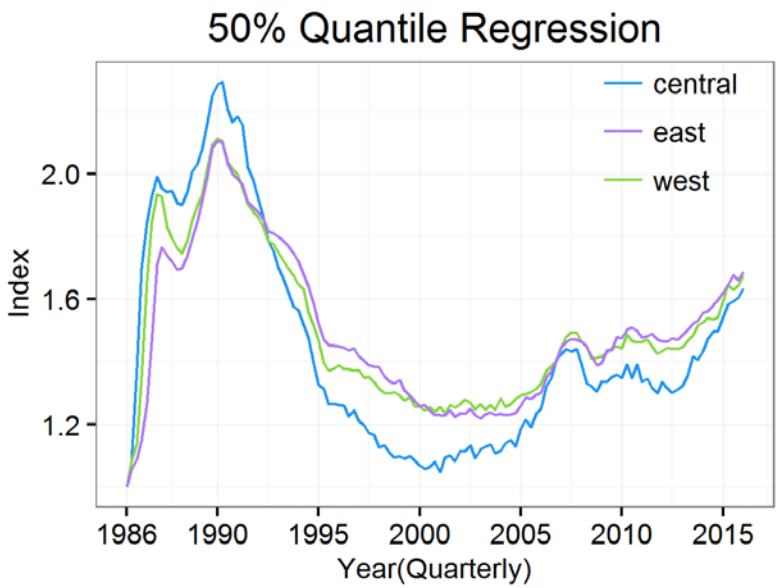


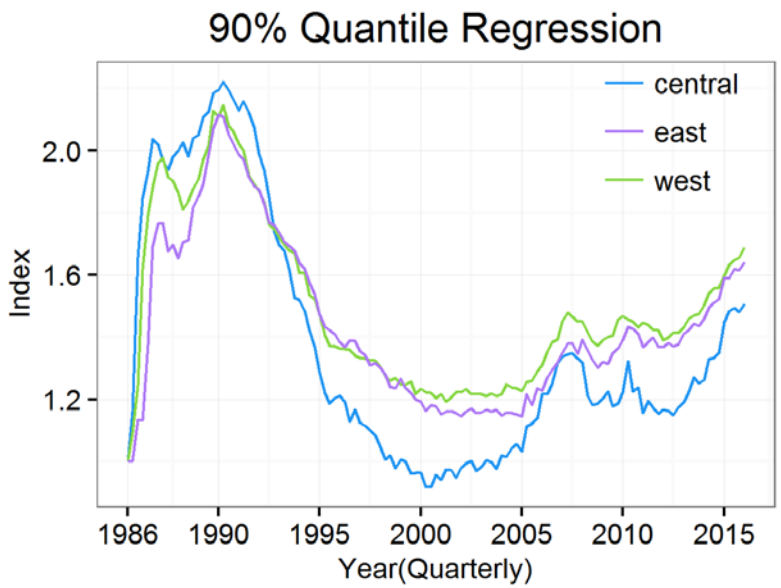
Tokyo: Quantile Regressions



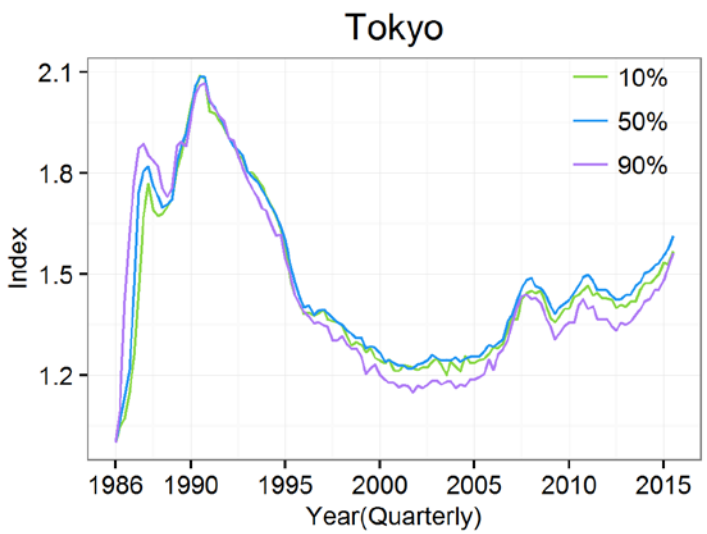
Tokyo Quantile Regressions by district

