CIRJE-F-561

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April 2008

April 18, 2008

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Abstract

We estimate the consumption values of urban agglomeration economies and social overhead capital for Japanese metropolitan areas. Following the pioneering work of Tabuchi and Yoshida (2000), our approach exploits the fact that consumers tolerate higher living costs if they benefit from urban agglomeration economies and/or better social overhead capital. This living cost approach requires an appropriate measure of the representative living cost in a metropolitan area; however, it is not easy to estimate because housing prices vary widely within a metropolitan area. Tabuchi and Yoshida (2000) choose the average land price for commercial use as a measure of housing costs in a metropolitan area. Because the prices of residential land are typically much lower than those of commercial land, this might have resulted in biased estimates. We estimate bid rent functions for suburban municipalities within metropolitan areas to cope with the aggregation problem. According to our estimation results, the elasticity of the real wage with respect to city size is about –9.3% if we use the land price as the housing price variable and about –7.9% if we use housing rent data. These numbers are comparable to those obtained by Tabuchi and Yoshida (between –7% and –12% depending on the specification). Another finding is that social overhead capital in a municipality has much larger and more significant effects than city size: the elasticity of the real wage with respect to social overhead capital is about –24.4% in the housing rent estimation and about –45.7% in the land price estimation.

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1 Introduction

Few studies have considered the estimation of consumption side urban agglomeration economies although many empirical studies exist on the production side[1]. As Glaeser, Kolko, and Saiz (2001) argue convincingly, agglomeration economies on the consumption side are extremely important but are not focused upon, compared with those on the production side. Tabuchi and Yoshida (2000) is a notable exception in estimating consumption side agglomeration economies. Their approach is to rely on the fact that consumers tolerate higher living costs if they value urban agglomeration. In particular, higher housing costs reflect the benefits of urban agglomeration.

This living cost approach requires an appropriate measure of the average living cost of each metropolitan area. The average living cost is not easy to estimate, however, because housing prices vary widely within a metropolitan area. Tabuchi and Yoshida (2000) choose the average land price for commercial use as the housing price of a metropolitan area. Because the prices of residential land are much lower than those of commercial land, this might have resulted in biased estimates. We use municipality-level commuting costs and land price data to obtain better estimates of urban agglomeration economies.

Another difference from Tabuchi and Yoshida (2000) is that we estimate the consumption values of social overhead capital in addition to urban agglomeration economies. We find that they are larger and statistically more significant than those of agglomeration economies if we use municipality-level social overhead capital data.

There are two approaches to the estimation of urban agglomeration economies and social overhead capital: primal and dual approaches. The living cost approach can be considered as a version of the latter. The dual approach uses dual functions such as cost, profit, expenditure, and indirect utility functions, or some other relationship derived from these equations. The primal approach typically estimates production functions. Although the dual approach can be applied to the consumption side as well as the production side, the primal approach cannot be applied to the former. The reason is that the consumption side counterpart of a production function, a utility function, cannot be estimated directly because we do not have data on utility levels. The dual approach is therefore the only choice for the consumption side benefits.

Tabuchi and Yoshida (2000) estimate a dual relationship derived from indirect utility functions. We use another dual function, a bid rent function, which is a more natural framework to handle spatial variation of housing prices within a metropolitan area.

In order to cope with data limitations, we have to take extra care in deriving an appropriate equation to be estimated. The most significant difficulty is that we only have municipality-level

[1] See Kanemoto, Ohkawara, and Suzuki (1996), Kanemoto and Saito (1998), Kanemoto, Kitagawa, Saito, and Shioji (2005) for our earlier work on Japanese metropolitan areas, and Rosenthal and Strange (2004) for an excellent survey.

aggregate data. For example, because residents in a municipality are heterogeneous, we have to modify the standard monocentric city model to account for the fact that not all residents commute to the CBD. Furthermore, there are considerable variations across municipalities in worker characteristics such as education levels and age composition. In order to deal with the first problem, we introduce local workers who do not commute to the CBD. The second problem is solved, at least partly, by using the education-level variable.

The organization of this article is as follows. Section 2 derives a reduced form bid rent function that can be estimated with municipality-level data. Section 3 explains the data set and the methods of constructing the variables used in our estimation. Section 4 reports estimation results and conducts robustness checks. Section 5 discusses the limitations of our approach and directions for future research.

