Comparative study of factors influencing used housing prices in Osaka and Fukuoka using Geographically Weighted Regression

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Abstract

Japan's rapid depopulation is creating a rising need to desterilize empty condominium units. However, the lack of a market for used housing, as well as a lack of transparency in the price structure, are making this problematic. This study intends to investigate spatial non-stationarity in the used housing market based on trends in Osaka and the smaller urban center Fukuoka. Specifically, it seeks to understand what kind of factors may motivate buyers in what kind of areas through Geographically Weighted Regression (GWR). Our choice of GWR is based on the fact that it enables analysis of local attributes. We found that floor space and the age of the building were the most important factors both in Osaka and Fukuoka, albeit in different types of areas. Such data may be useful for urban planning and infrastructural investment.

1 Introduction

Japan's rapid depopulation is creating a rising need to desterilize empty condominium units. The problem is that used houses aren't available in significant quantities because of natural disasters. Furthermore, the price structure lacks transparency, making the housing market a high-risk investment (Shimizu, 2004). Used housing prices generally tend to be influenced more by their location than new housing. For this reason we relied on GWR for our spatial regression model.

The importance of taking account of location in analyzing things having spatial attributes, such as distance from the nearest station, is widely recognized. This is because spatial attributes as independent variables influence each other, causing problems with accuracy in estimating factors affecting pricing. Unique goods, such as real estate, are analyzed primarily using hedonic price models. However, such models use OLS regression and generally cover wider areas (i.e. not local), and thus fail to capture spatial structure accurately. Geographically weighted regression (GWR) essentially specifies a separate regression model at every observation point, thus enabling unique coefficients to be estimated at each location (Brunsdon et al. 1996).

Spatial regression models including GWR are rapidly developing in spatial economics, ecology and spatial epidemiology. However, data is of a different nature depending on the field, and urban analysis has yet to firmly establish a coherent method. Studies using GWR exist with relation to land prices, land use and housing prices (Furutani 2004, Saizen 1999, Bitter 2006), but not with relation to used housing prices, the focus of this paper.

We aim to reveal the formative factors of used housing prices within large cities and more regional urban centers based on spatial attributes focusing on Osaka and Fukuoka. We do this by mapping the spatial patterns together with urban structure, and further compare the two cities.

The remainder of the paper is organized as follows. We begin with an interpretation of the data and methodology employed in the study. Next, the results of the OLS regression and GWR are detailed and compared. We then discuss the difference of the spatial pattern of the 2 study areas by visualizing the parameter estimates with GIS. In the final chapter we draw conclusions.

2 Methodology: GWR-Geographically Weighted Regression-

2.1.Data

We selected our variables based on data published for prospective buyers in SUUMO magazine, issued by Recruit Co. Ltd.. The magazine is a bi-weekly publication listing asking prices and other property attributes. It covers all kinds of housing, ranging from new and used houses to new and used condominiums. The major attributes are floor space, the number of rooms, the number of stories, administration and repair costs, the age of the building, the walking distance to the closest station, whether or not the building is of steel reinforced construction (SRC), the direction the unit is facing, whether the unit is a corner unit, on the ground floor or on the highest floor, and whether the house/unit is renovated. We also added to these the distance to the center business district, as this is a factor implicit in the pricing scheme.

We additionally used zoning attributes as variables (as these also influence the price of used housing), obtained as GIS data from the respective municipalities we studied. Concretely, the variables are: the density of buildings, the area of commercial land use, the area of residential land use, the area of governmental land use, the area of industrial land use, and the area of park and open space. Since each block has a different area, we divided the values by the area of the block to obtain a relative figure.

Table 1 lists all of the above variables.

Table 1. Candidate variable description

Variable	Description	Unit
RP	Resale price	Yen
FS	Floor space	㎡
NR	Number of rooms	room
FN	Floor number	story
NS	Number of stories in building	story
ARC	Administration and repair costs	Yen
AGE	Number of years since construction	year
PDB	% of density of buildings in same block	%
PC	% of commercial land use in block	%
PR	% of residential land use in block	%
PG	% of governmental land use in block	%
PI	% of industrial land use in block	%
PRG	% of recreational and green land use in block	%
DCBD	Distance to CBD*	m
WDCS	Walking distance to the closest station	minuetes
SFD	Dummy variable indicating south-facing or not	(0,1)
SRCD	Dummy variable indicating SRC** or not	(0,1)
CUD	Dummy variable indicating corner unit or not	(0,1)
GFD	Dummy variable indicating ground floor or not	(0,1)
HFD	Dummy variable indicating highest floor or not	(0,1)
RD	Dummy variable indicating renovated or not	(0,1)
PD	Dummy variable indicating parking lot or not	(0,1)

CBD*: Umeda(Osaka), Tenjin(Fukuoka)
SRC**: Steel Reinforced Concrete Construction

2.1.1.Osaka

Osaka city is the central city of Keihanshin (Osaka-Kobe-Kyoto) metropolitan area. It is also the capital city in Osaka prefecture and it is located at the mouth of the Yodo River, which comes from Biwako, the biggest lake in Japan, and flows into Osaka Bay. 2,665,314 people lived in Osaka city according to the national census in 2010 and it covers an area of 223 square kilometers. The public transportation network is highly developed in Osaka city with the subway, west Japan railway and five private railways of Hankyu, Hanshin, Keihan, Kintetsu and Nankai.

We obtained the used houses records in Osaka from "SUUMO magazine in Osaka city, Keihan and Hokusetsu" published from April 2010 to March 2011. The number of the records was 1,298 after removing the records which overlap with each other and they are located on the 575 blocks. Fig. 1 shows the distribution of the all records in Osaka city. The used houses in Osaka are concentrated mainly in the northern area where Umeda, center district, is located. The descriptive statistics except the dummy variables in Osaka city are provided in Table 2.