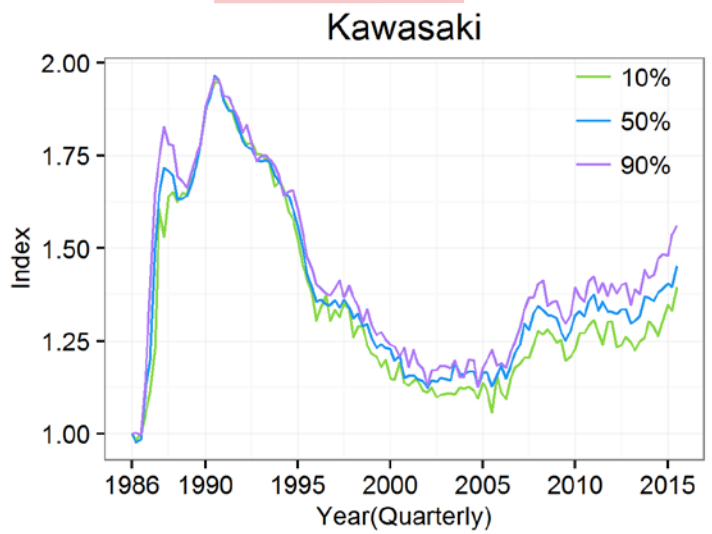


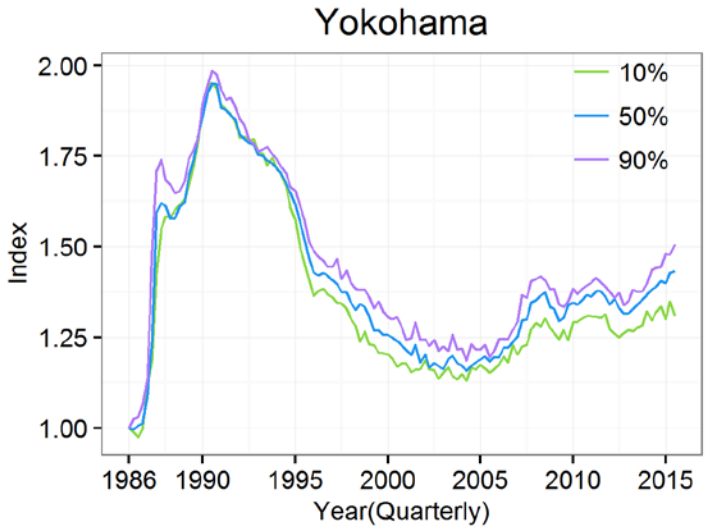


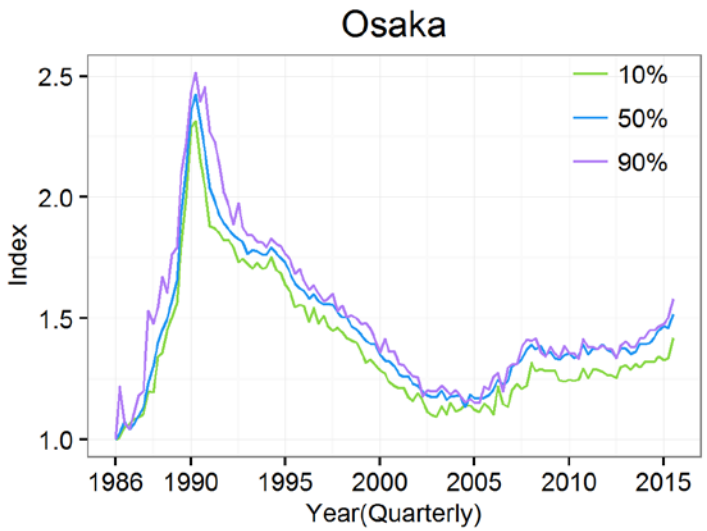


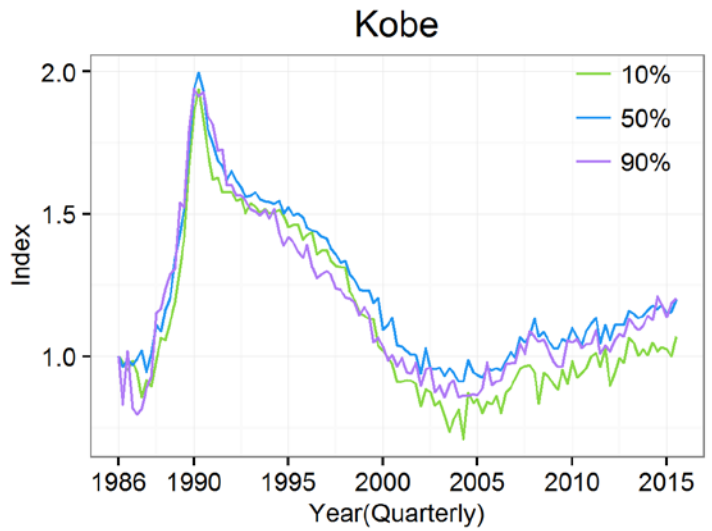
Quantile Regressions Index (Quarterly Time Dummy)