2 Bid Rent Functions with Consumption Side Agglomeration Economies

Because of tight regulation in Japan on the use of government statistics for scientific research, we cannot access individual micro data. The available data are limited to the municipality-level averages of household income, commuting time, housing rent, land price, and social overhead capital. The distribution of commuting time in a municipality is also available, but we do not know to which municipality a resident commutes. We model the consumer behavior in such a way that we can use these data most effectively.

The utility function of a consumer is $U(z,h,t,N,G)$, where z, h, t, N, and G are the composite consumer good, housing (or land if we use land price data), commuting time, city size, and social overhead capital, respectively. The budget constraint is $y = z + rh$, where y and r are income and housing price, respectively. We ignore pecuniary commuting costs because most employers pay for the commuting costs of their employees because commuting allowances are exempt from income taxation. The bid rent function is:

$$(1) \qquad R(y,t,N,G,u) \equiv \max_{\{z,h\}} \left\{ \frac{y-z}{h} : U(z,h,t,N,G) \geq u \right\}.$$

Under the assumption that free mobility between metropolitan areas equalizes utility levels across metropolitan areas, we could estimate the parameters of the bid rent function, if we had data on the income and commuting time of each consumer. The difficulty we are faced with is that we have only municipality-level averages. Consumers differ in their income levels, and only a fraction of them commute to the CBD. In order to deal with these heterogeneity problems, we assume a simple framework of three types of consumers: high ability and low ability CBD workers and local workers. A CBD worker commutes to the CBD and a local worker works in the neighborhood of his/her residence. We assume that local workers have the same ability as low ability CBD workers.

CBD workers of the same ability have the same income within a metropolitan area but their incomes vary across metropolitan areas. The incomes of local workers are different between different municipalities within a metropolitan area, reflecting variation in housing prices. We have data on the average income of a municipality but do not have separate data for the three consumer types. By assuming that workers who have longer commuting time are CBD workers and that college graduates are high ability workers, we estimate the shares of the three types in a municipality. With this information, we estimate the average income levels of the three types of workers.

The income of a low ability CBD worker in metropolitan area *m* is denoted by y_m and that of a high ability worker is assumed to be (1+*H*) times higher than this: $(1+H)y_m$. The income of a local worker in municipality *j* in metropolitan area *m* is y_{mj}. The bid rent functions of the low ability CBD and local workers can be written as:

$$R_{mj} = R^C(y_m, t_{mj}, N_m, G_{mj}) + \varepsilon_{mj} , \quad (2)$$

$$R_{mj} = R^L(y_{mj}, N_m, G_{mj}) + \eta_{mj} , \quad (3)$$

respectively, where ε_{mj} and η_{mj} are error terms that represent unobserved characteristics of individuals and municipalities, and the commuting time for local workers is normalized to be zero. The bid rent function of a high ability CBD worker is the same as that of the low ability type because a higher income level is offset by a higher utility level. In equilibrium the bid rents of the three types must equal:

$$R^C(y_m, t_{mj}, N_m, G_{mj}) + \varepsilon_{mj} = R^L(y_{mj}, N_m, G_{mj}) + \eta_{mj} . \quad (4)$$

Solving this equation for y_{mj} yields the income of a local worker in each municipality as a function of other variables and error terms:

$$y_{mj} = \varphi(y_m, t_{mj}, N_m, G_{mj}, \varepsilon_{mj}, \eta_{mj}) . \quad (5)$$

If N_m enters the bid rent functions in an additively separable way and if its effects on bid rents are the same between CBD and local workers, as we assume later, then it drops out of this equation.

The share of CBD workers in municipality *mj* is denoted by s_{mj}. The CBD workers are divided into low and high ability types, the shares of which we denote by s_{Lmj} and s_{Hmj}, respectively. The shares satisfy $s_{mj} = s_{Lmj} + s_{Hmj}$. Using these shares, we can write the average income of a municipality as:

$$\bar{y}_{mj} = y_m\left(s_{mj} + s_{Hmj}H\right) + y_{mj}\left(1 - s_{mj}\right). \quad (6)$$