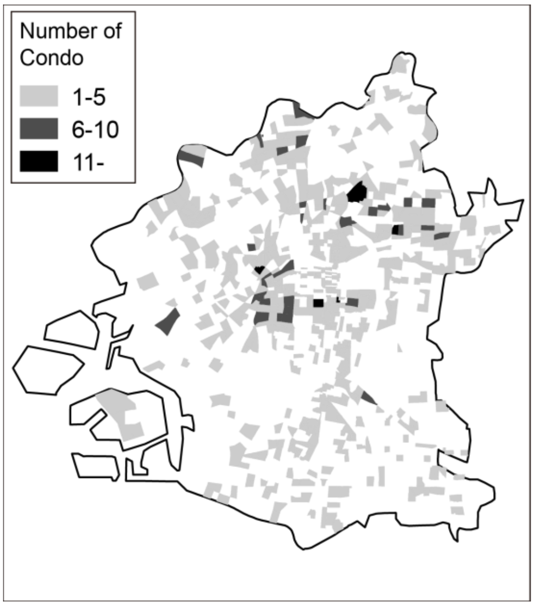

Fig. 1. Used housing distribution (Osaka)

Table 2. Descriptive statistics (Osaka)

Variable	Average	Std deviation	Minimum	Maximum
RP(10,000yen)	2226.55	1121.99	148.00	9980.00
FS	68.8	23.57	13.68	631.30
NR	2.61	0.83	1.00	8.00
FN	7.73	6.07	1.00	45.00
NS	14.5	7.91	3.00	54.00
ARC	17462.84	7064.21	0.00	102550.00
AGE	17.12	10.52	0.00	45.00
PDB	0.32%	0.16%	0.01%	0.89%
PC	7.50%	7.75%	0.18%	54.21%
PR	11.28%	6.80%	0.01%	37.03%
PG	1.11%	2.74%	0.00%	29.00%
PI	1.68%	2.26%	0.00%	17.96%
PRG	3.27%	4.26%	0.00%	47.00%
DCBD	4199.36	2432.18	538.14	12939.57
WDCS	6	3.899	1	25

2.1.2.Fukuoka

Fukuoka is one of the major cities in local region in Japan. It is the capital city of Fukuoka Prefecture and is situated on the northern shore of the island of Kyushu. It is bordered on three sides by mountains and opens, on the north, to the Sea of Genkai. There are 1,463,743 people inhabiting Fukuoka city according to the national census in 2010 and it covers an area of 340 square kilometers. The Fukuoka city subway runs east-west and the Nishi Nippon railroad runs north-south. The housings are accumulated around them.

We obtained the used houses records in Fukuoka from “SUUMO magazine in Fukuoka” published from April 2010 to March 2011. The number of the records was 1,117 after removing the records which overlap with each other and they are located on the 433 blocks. Fig. 2 shows the distribution of the all records in Fukuoka city. The used condominiums are basically located along the Fukuoka city subway and the Nishi Nippon railroad and they are distributed like T. Table. 3 shows the descriptive statistics except the dummy variables in Fukuoka city.

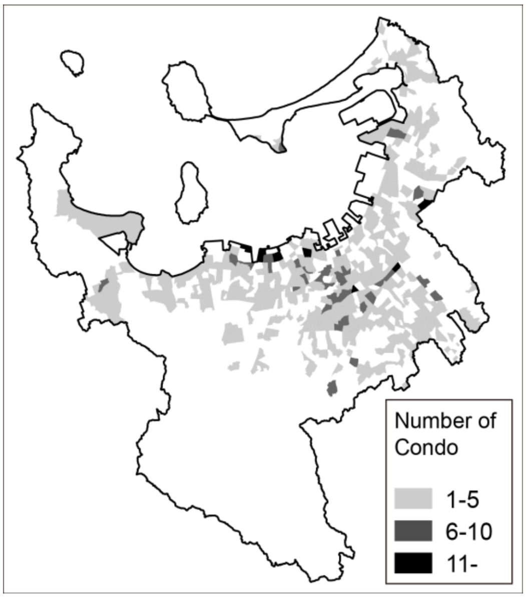

Fig. 2. Used housing distribution (Fukuoka)

Table 3. Descriptive statistics (Fukuoka)

Variable	Average	Std deviation	Minimum	Maximum
RP(10,000yen)	1697.79	1072.94	160.00	7800.00
FS	74.87	20.71	15.90	214.50
NR	2.99	0.83	1.00	6.00
FN	5.15	3.72	1.00	32.00
NS	9.43	4.80	2.00	42.00
ARC	17057.03	6706.71	0.00	59980.00
AGE	16.98	9.01	0.00	41.00
PDB	0.20%	0.08%	0.01%	0.43%
PC	9.32%	8.85%	0.00%	54.00%
PR	41.86%	16.84%	0.00%	79.00%
PG	0.63%	2.57%	0.00%	44.00%
PI	1.24%	3.15%	0.00%	35.00%
PRG	3.46%	6.41%	0.00%	89.00%
DCBD	4497.73	2720.19	432.68	14156.20
WDCS	7.53	5.983	1	63

2.2. GWR -Geographically weighted regression model-

The parameters for geographically weighted regression (GWR) are estimated locally by weighting the data surrounding each point. Although the parameters of the general hedonic price model, which is global, are estimated over space, GWR model can capture finer local effects. The model can be expressed as

$$Y_i = \alpha(u_{i,} v_i) + \sum_{k=1}^{n} \beta_k (u_{i,} v_i) X_{ik} + \varepsilon_i \tag{1}$$

where (u_i, v_i) denotes the coordinates of the point i in space, $\alpha(u_i, v_i)$ represents a constant and $\beta_k(u_i, v_i)$ is a set of parameters at point i.