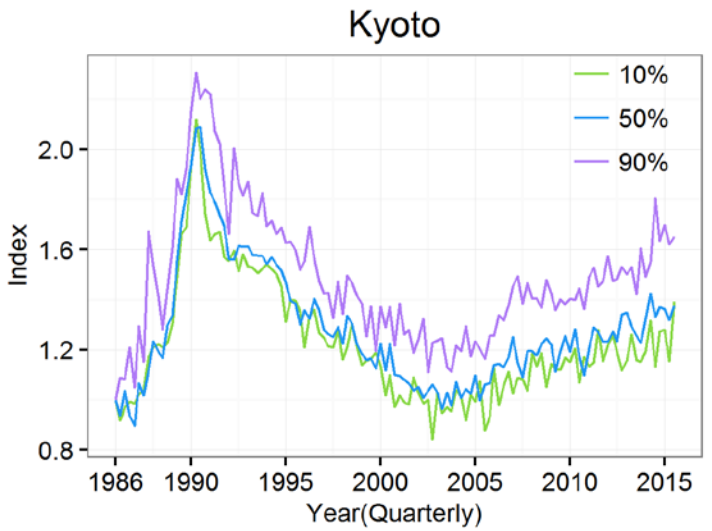




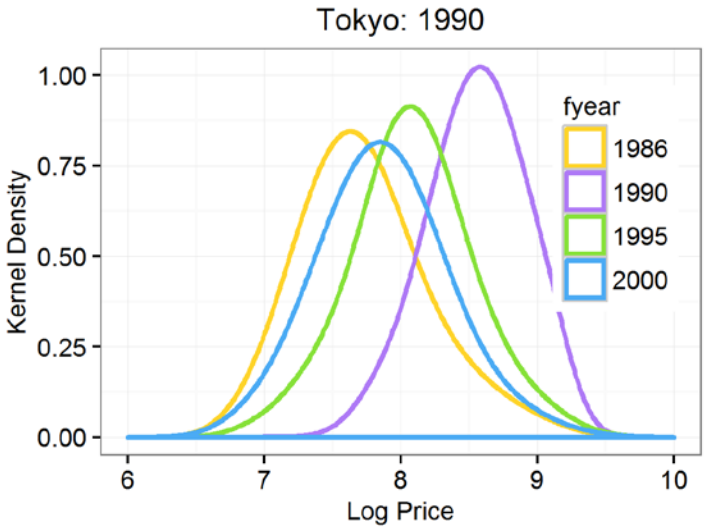


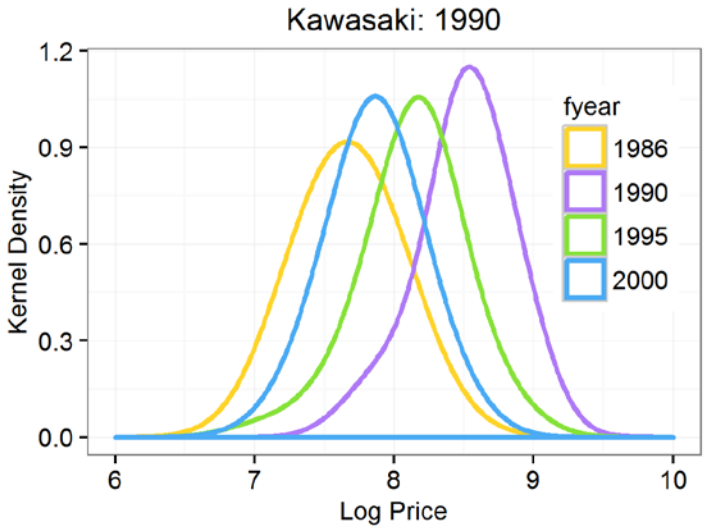


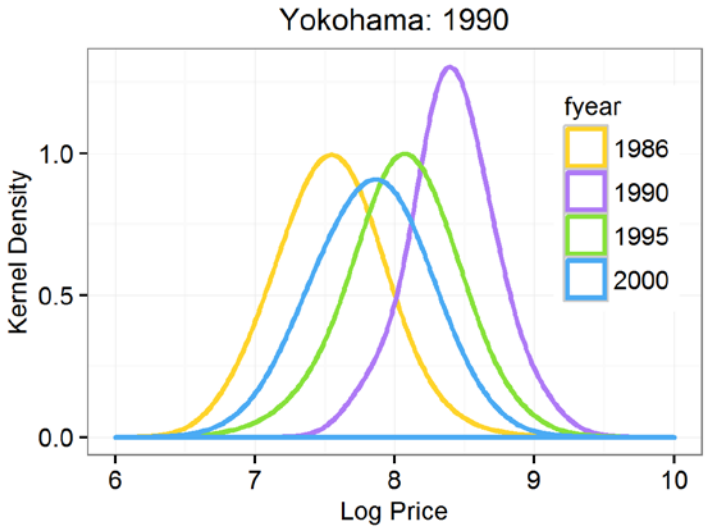


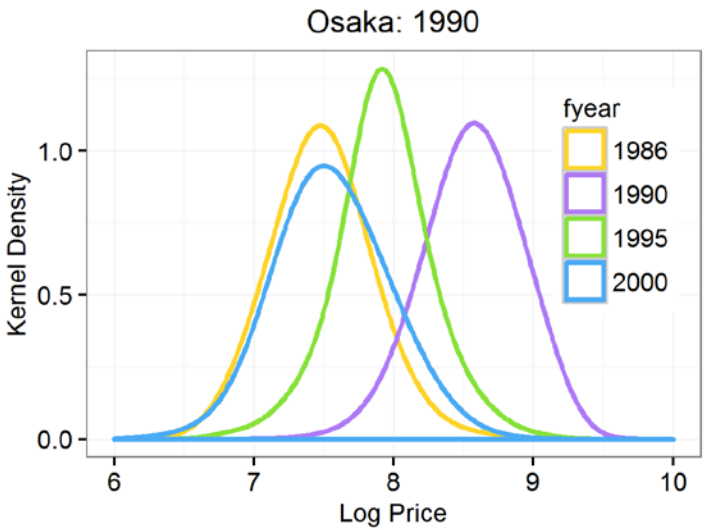