Combining this equation with (5), we obtain the relationship between y_m and $\bar{y}_{mj}$:

$$y_m = \phi(\bar{y}_{mj}, t_{mj}, N_m, G_{mj}, s_{mj}, s_{Hmj}H, \varepsilon_{mj}, \eta_{mj}) . \quad (7)$$

Substituting this into the bid rent function yields:

$$R_{mj} = R^C(\phi(\bar{y}_{mj}, t_{mj}, N_m, G_{mj}, s_{mj}, s_{Hmj}H, \varepsilon_{mj}, \eta_{mj}), t_{mj}, N_m, G_{mj}) + \varepsilon_{mj} . \quad (8)$$

2-1 Bid rent functions linear in income and commuting time

The reduced form bid rent function (8) is in general very messy. In order to make it easy to estimate, we assume the following functional forms for the bid rent functions of CBD and local workers, (2) and (3).

(9) $$\ln(R_{mj}) = a_0 + a_1 y_m + a_2 \ln(N_m) + a_3 \ln(G_{mj}) + a_4 t_{mj} + \varepsilon_{mj}$$

(10) $$\ln(R_{mj}) = a_0 + a_1 y_{mj} + a_2 \ln(N_m) + a_3 \ln(G_{mj}) + \eta_{mj}$$

Note that these equations are log-linear in R_{mj}, N_m, and G_{mj}, but linear in y_m and t_{mj}. As mentioned in the preceding section, we only have data on municipality average income, $\bar{y}_{mj}$, and do not know those for CBD and local workers, y_m and y_{mj}. In equilibrium, however, the bid rents of all types must equal, which yields the following relationship between them.

(11) $$y_{mj} = y_m + \frac{1}{a_1}(a_4 t_{mj} + \varepsilon_{mj} - \eta_{mj})$$

Using this relationship, we can rewrite the average income of a municipality (6) as:

(12) $$\bar{y}_{mj} = y_m \{1 + s_{Hmj} H\} + (1 - s_{mj}) \frac{1}{a_1}(a_4 t_{mj} + \varepsilon_{mj} - \eta_{mj}) .$$

Solving this equation for y_m, we obtain a specific form of (7):

(13) $$y_m = \frac{\bar{y}_{mj} - (1 - s_{mj}) \frac{1}{a_1}(a_4 t_{mj} + \varepsilon_{mj} - \eta_{mj})}{1 + s_{Hmj} H} .$$

Substituting this into (9) or (10) yields the reduced form bid rent function,

(14) $$\ln(R_{mj}) = a_0 + a_1 \left(\frac{\bar{y}_{mj}}{1 + s_{Hmj} H} \right) + a_2 \ln(N_m) + a_3 \ln(G_{mj}) + a_4 t_{mj} \left(\frac{s_{mj} + s_{Hmj} H}{1 + s_{Hmj} H} \right) + \tilde{\varepsilon}_{mj} ,$$

where

(15) $$\tilde{\varepsilon}_{mj} = -\left(\frac{1 - s_{mj}}{1 + s_{Hmj} H} \right)(\varepsilon_{mj} - \eta_{mj}) + \varepsilon_{mj} .$$

3 Data and Construction of Variables

We estimate the reduced form bid rent function (14), using municipality average data from several government statistics. In addition to typical economic variables such as income, city size, and social overhead capital, we use the snowfall variable (number of days of snow cover) to represent weather conditions that affect consumer welfare. The equation to be estimated is then:

(16) $$\ln(R_{mj}) = a_0 + a_1 I_{mj} + a_2 \ln(N_m) + a_3 \ln(G_{mj}) + a_4 T_{mj} + a_5 \ln(Snow) + \tilde{\varepsilon}_{mj} ,$$

where

$$I_{mj} = \frac{\bar{y}_{mj}}{1+s_{Hmj}H}, \quad T_{mj} = t_{mj}\left(\frac{s_{mj}+s_{Hmj}H}{1+s_{Hmj}H}\right)$$

and

$$Snow = 1 + \text{Number of days of snow cover}.$$

Our samples are restricted to suburban municipalities in the 30 largest metropolitan areas. This means that we exclude central cities and small size metropolitan areas. The number of municipalities that fits this category is 424 altogether. The number of suburban municipalities in a metropolitan area varies widely from Tokyo's 159 to Takamatsu's 1. Table 1 shows the number of employed persons and the number of sample municipalities in each metropolitan employment area (MEA).[2]

[Insert Table 1]

We have two alternatives for the rent variable R_{mj}: residential land price per square meter (10,000 yen per square meter, 1998 "Published Land Prices" by the Ministry of Land, Infrastructure and Transport) and housing rents of living space for nonwooden houses[3] (yen per tatami unit[4], 1998 Housing and Land Survey). The income variable $\bar{y}_{mj}$ is obtained by dividing the total taxable income of a municipality in 1995 (million yen per year) by the number of employed persons there (1995 Population Census). The metropolitan area size N_m is the total number of employed persons in a metropolitan area from the 1995 Population Census.