In general hedonic regression, parameters are estimated through least squared method, as follows:

$$\min_{\hat{\beta}_0,\hat{\beta}_1} \sum_{j}^{n} \left[y_j - \hat{y}_j\left(\hat{\beta}_0,\hat{\beta}_1\right)\right]^2 \tag{2}$$

To calibrate the model, it is assumed that the observed data close to point i have a great influence on the estimation of the $\beta_k(u_i, v_i)$ parameters, which can be calculated by solving the minimization problem through the following equation:

$$\min_{\hat{\beta}_0(u_i,v_i),\hat{\beta}_1(u_i,v_i)} \sum_{j}^{n} \left[y_j - \hat{y}_j\left(\hat{\beta}_0(u_i, v_i), \hat{\beta}_1(u_i, v_i)\right)\right]^2 w_{ij} \tag{3}$$

The parameters at point i are estimated from the geographically weighted data at point j. Repeated estimations through this local weighting at each point reveals finer parameters over the study area.

To estimate parameters using the Eq. (3), it is important to decide the weighting matrix. The role of the weighting matrix in GWR is to represent the importance of individual observations at each location. In spatial analysis, it is commonly assumed that points close to a location i will exert more influence on the parameter estimates at that location than those farther away from it. Accordingly, when estimating the parameters at location i, more emphasis should be given to closer areas. Thus the Kernel functions are generally used for the weighting matrix. One typical Kernel function is the hat-shaped Gaussian distance decay, proposed by Brunsdon et al. (1996). The equation is shown in (4)

$$w_{ij} = \sqrt{exp\left(-\left(d_{ij}/h\right)^2\right)} \tag{4}$$

here d_{ij} denotes distance between location i and j. The distance is usually defined as a Euclidean distance. The weight will decrease as d_{ij} increase along the Gaussian curve. The weight at the estimated point is 1, and it moves closer to 0 as the distance between location i and j greater. h stands for a non-negative parameter known as bandwidth. The results of GWR are sensitive to the choice of bandwidth, as weighting procedures that specify a wide bandwidth and allow for only minimal distance decay will produce results that are similar to a global model. Conversely, if the bandwidth is narrow, only points in close proximity will be considered, which will lead to high variances in the estimators (Fotheringham et al. 2000).

3 Results

3.1. Selection of Variables based on OLS

We estimated the global model through ordinary multiple regression analysis by adding and removing candidate variables. We also checked the multi-colinearity among all candidate variables using VIF. Whenever we found a strong correlation, the variable was removed. We then conducted OLS regression and used the remaining independent variables for GWR.

In Osaka the VIF of PDB was 11.139 and that of DR was 9.027. Since they correlated strongly, we removed PDB. Subsequent OLS regression left the following thirteen independent variables: FS, AGE, DCBD, FN, PI, WDCS, NS, PR, PC, NR, SFD, PG and RD. The Adjusted R^2 was 0.827, suggesting that the model is accurate.

As shown in Table 5, there was no strong multi-colinearity for Fukuoka. Here the thirteen independent variables after OLS regression were FS, AGE, DCBD, PI, FN, RD, PG, NS, PR, ARC, PD, CUD and PRG. The Adjusted R^2 was 0.809, which is also accurate.

The nine variables FS, AGE, DCBD, FN, PI, NS, PR, PG and RD were common between the two cities. The absolute value of the standardized coefficient for FS and AGE are about .5, meaning that they influence the models strongly. We were able to confirm that floor space and age are universal attributes. We selected WDCS, PC, NR and SFD for Osaka, and ARC, PD, CUD, and PRG for Fukuoka. The fact that WDCS is selected in Osaka and PD is selected in Fukuoka suggests that the primary means of transportation is different between the two cities.

Table 4. Global model (Osaka)

Selected Variable	Standardized Coefficients		Correlation Coefficient		Collinearity Statistics	
					Tolerance	VIF
FS	.535	**	.692	**	.603	1.659
AGE	-.501	**	-.673	**	.736	1.359
DCBD	-.146	**	-.139	**	.645	1.551
FN	.081	**	.428	**	.554	1.806
PI	-.068	**	-.133	**	.818	1.223
WDCS	-.050	**	-.117	**	.841	1.190
NS	.077	**	.465	**	.479	2.088
PR	.072	**	-.024		.675	1.482
PC	.064	**	.089	**	.564	1.772
NR	.040	**	.263	**	.610	1.640
SFD	.033	**	.119	**	.944	1.059
PG	.033	**	.044		.875	1.142
RD	.028	*	-.213	**	.887	1.128
R^2	.827					
Adj. R^2	.825					
N	1308					

Excluded Variables	Beta In				Collinearity Statistics	
					Tolerance	VIF
ARC	.004^{n}		.260	**	.599	1.670
SRCD	-.013^{n}		-.221	**	.831	1.204
PD	.008^{n}		.125	**	.917	1.091
CUD	-.004^{n}		.132	**	.952	1.050
GFD	-.010^{n}		-.109	**	.931	1.074
HFD	.022^{n}		.058	*	.849	1.178
PRG	.024^{n}		.036		.825	1.212

**p<.01 *p<.05

Table 5. Global model (Fukuoka)

Selected Variable	Standardized Coefficients		Correlation Coefficient		Collinearity Statistics	
					Tolerance	VIF
FS	.507	**	.711	**	.546	1.830
AGE	-.478	**	-.659	**	.604	1.655
DCBD	-.197	**	-.150	**	.917	1.090
PI	-.092	**	-.176	**	.852	1.174
FN	.070	**	.290	**	.560	1.786
RD	.061	**	-.115	**	.949	1.053
PG	.055	**	.048	*	.951	1.052
NS	.076	**	.344	**	.497	2.012
PR	.048	**	.169	**	.790	1.266
ARC	.056	**	.328	**	.605	1.653
PD	.037	*	.434	**	.724	1.382
CUD	.030	*	.153	**	.932	1.073
PRG	-.028	*	-.001		.957	1.045
R^2	.811					
Adj. R^2	.809					
N	1177					

Excluded Variables	Beta In			Collinearity Statistics	
				Tolerance	VIF
NR	-.028[n]	.380	**	.514	1.944
WDCS	-.010[n]	.004		.975	1.026
SRCD	-.002[n]	.017		.708	1.413
SFD	-.004[n]	.030		.958	1.044
GFD	-.016[n]	-.049	*	.863	1.159
HFD	-.012[n]	-.008		.821	1.218
PC	-.028[n]	-.191	**	.526	1.899

**p<.01 *p<.05

3.2.Results of the GWR model

The all estimation was done by R software, spgwr package.