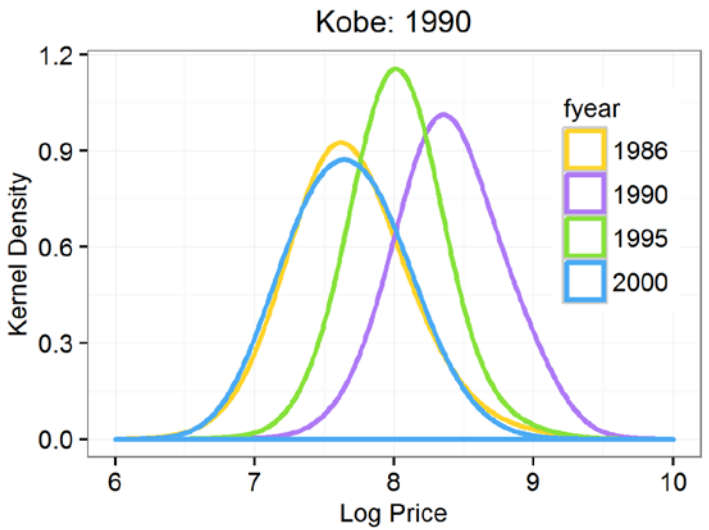
Kernel Density: asset bubble 1990

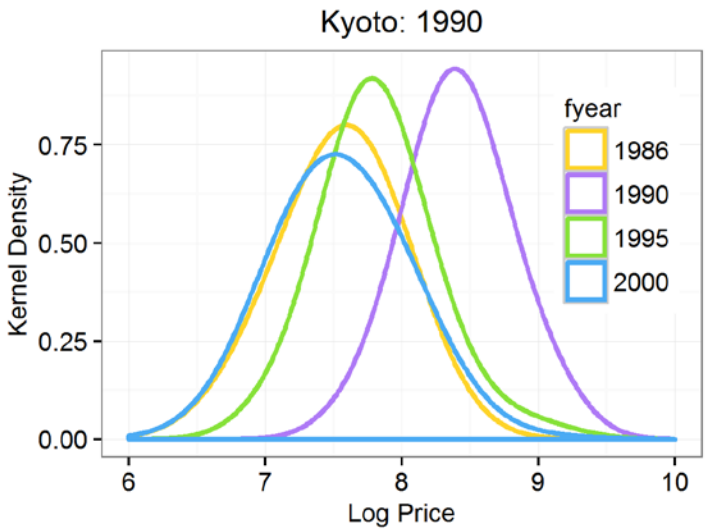




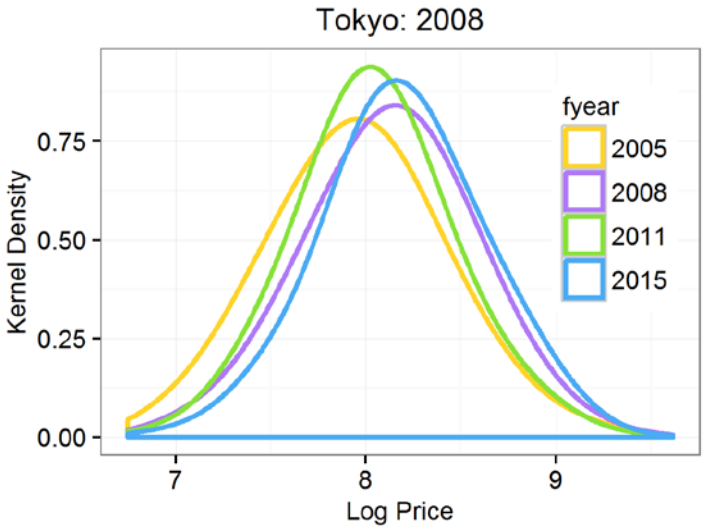