We use the municipality-level social overhead capital data provided by the Policy Research Institute for Land, Infrastructure and Transport in the Ministry of Land, Infrastructure and Transport. These data are constructed from the prefecture-level data of the Cabinet Office's Japanese Social Overhead Capital (2002) by proportional allotment using a variety of variables such as physical stock data. Our social overhead capital variable G_{mj} is per unit area.[5] For the area size of a municipality we use inhabitable land, although we report estimation results for other land area definitions such as city planning area and urbanization promotion area later in Table 6. Social overhead capital has four (4) categories, agriculture and fishery, national land preservation (flood control, afforestation, and coast preservation), daily life (municipal road, sewerage, wastes, parks, water, rental housing, schools, and social education), and industry infrastructure (national and prefectural road, tolled expressways, ports, airports, and industrial water). Among these four types we find that the daily life type is statistically most significant.

The commuting time for a CBD worker t_{mj} is from the 1998 Housing and Land Survey.

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2 See Kanemoto and Kurima (2005) for the definition of an MEA and how economic data are constructed for MEAs.

3 We use only the municipalities with a sample of at least 50 rental units. The Housing and Land Survey has data on wooden rental housing but the sample size is smaller than nonwooden units.

4 One tatami unit is 3.3 square meters.

Because the survey does not tell us where a resident commutes to, we assume that workers who commute longer than 30 minutes are CBD commuters and the commuting time variable is obtained by computing the average commuting time of these workers. This procedure does not work for central city residents who live close to the CBD. We therefore exclude central cities of metropolitan areas from our sample and use only suburban municipalities. The share of CBD workers s_{mj} is the share of workers whose commuting times exceed 30 minutes.

The share of high ability workers s_{Hmj} is proxied by the share of college graduates. Because the education data are not available in the 1995 Population Census, we use the 1990 Population Census data. In the estimation of the bid rent function we have to specify the income premium of college graduates, *H*. We could estimate this parameter together with *a*'s when we estimate (14). This does not however provide a reliable estimate of *H* because of multicollinearity and other problems. We could instead use relationship (12). This relationship can be rewritten as:

(17) $$\bar{y}_{mj} = (b_0 + b_m d_m)\{1 + s_{Hmj} H\} + b_1 (1 - s_{mj}) t_{mj} + \xi_{mj} ,$$

where d_m is a dummy variable representing metropolitan area *m* except for Tokyo, which is taken as the base case. Specifically, we have 29 dummy variables for metropolitan areas other than Tokyo, where $d_m = 1$ for metropolitan area *m* and $d_m = 0$ for other metropolitan areas. The income of a low ability CBD worker of metropolitan area *m* is estimated as:

(18) $$b_0 + b_m d_m = y_m ,$$

where b_0 is that of Tokyo. Coefficient b_1 and error term ξ_{mj} satisfy:

(19) $$b_1 = a_4 / a_1 , \quad \xi_{mj} = \frac{1}{a_1}(1 - s_{mj})(\varepsilon_{mj} - \eta_{mj}) .$$

Estimating this equation yields an extremely high value of *H* (2.28 with the standard error of 0.16). This might suggest serious problems with this estimation method. Although we report results with this parameter value in Table 4, we adopt a simpler approach that uses the estimates from nationwide earnings data. According to the Basic Survey on Wage Structure (Ministry of Health, Labor and Welfare), the difference is about 30%.

Large cities have various statistics for their wards. Most of them are central cities, which are excluded from our sample, but three cities in the Tokyo metropolitan area, Yokohama, Kawasaki, and Chiba are included. For these cities, we use the ward-level data whenever available. The social overhead capital data are not available for wards, and the 1990 Population Census does not have the ward-level education data for Chiba city. In these cases, we use the city-level averages for each ward.

