Econometric Analysis of the Effects of Zoning Ordinance on Residential Land Price

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This paper is intended to empirically analyze the effects of zoning ordinance on residential land price. Hedonic land price models are applied to data in both a local city (Sendai) and the capital (Tokyo) of Japan to make an inter-city comparison of economic effects of zoning ordinance. The result of this comparison suggests that it is meaningless to apply the zoning ordinance uniformly regardless of differences in characteristics among cities. Structural change in land price functions with time in a city is investigated as well.

KEYWORDS: zoning ordinance, residential land price, hedonic model

1. Introduction

This paper is intended to empirically analyze the economic effects of zoning ordinance by examining residential land price functions. Hedonic land price models are applied to data at different time periods in Sendai city, a central city in northern region in Japan, which enables us to investigate structural change in land price functions with time. Moreover these models are applied to Tokyo data, (the capital of Japan) as well in order to make an inter-city comparison of economic effects of zoning ordinance. In particular, it is of interest to see whether its effects depend on city size or not. The result of this comparison suggests that it is meaningless to apply the zoning ordinance uniformly regardless of differences in characteristics among cities.

In section 2, the literature to date in the relevant field is reviewed. In section 3, the data and econometric model used for analysis are explained. Section 4 examines the estimation results of a land price function based on the data at 1995 in Sendai city. Section 5 is devoted to comparison of land price functions between Sendai and Tokyo. Section 6 intends to analyze the structural change of the land price function over time.

2. Review of literature

A major goal of land use control such as zoning is to preserve a better residential environment. Thus, land price is influenced by particular zoning ordinances to the extent that location choice of residents is affected by the residential environment.

There are various attributes which determine the quality level of a residential environment. Among them are the "quietness and cleanliness" which can be brought about by restricting land use for industry and business activities and/or restricting the height of buildings, and the "convenience" which reflects better access to shopping centers and various facilities. So far, many empirical studies of zoning ordinance effects on the residential land price in the U.S. have been published, but the extent and significance of the price effects vary among studies.

Stull's analysis [1975] using data from a Boston suburban area suggests that the ratio of land used for high-rise residential buildings, and commercial and industrial activities in a community has a significant, negative effect on the residential land price in that community, which is termed the "neighborhood effect". In particular, when a quadratic function is applied, the coefficient of the squared value of land use ratio for commerce is significantly negative, implying that a positive effect of "convenience" works until a threshold level of the commercial land use ratio is reached, and after it, the external diseconomy effect of the agglomeration of commercial activities becomes dominant.

Crane's [1983] analysis, based on the data in Foster city, California shows that an increase in the land use ratio for apartment houses has a negative effect on the residential land price in a community under consideration.

Donald Jud [1980] estimated the function of housing price per floor space using data from Charlotte city, North Carolina where three explanatory variables associated with the neighborhood effect were introduced: a dummy variable for the area zoned for single family residential housing only, the dummy variable for the area where minimum lot size is above 1500 m², and the land area shares for commerce, industry and vacancy, respectively. As a result, the dummy variable for single family residential housing areas had a significant positive effect on the land price while the land share for industry activity had a significantly negative effect. In contrast to Stull [1975], the coefficient of the squared land-share for commerce was found to be significantly positive. An interpretation is that the location of small-sized shops in a neighborhood will lower the price of residential land in
that area while the location of large shopping centers will increase the value of residential land in that area. The coefficient of the dummy variable for minimum lot size would work adversely on the residents' preference because a negative effect of higher expenditure for housing more than offsets a positive effect of promoting a quiet environment.

In the study of Maser et al. [1977] based on the data in Rochester city, the coefficient of dummy variables for apartment houses and business areas were not significant, and thus no price effect of zoning ordinance is suggested.

In the application of residential land price functions to the data in Pittsburgh, Crecine et al. [1967] and Ruet- er [1973] found results of zoning variables to be not significant, and concluded that the land price does not depend on the neighborhood effect.

Lafferty and Frelch [1978] insist that the neighborhood externality works at two different levels, and those effects should be distinguished from each other. That is, the city-wide externality due to concentration of production activities in a particular city will work to increase overall residential land price in the city: the local externality due to the concentration of production activities in a particular district in a city will operate so as to lower the relative residential land price in the district in a city.