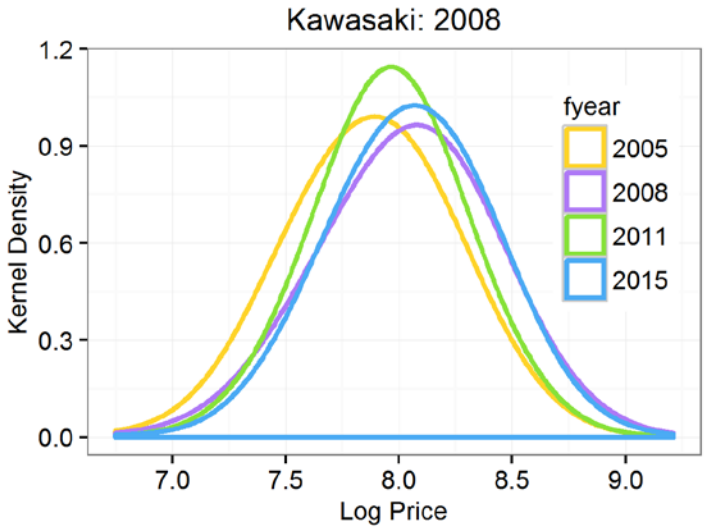


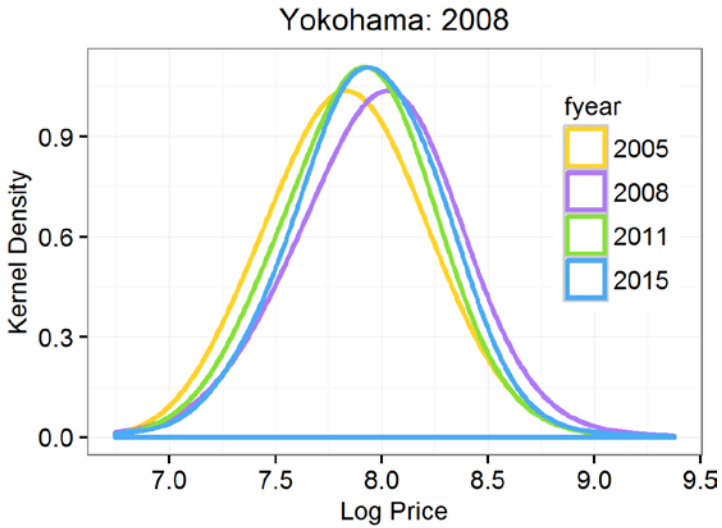


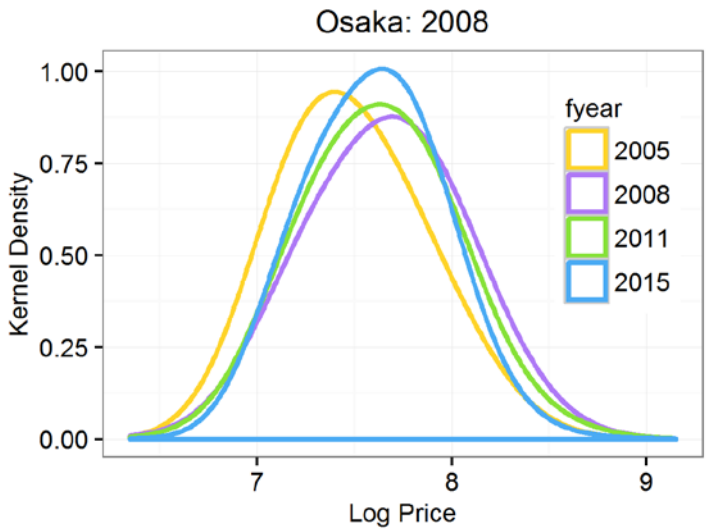


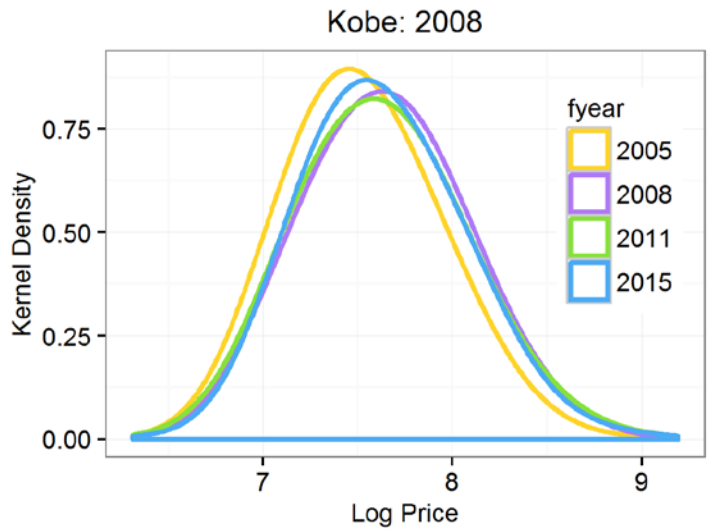
Kernel Density: Financial Crisis 2008