3.2.1.Estimation of weights and bandwidths

As aforementioned, it is necessary to decide the bandwidths and calculate the weighting matrix before GWR. The bandwidths were decided by the interval search from 800 to 2,000 m in 100 m steps and using fixed kernel. The criteria is AICc which is a mean of comparison of model selection indicators with different bandwidth sizes. In this time, it was estimated that the bandwidth of Osaka is 1500 and the bandwidth of Fukuoka is 1800, because the values of AICc are smallest.

3.2.2.The GWR parameter estimates and the test

The GWR model of Osaka and Fukuoka was estimated by using the selected variables and the calculated weighting matrix. The GWR parameter estimates vary at each of the 575 observation points in Osaka and the 433 observation points in Fukuoka. This means that Osaka has the 575 regression equations and Fukuoka has the 433 regression equations. Tables 6 anrd 7 show their minimum, median and maximum values, as well as the interquartile range. The last rows show the different r^2 values as automatically calculated using the GWR model on R.

Table 8 compares the GWR model with the OLS regression model in terms of the residual sum of squares, the AIC, and the adjusted R^2. They are automatically calculated on R using GWR models. The residual sum of squares for Osaka improved from 10.76197 to 7.602361. The residual sum of squares for Fukuoka improved from 16.107193 to 9.109369. The AIC for Osaka went from -2542.692 to -2875.608. The AIC for Fukuoka went from -1680.865 to -2258.29. The adjusted R^2 (the medians in Tables 6 and 7) indicates the appropriateness of the models. As can be seen in the tables, it is bigger with GWR than with OLS regression. Based on these figures it is fair to say that the GWR model is more appropriate than the OLS regression model.

Due to our selection of variables based on factors explicitly affecting real estate prices in the Japanese market, as well zoning considerations, we have excluded such variables as walkability, cyclability, access to highways and new housing nearby. Including such factors would likely yield even more accurate results.

Table 6. GWR model (Osaka)

Independent variable	Minimum	Lwr quartile	Median	Upr quartile	Maximum
Intercept	2.83E+00	2.96E+00	2.99E+00	3.25E+00	4.38E+00
FS	1.24E-01	5.77E-01	6.44E-01	6.90E-01	8.24E-01
AGE	-9.99E-01	-8.98E-01	-1.47E-01	-1.22E-01	-1.11E-01
DCBD	-9.99E-01	-2.80E-01	-2.17E-01	-1.51E-01	-1.10E-01
FN	1.13E-01	2.22E-01	2.85E-01	4.31E-01	9.99E-01
PI	-9.50E-01	-9.50E-01	2.85E-01	3.54E-01	3.99E-01
WDCS	-9.59E-01	-6.37E-01	-5.12E-01	-3.92E-01	-2.13E-01
NS	-9.92E-01	2.38E-01	2.76E-01	3.24E-01	3.98E-01
PR	-9.00E-01	2.16E-01	2.47E-01	2.72E-01	3.97E-01
PC	-9.95E-01	1.47E-01	1.82E-01	2.51E-01	6.75E-01
NR	1.18E-01	2.49E-01	3.59E-01	4.67E-01	8.98E-01
SFD	-9.50E-01	2.27E-01	2.85E-01	3.54E-01	3.99E-01
PG	2.16E-01	2.94E-01	4.37E-01	6.91E-01	3.24E+00
RD	-9.95E-01	1.47E-01	1.82E-01	2.51E-01	6.75E-01
Adj. R-square	0.73298	0.85612	0.8724	0.89645	0.99745

Table 7. GWR model (Fukuoka)

Independent variable	Minimum	Lwr quartile	Median	Upr quartile	Maximum
Intercept	2.47.E+00	2.79.E+00	2.90.E+00	2.98.E+00	3.99.E+00
FS	3.38.E-01	6.83.E-01	7.23.E-01	7.85.E-01	8.97.E-01
AGE	-1.81.E-01	-1.54.E-01	-1.42.E-01	-1.26.E-01	-1.16.E-01
DCBD	-9.62.E-01	-4.46.E-01	-3.44.E-01	-2.31.E-01	-1.10.E-01
PI	-1.87.E+00	-7.48.E-01	-5.58.E-01	-4.94.E-01	-3.36.E-01
FN	3.46.E-01	4.98.E-01	5.83.E-01	6.17.E-01	7.89.E-01
RD	2.26.E-01	3.26.E-01	3.63.E-01	4.63.E-01	6.93.E-01
PG	2.87.E-01	4.28.E-01	4.88.E-01	7.61.E-01	1.89.E+00
NS	1.12.E-01	2.85.E-01	3.31.E-01	3.85.E-01	9.75.E-01
PR	-9.94.E-01	-6.73.E-01	1.19.E-01	1.64.E-01	9.84.E-01
ARC	2.38.E-01	2.38.E-01	4.47.E-01	4.98.E-01	5.74.E-01
PD	2.12.E-01	2.73.E-01	3.51.E-01	4.18.E-01	5.98.E-01
CUD	1.79.E-01	2.37.E-01	2.94.E-01	3.62.E-01	5.92.E-01
PRG	-4.64.E-01	-2.26.E-01	-1.79.E-01	-1.55.E-01	-1.16.E-01
Adj. R-square	0.7314	0.8649	0.8725	0.8852	0.9931

Table 8. Test statistics of OLS and GWR

	Osaka		Fukuoka	
Test statistic	OLS	GWR	OLS	GWR
Residual sum of squares	10.76197	7.602361	16.107193	9.109369
AIC	-2542.692	-2875.608	-1680.865	-2258.29
Adjusted R^2	0.825	0.870548802 （Median）	0.8086	0.871732858 （Median）

4 Discussions

4.1.Comparative analysis of the parameter estimates between 2 cities

The parameter estimates for the 9 common independent variables has develop a different tendency between Osaka and Fukuoka as shown by Table 6 and Table 7.