To sum up, the literature so far indicates that the price effects of zoning ordinance vary depending on cities and types of zoning examined.

The price effect of zoning ordinance in Japan was investigated by Ohnishi and Kitaki (1993). They applied a hedonic price function to data in Tokyo at 1980, '85, and '90 where the entire area of Tokyo city was zoned into six different land-use districts. Their major results were:
1. Zoning ordinances affect land price particularly in type 1 residential and commercial districts.
2. In regression using only data from the type 1 residential district, the variables of land area and distance to the nearest station of public transportation have significant effects on the land price, but the permitted limit of FAR does not.

3. The data and model

With the intention to evaluate the uniform criteria of zoning in Japanese city planning (e.g., the permitted limit of FAR in a particular zoning is the same in every city of Japan), data of two cities, Tokyo and Sendai, are independently analyzed. As the land price per unit area, the data provided by the Land Planning Agency is used. The residential area in the sample is classified into three zoned districts: "type 1", "type 2" and "other" residential districts. Our hypothesis is that more restricted zone provide quieter but less convenient environment.

A general form of hedonic the land price function used below is:

\[ P = f(A, Z, S, u_1, u_2, u_3, F, D, RWD, PT, CT) \]  \hspace{1cm} (1)

where

- \( P \): land price (yen/m²)
- \( A \): lot size (m²)
- \( S \): shape of lot represented by
  \[
  \left| \frac{\text{width/length}}{3} - 2 \right|
  \]
- \( D \): distance to the nearest railway or subway station (m)
- \( RWD \): dummy variable representing "subway" in calculating \( D \)
- \( PT \): time-distance to a city center by public transportation (minute)
- \( CT \): time-distance to a city center by automobile (minute)

The following variables represent characteristics of the zoning ordinance

- \( u_i \): dummy variable of zoned district for type \( i \) residence,
  - \( i = 0 \): type 1 residential district with the building-to-land ratio (BLR) being less than 40% and FAR less than 60%, \( i = 1 \): other type 1 residential district, \( i = 2 \): type 2 residential district, \( i = 3 \): other residential district.
- \( Z \): permitted limit of FAR
- \( F_i \): dummy variable representing the restriction on building structure for fire protection,
  - \( i = 0 \): no restriction, \( i = 2 \): weak restriction, \( i = 3 \): strong restriction.

Data on \( A, Z, S, u, FD, RWD \) are collected by the Land Planning Agency together with the data on \( P \). Data on PT and CT are taken from the Person-trip Survey by the Japanese Construction Ministry. Tables 1 and 2 summarize the data of Sendai and Tokyo cities, respectively.
Table 1. Summary of data of Sendai in 1995 (sample size is 268).

<table>
<thead>
<tr>
<th>Variable</th>
<th>Value</th>
<th>Mean</th>
<th>Maximum</th>
<th>Minimum</th>
<th>Standard Variance</th>
</tr>
</thead>
<tbody>
<tr>
<td>P(1000 yen/m²)</td>
<td></td>
<td>123.10</td>
<td>1040</td>
<td>12</td>
<td>76.78</td>
</tr>
<tr>
<td>A(m²)</td>
<td></td>
<td>256.97</td>
<td>2243</td>
<td>109</td>
<td>195.61</td>
</tr>
<tr>
<td>D(m)</td>
<td></td>
<td>2499.63</td>
<td>20000</td>
<td>110</td>
<td>2382.12</td>
</tr>
<tr>
<td>BLR(%)</td>
<td></td>
<td>55.04</td>
<td>60</td>
<td>40</td>
<td>6.39</td>
</tr>
<tr>
<td>FAR(%)</td>
<td></td>
<td>148.28</td>
<td>200</td>
<td>60</td>
<td>61.36</td>
</tr>
<tr>
<td>PT(minute)</td>
<td></td>
<td>43.65</td>
<td>70</td>
<td>30</td>
<td>8.46</td>
</tr>
<tr>
<td>CT(minute)</td>
<td></td>
<td>34.14</td>
<td>50</td>
<td>20</td>
<td>6.63</td>
</tr>
</tbody>
</table>

Table 2. Summary of data of Tokyo in 1995 (sample size is 988).