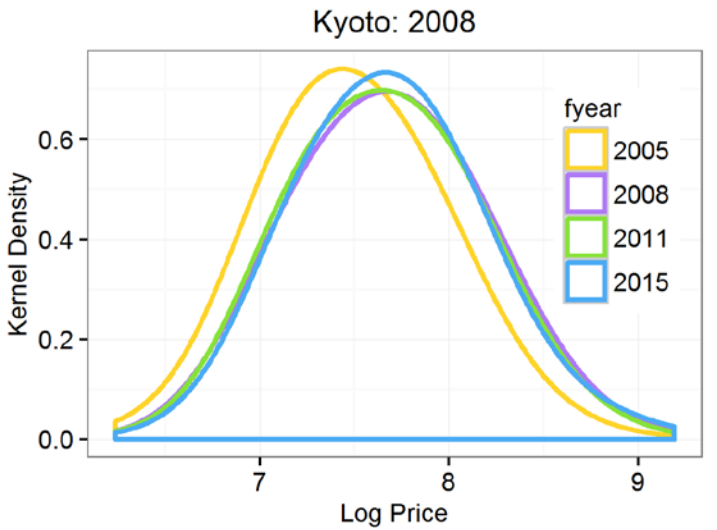






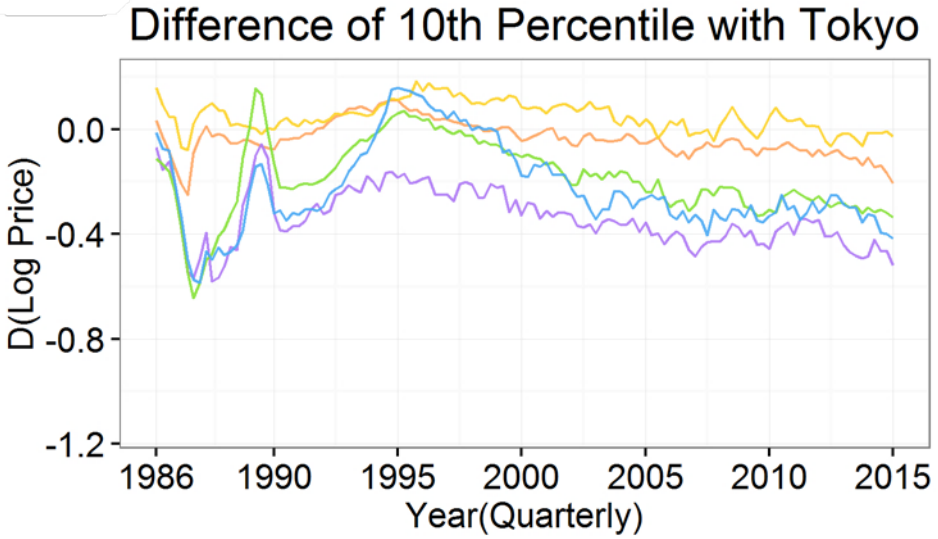


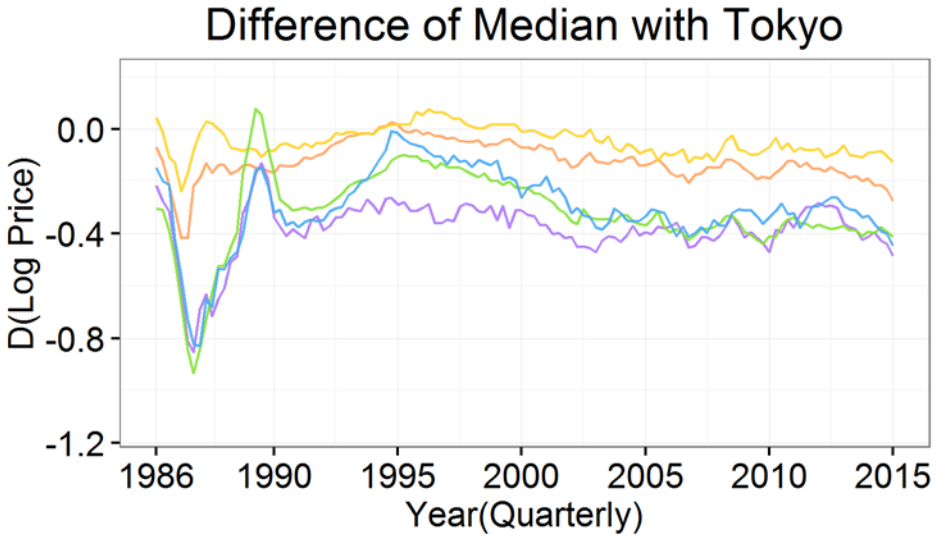


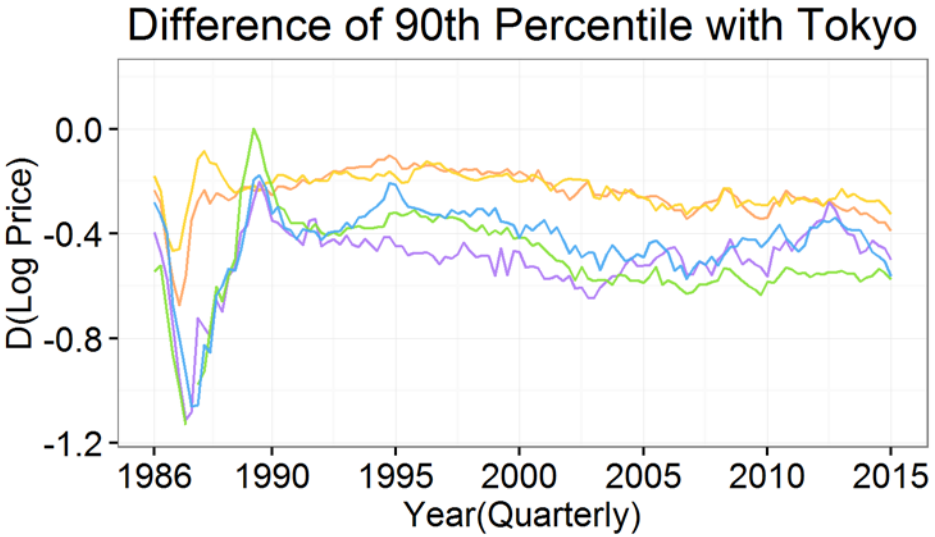


Time of Bubble

- Difference with Tokyo
  - City minus Tokyo
  - Tokyo earlier in boom
  - Tokyo later in burst than Kansai Area
  - Difference notable in high-priced house







Conclusion

- Distribution of House Prices in Japanese Cities
  - Distribution Change is notable around 1990's asset bubble period.
  - In the bubble period, Tokyo area booms earlier than Kansai area.
    Tokyo area bursts later than Kansai area.