The absolute value for AGE is bigger in Osaka than in Fukuoka. The value for FS, DCBD, PG and PR estimates don't have huge difference between 2 cities. The signs of the PI, NS, PR, PC, SFD and RD estimates for Osaka are different depending on the location. The value for PI estimates are completely different between the 2 cities.

4.2.Local analysis of the factors to formulate used housing prices

One advantage of GWR is that the spatial patterns inherent in the parameter estimates are easy to map and visualize. We thus analyzed the factors influencing housing prices locally by mapping each parameter estimate using ArcGIS. We used standard deviation, since the obtained data wasn't unified and the marginal prices were different with each variable. Our evaluation was based on how far each parameter was off the standard deviation.< -1.5 Std.Dev.

-1.5 Std.Dev. - -0.5 Std.Dev.

-0.5 Std.Dev. - 0.5 Std.Dev.

0.5 Std.Dev. - 1.5 Std.Dev.

> 1.5 Std.Dev.

-0.5 Std.Dev, for instance, means that the value was off from the average of the parameter by 0.5 times standard deviation. Points that were not significant at the 0.05 level are marked separately.

Furthermore, the regression points whose parameters weren't 5 % significant are visualized by small black points.

4.2.1. 9 common attributes

Fig. 3 shows the spatial pattern for FS. In Osaka, resale prices rise dramatically in the city center and the suburban as floor space becomes larger. It appears that FS is important in the city center of Osaka. The wideness of the floor space influences the value of used housing positively in the city center of Fukuoka also. The effect is highest in Tenjin and higher the area around the railway which runs to south. Thus different tendency in each city center appears.

Fig. 4 shows the spatial pattern for AGE. Resale prices are hard to lower with age in Umeda and the area located in southeastern Umeda. The area is business district and less susceptible to Age than Umeda. In Fukuoka, resale prices along the subway line aren't depreciated too much by aging. This indicates that these areas are attractive because people have easy access to the city center.

Fig.5 shows the spatial pattern for DCBD. In Osaka, resale prices depreciate as distance from CBD becomes larger. The fact that the parameters aren't significant in Nanba located on the Chuo ward indicates that Nanba also should be treated as CBD. In Fukuoka, resale prices along the subway line from Tenjin to Meinohama aren't influenced too much by DCBD. It is safe to say that the area is attractive in Fukuoka.

Fig.6 shows the spatial pattern for FN. The floor number isn't important in the city center of Osaka and resale prices in the southern area are easy to rise. In the near area from CBD, accessibility is superior to the view. In Fukuoka, resale prices rise easily as the regression points are near from the sea.

Fig.7 shows the spatial pattern for PI. In Osaka, the unique tendency can be observed. Factories are positive in the northern area and negative in the southern area. Conversely, the spatial pattern of Fukuoka is clear because the suburb is easy to depreciate and the city center is hard to depreciate.

Fig.8 shows the spatial pattern for NS. The city center of Osaka is average, but huge condominium influences the value of used housing negatively in southern area. In Fukuoka, Resale prices aren't influenced by the scale of the condominium except the southwestern area.

Fig.9 shows the spatial pattern for PR. The number of 5 % significant points is few in both cities. Opposite tendency can be seen in Fukuoka. Residential land use influence negatively in Jonan ward but positively in the southern Fukuoka airport.

Fig.10 shows the spatial pattern for PG. In Osaka, administrative convenience rise resale price as the regression point is far from the city center. In Fukuoka, PG is important in Chiyo, Hakozaki and the surrounding area of Fukuoka airport.

Fig.11 shows the spatial pattern for RD. Renovated condominiums tend to raise resale price more in the suburb in Osaka than the city centers. In Fukuoka, it appears that RD is important in Hakozaki and Yosidsuka located on the Higashi ward.