<table>
<thead>
<tr>
<th>Variable</th>
<th>Value</th>
<th>Mean</th>
<th>Maximum</th>
<th>Minimum</th>
<th>Standard Variance</th>
</tr>
</thead>
<tbody>
<tr>
<td>P(1000 yen/m²)</td>
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<td>610.42</td>
<td>4500</td>
<td>150</td>
<td>325.80</td>
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<tr>
<td>A(m²)</td>
<td></td>
<td>207.07</td>
<td>4069</td>
<td>40</td>
<td>173.91</td>
</tr>
<tr>
<td>D(m)</td>
<td></td>
<td>850.70</td>
<td>3900</td>
<td>100</td>
<td>594.44</td>
</tr>
<tr>
<td>BLR(%)</td>
<td></td>
<td>55.74</td>
<td>60</td>
<td>30</td>
<td>6.58</td>
</tr>
<tr>
<td>FAR(%)</td>
<td></td>
<td>184.89</td>
<td>400</td>
<td>60</td>
<td>80.12</td>
</tr>
<tr>
<td>PT(minute)</td>
<td></td>
<td>52.82</td>
<td>90</td>
<td>30</td>
<td>10.71</td>
</tr>
</tbody>
</table>

4. Land price function in Sendai in 1995

This section analyzes the price effect of zoning ordinance using data from Sendai in 1990. Z takes three different values: 60%, 80%, and 200%. The 60%-FAR is applied only to some parts of the type 1 residential district while the limit of 200% is never applied to any parts in the type 1 residential district. FAR’s permitted limit is 200% where the value of F takes 3 (i.e., strong restriction on building structure for fire protection). In this sense, the three zoning-related variables (u, Z, and F) commonly share some properties. Changing combinations of explanatory variables in (1), 31 alternative linear equations and 9 alternative log-linear equations were estimated. Main estimation results are summarized as follows:

1. The coefficient of lot-size variable A is positive and significant at a 1% level in most cases. That is, the land price per area increases with area, which is called “quantity premium” of land (Tabuchi (1996)). Such a quantity premium arises because land is indivisible or very difficult to divide, and thus a large lot can be used more efficiently. Ohnishi and Kitaki (1993) also observed the “quantity premium” of land. To the contrary, in the estimation of Donald Jud (1980) the coefficient of lot size was negative: i.e., a “quantity discount” arises. The estimation results of log-linear equations indicate that the land price increases at the rate of 10%.

2. Both PT and CT have a negative effect on the price, and are significant at a 1% level. The estimation results of linear equation indicate that the land price per m² increases by 20,000–22,000 yen when the time-distance to a city center by public transportation decreases by 10 minutes, and the price increases by 30,000–37,000 yen when the time-distance by automobile decreases by 10 minutes. This reflects that the distance moved by an automobile in a certain time is greater than that of public transportation. The estimation results of log-linear equations indicate that the coefficient of log PT and log CT are almost equal, and a 10%-decrease in the time-distance, whether by public transportation or automobile, brings about a 7%-increase in residential land price.

3. The coefficient of D is negative as expected, but not significant where PT is incorporated in the same equation. This is because PT includes information on D as well. It does not matter to residents whether the nearest station is for a railway or for a subway insomuch as the coefficient of RWD is not significant.

4. As for the variable of land-shape represented by the width-length ratio, the sign is indeterminate and not significant. Thus, it is safely concluded that the land-shape has little effect on the land price.

5. The effects of zoning-related variables are examined. As for the zoning variable, the effect of u₀ is stan-

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1According to Asami (1994), the width-length ratio of the standard shape of a residential lot in Japan is equal to 2/3. So, in this study, the variable S is defined as the difference between the actual and standard width-length ratios.

2The convenience characteristic of a location in a particular district with stronger restriction on building structure should be distinguished from the attribute of stronger restriction itself. Stronger restriction on building structure for fire protection is an advantage of residing in such district since it is safer against fire, but housing is more expensive in such district because construction of a fireproof building costs more. Therefore, it is unambiguous whether stronger restriction on building structure for fire protection is beneficial or not to residents.
standardized at the value of constant term, and therefore, the coefficient of \( u_i \) \((i \neq 0)\) represents the effect relative to that of \( u_0 \). If a residential district in a quieter environment is more highly valued, then the coefficient of \( u_i \) \((i \neq 0)\) is negative and its absolute value increases with the value of \( i \) \((i = 1, 2, 3)\). To the contrary, if households put higher weight on the convenience or efficiency of residential land, then the coefficient of \( u_i \) \((i \neq 0)\) is positive, and its value also increases with the value of \( i \). Estimation results show that a sign of \( u_i \) is indeterminate, and insignificant in any case. It can be only stated that the coefficient of \( u_i \) is positive and its absolute value is larger than those of \( u_i \) and \( u_0 \) in every case. This might suggest that the convenience or efficiency is favored more than quiet neighbors. However, from the viewpoint of statistics, there is no significant difference in the price effects among four zoned districts.

On the other hand, the coefficients of the fire-protection dummy variables \( F_i \) \((i = 2, 3)\) are positive in every case, and highly significant in most cases. Stronger restriction on building structure for fire-protection tends to be imposed in a city’s central area, and thus the variable \( F \) can be a proxy of the convenient environment in a district. Even where the time-distance variables, \( PT \) and \( CT \) are incorporated, the coefficient of \( F \) is significantly positive. This implies that \( F \) represents more than the effect of better access to a city center, i.e., the convenience or efficiency of a particular location. Why are the coefficients of \( F \) significant while those of \( u_i \) are insignificant? An interpretation is that the difference between the districts with and without restriction on building structure for fire-protection is greater than the difference between the type 1 residential district and other residential districts.

Another zoning-related variable, \( Z \), is introduced in three equations, and has a positive sign in every equation, which reflects relatively efficient use of land at a particular location with a large \( Z \). However, when the distance to a city center is introduced together, the coefficient of \( Z \) is insignificant even at a 5% level. When \( Z \) and \( F \) are incorporated together in the equation, both coefficients are positive but insignificant at a 5% level. This implies that these two zoning-related variables include common (although not the same) information. When \( F \) is introduced together with \( u_i \) variables, its coefficient is significant at a 5% level.

6. The goodness-of-fit of the models is not high. Judging from \( R^2 \) adjusted for degree of freedom, the following models showed the best result for linear and log-linear models, respectively.

\[
P = 265.3398 + 0.1395A + 16.9533F - 2.0102PT - 2.6903CT : R^2 = 0.310
\]

\[
\log P = 8.8942 + 0.14729 \log A + 0.064075 \log Z - 0.747644 \log PT - 0.709070 \log CT : R^2 = 0.461
\]

where figure in parenthesis is t-value.

5. Comparative analysis between Tokyo and Sendai

Ohnishi and Kitaki (1993) analyzed land price functions in Tokyo for 1980, ’85 and ’90 using data for all zoned districts. Their important result is that the coefficients of dummy variables for type 1 residential, type 2 residential, other residential, quasi-commercial, and commercial districts are all positive and highly significant. This implies that the zoning ordinance is effective, except for the quasi-industrial district, so as to increase the land price. This result makes a sharp contrast to the result in Sendai in the preceding section. The difference stems from the following reasons. First, the city size and the extent of social and economic agglomeration differ between the two cities. Second, the coverage of land-use pattern differs between the two studies: Ohnishi and Kitaki’s analysis includes both the residential, commercial, and industrial districts while our study treats only the residential districts. For instance, the permitted limit of FAR is a more important characteristic to commerce or business districts than to residential districts. Besides, a difference in residential environment among zones is not large in a medium-sized city like Sendai while it is large in a big city like Tokyo. At any rate, the effect of zoning can be different among cities in Japan as the literature reviewed in section 2 showed for U.S. cities.

This section intends to more accurately compare the effect of zoning on residential land price between the two cities. To do so, the land price functions were newly estimated using only data on residential districts in 1995. The data on CT was not available in Tokyo, and the type 1 residential district was not divided in Tokyo since there are few type 1 residential districts with the limit of 40%-BLR and 60%-FAR.