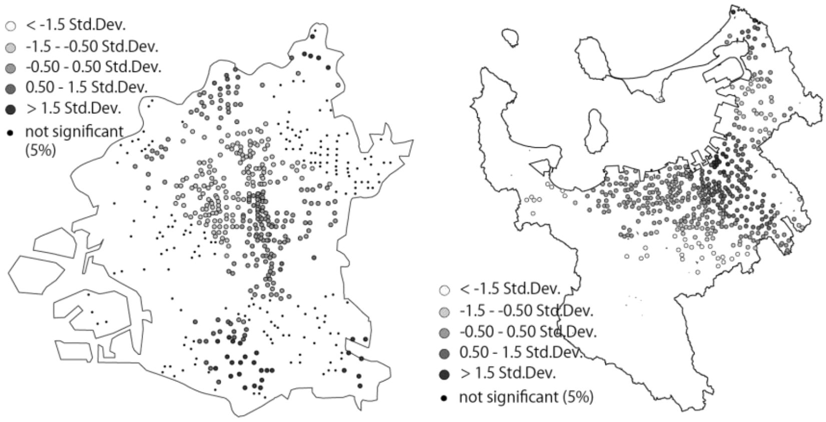

Fig. 3. Spatial pattern of FS

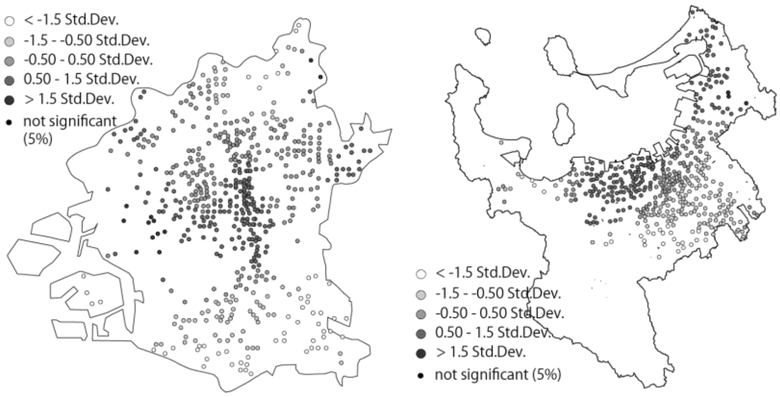

Fig. 4. Spatial pattern of AGE

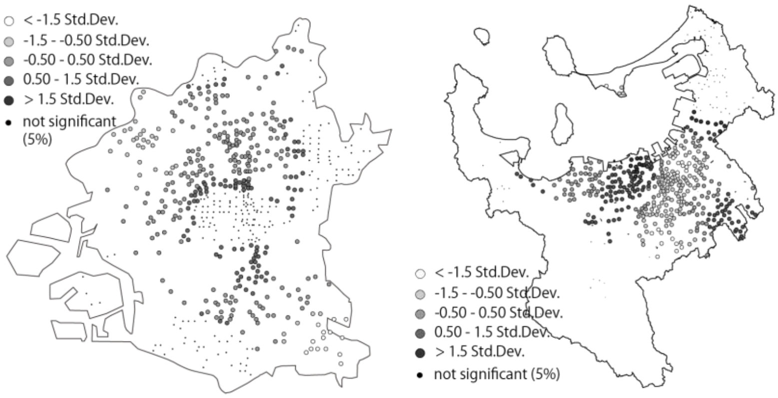

Fig. 5. Spatial pattern of DCBD

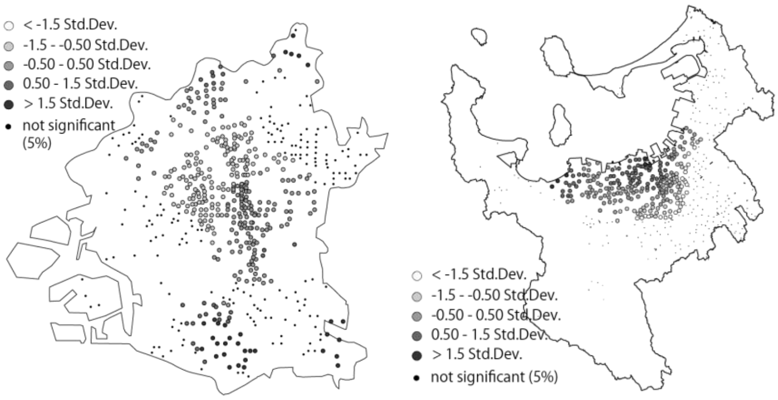

Fig. 6. Spatial pattern of FN

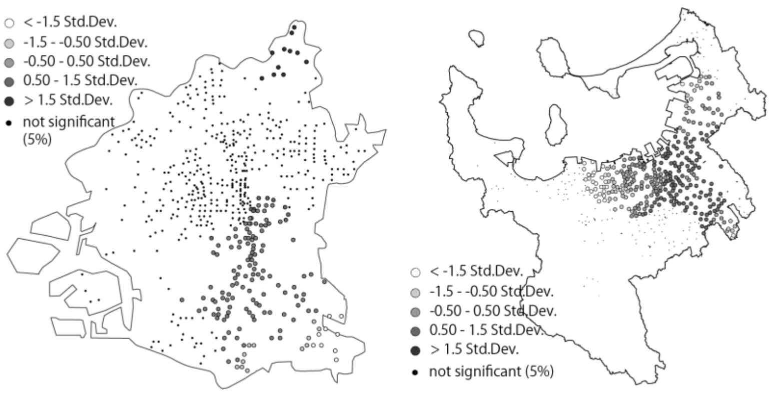

Fig. 7. Spatial pattern of PI

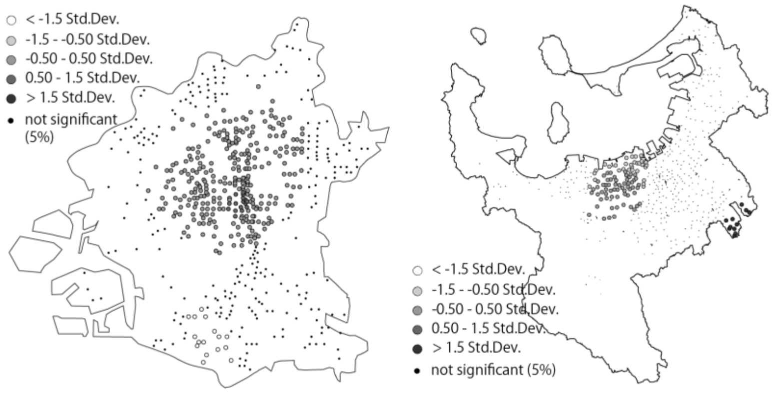

Fig. 8. Spatial pattern of NS

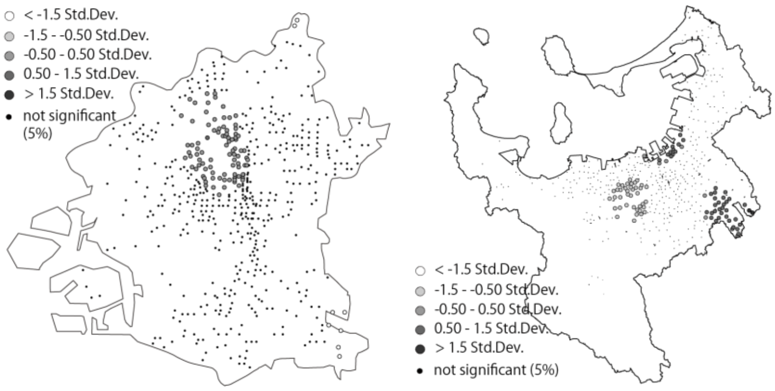

Fig. 9. Spatial pattern of PR

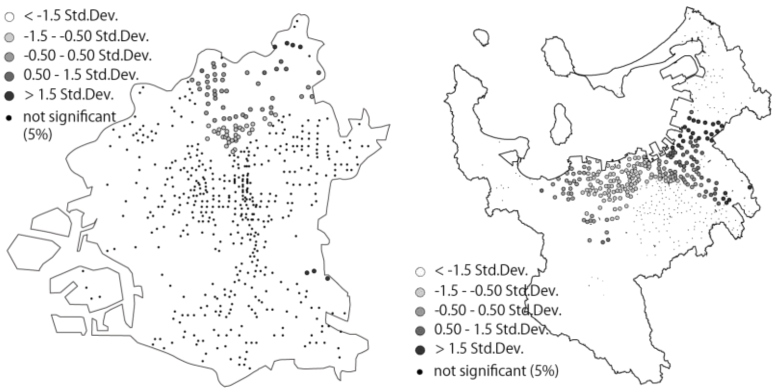

Fig. 10. Spatial pattern of PG

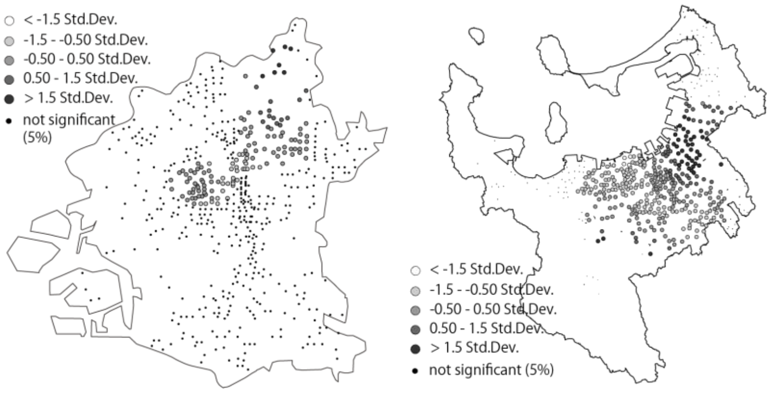

Fig. 11. Spatial pattern of RD

4.2.2. 4 distinctive attributes for each city

The 4 distinctive variables, WDCS, PC, NR and SFD are selected for Osaka. Fig. 12 shows each spatial pattern of them. The spatial pattern for WDCS appears that resale prices lower as the regression points are far from the city center of Osaka and the area around Osaka castle isn't influenced too much by it. The spatial pattern for PC shows that convenience is important in Miyakojima ward and Joto ward. NR enhances dramatically the value of used housings on the Abeno ward as shown in the spatial pattern. SFD parameters are average around Osaka castle.

The 4 distinctive variables for Fukuoka are ARC, PD, CUD, and PRG. Fig. 12 shows each spatial pattern of them. Resale prices in the Ohori area and the Momochi area rise by PD. CUD influences resale prices on the Minami ward and Higashi ward. The significant points exist on the area along with Nishitetsu railway line, this appears that the area has a tendency that recreational and green environment is important.