Twenty-two linear equations and eighteen log-linear equations are estimated. Main results are summarized as follows:

1. The coefficients of \( u_2 \) and \( u_3 \) denote zoning effects of type 2 and other residential districts, respectively in excess of the zoning effect of type 1 residential district. They are negative in all the log-linear models and in most linear models. Even when \( u_2 \) and \( u_3 \) are introduced together with \( Z \) or \( F \), they are significantly negative. Variables \( Z \) or \( F \) indicate the extent of convenience or efficiency of a particular location, and tend to take larger values in type 2 and other residential districts than in type 1 residential district. Thus, the coefficients of \( u_2 \) and \( u_3 \) are expected to represent an effect different than convenience, i.e., the effect of a "quiet environment". Estimation results show that the effect of quiet neighbors is significant so that resi-
dents in Tokyo are ready to pay higher prices for type 1 residential district. As seen in the preceding section, the effect of residential zoning in Sendai is not so significant as to be capitalized in the land price because the difference in quiet environment is not large in a medium-sized city. This suggests that it is meaningless to apply the zoning ordinance uniformly to every city without considering particularities of each city.

2. The coefficient of lot size \( A \) is significantly positive, showing the effect of area-premium like in Sendai city.

3. The time-distance to a city center by public transportation has a significant, negative effect on land price.

4. The coefficient of physical-distance to the nearest station is negative and significant at a 1% level in most equations. It is noted that this coefficient was insignificant in Sendai case, but it is highly significant in Tokyo even where PT is introduced together. This implies that the distance to the nearest station has information independent of time-distance to a city center. For instance, since people in Tokyo make frequent trips to some facilities and shopping centers in subcenters, shorter distance to a station brings them convenience. Also, because of high crime rates in a large city, people expect that residence near to a station is safer, in particular, during night time.

5. For the other two zoning-related variables, \( (Z \) and \( F \) both effects are significantly positive. This makes a contrast to the result in Sendai where their effects are insignificant when both variables are incorporated in an equation.

6. The shape of a lot has no effect on that land price.

7. The goodness-of-fit of models is higher, overall, than that of the models for Sendai. The best results for linear and log-linear models, respectively are shown as follows.

\[
P = 529.864 + 0.891A - 185.394u_2 - 273.59u_3 + 60.33F - 0.031D - 8.074PT + 1.96Z,
\]

\[
R^2 = 0.5672
\]

\[
\log P = 7.1896 + 0.243049 \log A - 0.206691u_2 - 0.276078u_3 + 0.0822598F
\]

\[
- 0.10824 \log D - 0.72596 \log PT + 0.280556 \log Z,
\]

\[
R^2 = 0.57361
\]

The extent of each variable's effect is compared between the two cities on the basis of the elasticity which is not influenced by the size of a city. The average elasticity is calculated in Table 3 using only the results of models in which the variable considered has a significant effect. Table 3 shows that the extent of each variable's effect on land price is nearly equal except for the effect of \( A \) between the two cities. The effect of area-premium is larger in Tokyo, two or three times that of Sendai.

Another difference between the two cities is observed as for the elasticity of \( D \) when PT is not introduced. As described above, the coefficient of \( D \) is insignificant in Sendai when PT is simultaneously introduced since the information on \( D \) is included in the information on PT. On the other hand, in Tokyo, the variable \( D \) has more information than that of PT: thus when PT is not introduced in the log-linear model, the coefficient of \( D \) takes a larger value, about two times the value observed when PT is introduced (see in the parenthesis).

The average permitted limit of FAR is by far higher in Tokyo than in Sendai, and thus a given area of land can be used more efficiently. But, it is notable that the elasticity of land price with respect to FAR is almost equal between the two cities.

6. **Time-series structural change of land price function**

In order to examine the time-series structural change of land price function, in addition to the data at 1995, models are applied to the data in Sendai at 1975, '80, '85, and '90, respectively. Table 4 summarizes the

<table>
<thead>
<tr>
<th>Table 3. Comparison of Land-price elasticity.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Variable</td>
</tr>
<tr>
<td>-----------</td>
</tr>
<tr>
<td>PT</td>
</tr>
<tr>
<td>D</td>
</tr>
<tr>
<td>A</td>
</tr>
<tr>
<td>Z</td>
</tr>
<tr>
<td>F</td>
</tr>
</tbody>
</table>

*: When PT is not introduced.
**: When \( u_2 \) and \( u_3 \) are introduced.
Table 4. Estimation results of land price function for Sendai (log-linear model).

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>PT</td>
<td>-1.15 ~ -1.36</td>
<td>-0.87 ~ -1.05</td>
<td>-0.70 ~ -0.88</td>
<td>-0.45 ~ -0.60</td>
<td>-0.70 ~ -0.78</td>
</tr>
<tr>
<td></td>
<td>D*</td>
<td>-0.9098</td>
<td>-0.0445</td>
<td>-0.0616</td>
<td>not significant</td>
<td>not significant</td>
</tr>
<tr>
<td></td>
<td>A</td>
<td>not significant</td>
<td>not significant</td>
<td>0.16 ~ 0.19</td>
<td>-0.13 ~ -0.14</td>
<td>0.10 ~ 0.20</td>
</tr>
<tr>
<td></td>
<td>F</td>
<td>0.26 ~ 0.29</td>
<td>0.29 ~ 0.30</td>
<td>0.25 ~ 0.27</td>
<td>0.20 ~ 0.25</td>
<td>0.05 ~ 0.09</td>
</tr>
<tr>
<td></td>
<td>Z</td>
<td>0.11767</td>
<td>not significant</td>
<td>0.14 ~ 0.25</td>
<td>not significant</td>
<td>0.05 ~ 0.09</td>
</tr>
<tr>
<td></td>
<td>$u_i$</td>
<td>not significant</td>
<td>not significant</td>
<td>not significant</td>
<td>not significant</td>
<td>not significant</td>
</tr>
</tbody>
</table>

*: when D is introduced together with PT.

coefficient value based on only the log-linear model in which each variable has a significant effect. According to Table 4, the structure of a function seems to vary with time. The fire-protection dummy coefficient is relatively robust, taking similar values between 1975 and 1995. For other variables, the value of the coefficient is not stable. Not only the values of coefficients differ among time periods, but some coefficients are not significant at some time periods. In particular, concerning the zoning variable $u_i$, their effect is significant only in 1985, and insignificant in other time periods. It is difficult to explain why they are significant only in 1985. The coefficient of PT seems to change over time in a more systematic way: it continues to decrease until 1990, and possible hypothesis for explaining this change is proposed as follows. It is supposed that the resident's bid-rent at a particular location depends not on the time-distance to a city center, but on the time-cost of a trip to a city center. Thus, letting the time-cost be denoted by

$$C = W \times PT$$

where W is the wage rate, it holds that

$$\log P_t = \beta \log C_t + \text{other terms}$$

$$= \beta (\log W_t + \log PT_t) + \text{other terms}$$

where $\beta < 0$ and t is time period. Differentiating it with respect to t gives us:

$$\frac{d \log P_t}{dt} = \beta \left( \frac{d \log W_t}{dt} + \frac{d \log PT_t}{dt} \right)$$

and therefore

$$\frac{d \log P_t}{d \log PT_t} = \gamma_t = \beta \left( 1 + \frac{d \log W_t}{d \log PT_t} \right)$$

In reality, it is that $(d \log W_t/dt) > 0$ and $(d \log PT_t/dt) < 0$, and it is supposed to ensure $\gamma_t < 0$ that $|d \log W_t/dt| < |d \log PT_t/dt|$. During the period from 1975 to 1990, $|d \log PT_t/dt|$ has been small relative to $d \log W_t/dt$, and thus $\gamma_t$ has been lowered: in 1992, the subway in Sendai was extended to Izumi Chuo (North), whereby $|d \log PT_t/dt|$ increased, and as result, $\gamma_t$ is increased.

7. Conclusion

This paper has analyzed the residential land price function in Sendai, comparing functions between Tokyo and Sendai cities, and examined the time series structural change. Main results are summarized as follows.

1. In a big city like Tokyo, zoning ordinance has a significant effect on land price, but in a local, medium-sized city like Sendai, the effect is insignificant. This is because, in a local medium-sized city, environmental difference among residential zoned districts is not so large, and thus, it is meaningless to apply uniformly the zoning ordinance to every city in a nation.

2. The extent of restriction on building structure for fire-protection has a significant and positive effect on residential land price in both cities.

3. The effect of permitted limit of FAR is not significant in Sendai when that variable is introduced together with F. On the other hand, in Tokyo, an increase in FAR significantly increases the price reflecting more
efficient use of land.

4. As far as the land price elasticity is concerned, it is nearly equal for the two cities for most variables.

Acknowledgement

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REFERENCES