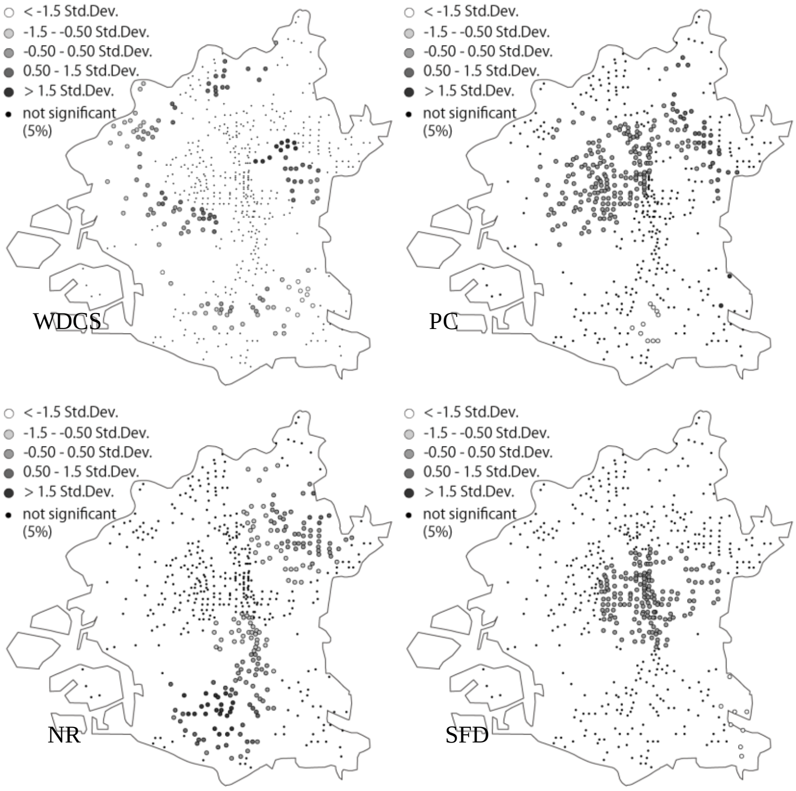

Fig. 12. 4 distinctive spatial patterns for Osaka

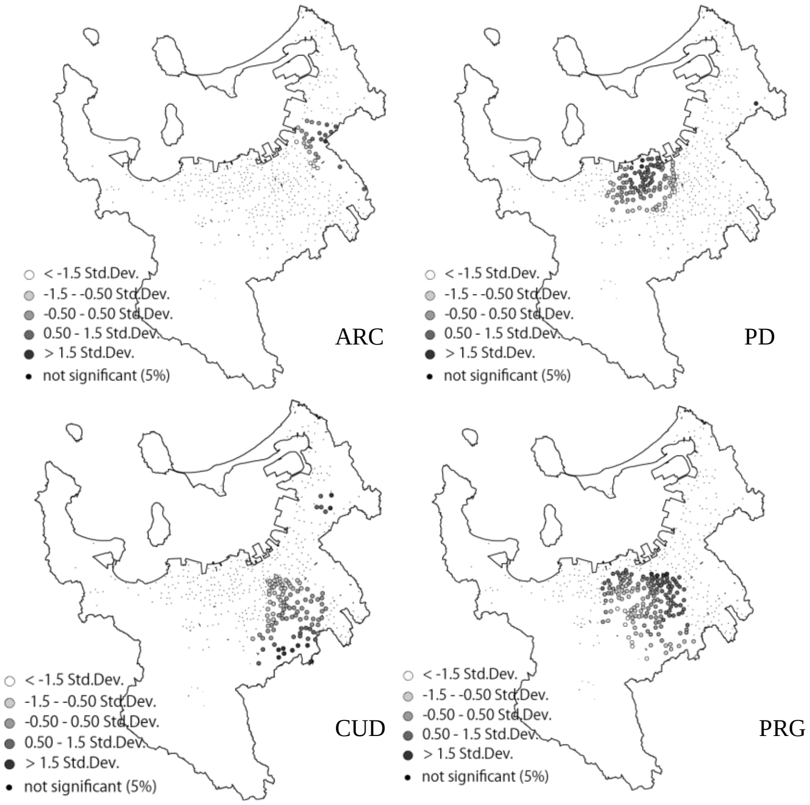

Fig. 13. 4 distinctive spatial patterns for Fukuoka

5 Conclusions

In this paper we have investigated spatial non-stationarity in Osaka and Fukuoka's used housing markets through GWR using parameters selected using OLS analysis. We plotted the parameter estimates visually using a GIS application and compared and analyzed the factors affecting used housing prices. Or main findings were as follows:

1) Predictably, floor space affects the value of used housing in the city center of Osaka. In Fukuoka, on the other hand, this tendency is stronger along the railway line running north-south, and not so much along subway line, which runs east-west.

2) In Osaka resale prices are barely affected by age in the area encompassing the main commercial district Umeda and the main business district directly southeast thereof. In Fukuoka the same tendency is evident along the subway line.
3) Variables such as PR and PG were inversely related to housing prices, depending on the location.

Analysis of the sort we have conducted may be useful for anticipating potential and/or problems when considering areas for development, thus allowing municipalities to conduct more productive infrastructural investment in areas with maximum potential.

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References

Bitter, C., Gordon, F. Mulligan, Dall'erba, S. (2006) Incorporating spatial variation in housing attribute prices: a comparison of geographically weighted regression and the spatial expansion method. Journal of Geographical Systems, Vol.9, pp.7-27.

Brunsdon, C., Fotheringham, S., and Charlton, M. (1996) Geographically weighted regression: A method for exploring spatial non-stationarity. Geographical analysis, Vol. 28, pp.281-289.

Cliff, A., Ord, J.K. (1973) Spatial Autocorrelation, Pion.s

Fotheringham A., Brunsdon, C., Charlton, N. (2000) Quantitive geography: perspectives on spatial data analysis. Sage Publications, London.

Fotheringham, A. S., Brunsdon, C., Charlton, M. (2002) Geographically Weighted Regression: The Analysis of Spatially Varying Relationships, John Wiley & Sons.

Furutani, T. (2004), Bayesian Geographically Weighted Regression Model and Its Application for Land Price Model Estimation. Journal of the City Planning Institute of Japan, Vol. 39-2/39-3, pp.39.3,787-792.

Moran, P. A. P. (1948) The interpretation of statistical maps. Jounal of the Royal Statistical Society B, Vol. 10, pp. 243-251

Recruit, (2010.4.-2011.3.) SUUMO magazine in Osaka city, Keihan and Hokusetsu. Recruit.

Recruit, (2010.4.-2011.3.) SUUMO magazine in Fukuoka. Recruit.

Saizen, I., Mizuno, K., Kobayashi, S. (1999) Analysis on spatial distribution of land use by geographically weighted regression. Journal of Rural Planning Association, Vol. 18, pp.325-330.

Shimizu, C. (2004), Fudousanshijoubunseki -Futoumei na Fudousanshijou wo Yomitoku Gijutsu- [Real estate marketing -the technique of reading and understanding obscure real estate market-]. Tokyo: Jutaku Shinpo Sha,

Shimizu, C., Karato, K. (2007) Fudosansijo no Keiryo Keizai Bunseki [Econometric model analysis in real estate market]. Tokyo: Asakura publiching Co., Ltd

Sugiura, Y (2003) Chiri Kukan Bunseki [Geography space analysis]. Tokyo: Asaklura publishing Co., Ltd

Tanimura, S. (2010) R de manabu data science -Chiri Kukan Data Bunseki- [analysis of Spatial data (data science by learning with R)]. Tokyo: Kyoritsu Shuppan Co., LTD.