4 Estimation Results

Table 2 presents our main estimation results for the reduced form bid rent function. All the

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[5] We have experimented with social overhead capital per person, but this did not yield good estimates.

estimates in this table use the daily life type for the social overhead capital variable. The first three columns use the natural logarithm of land price as the dependent variable, and the last three use the natural logarithm of housing rent. The coefficients for city size and social overhead capital are significant and have the expected signs in the simple OLS estimates, but those for commuting time are insignificant.

[Insert Table 2]

Most of the right-hand-side variables might have endogeneity problems. Particularly important in this respect is the city-size variable that cannot be considered as exogenous. In the instrument variables (IV) estimations, we use two instrumental variables: the metropolitan population size in 1920 and the ratio of habitable land area to total land area for a metropolitan area. This increases the coefficients for city size but the differences are small.

Because we have a two-level structure of metropolitan areas and municipalities within them (30 metropolitan areas with 424 suburban municipalities altogether), error terms have two components, one across metropolitan areas and the other across municipalities within a metropolitan area. In order to deal with this error component structure, we next try a random effect model with the same instruments as the IV estimations. The coefficient for city size in the land price case is larger but less significant. The change in the other coefficients is small.

In order to test for the random effects model, we apply the Breusch–Pagan Lagrange multiplier test for unbalanced panels proposed by Baltagi and Li (1990). The Lagrange multiplier (LM) statistics reported in Table 2 show that in the estimation with land price data the test statistics exceed the 99% critical value of 6.63. With housing rent data, however, we cannot reject the null hypothesis that the variance of the intermetropolitan error term is zero. This appears to reflect the fact that the variation across metropolitan areas is much smaller for housing rent than for land price.

Sargan’s *J* statistics test the orthogonality condition for the instrumental variables. Although the *J* statistics are significant for the case of simple IV estimation of land price, in the other three cases the instruments we employ are valid for the endogenous variables at 5% significance levels. Because the sizes of the metropolitan areas and municipalities vary greatly, we are bound to have heteroskedasticity. The White test indeed confirms the presence of heteroskedasticity. We therefore report White-adjusted standard errors in Table 2 and all the tables that follow.

The coefficient for city size shows the magnitude of agglomeration economies measured in land price per unit area. In order to convert this into income terms, we divide it by the coefficient of the income variable to compute $\gamma = a_2 / a_1$. If the city size is doubled, the real income of a resident increases by γ million yen. In the random effect estimation of the land price case, doubling the city size increases real income by about 0.297 million yen and in the housing rent estimation by about 0.254 million yen. Numbers in parentheses are the Wald restriction standard errors of γ computed by the Delta method. In the random effect IV estimation, γ is significant at the 10% level in both the land price and housing rent cases. Dividing γ by income yields a more commonly used elasticity expression, $\lambda = \gamma / y$. The table reports this elasticity at the sample average taxable income. The elasticity is around 0.093 in the land price estimation and 0.079 in the housing rent estimation. These results are consistent with Tabuchi and Yoshida (2000), whose estimates range from 0.07 to 0.12.

To our surprise, the social overhead capital variable has large and significant coefficients. We compute the shadow price of social overhead capital in the same way as our computation of γ above. This yields 1.452 in the random effect estimation of the land price case and 0.786 in the housing rent case, which means that doubling the social overhead capital in a municipality increases the real income of its residents by about 1.452 and 0.786 million yen, respectively. Elasticities are about 0.457 and 0.244. All the estimates are significant at the 1% level. Note that our social overhead capital is the municipality-level data. In earlier estimations that use metropolitan-level aggregates, the social overhead capital variable is frequently insignificant or its coefficient has a negative sign, e.g., Kanemoto, et al. (2005). Considering that most of the social overhead capital that affects our daily life is quite local, this difference is reasonable.

The last three columns show the estimates for housing rents. The sample size is smaller at 333 because we omit municipalities with samples of less than 50 rental units. Compared with the land price case, the coefficient for city size is about half the value and slightly less significant. The value of agglomeration is however not very different from the land price case because the coefficient for income is also small. The coefficient for social overhead capital is smaller and less significant. Its value and elasticity are also significantly smaller than the land price case. Another difference is that the snowfall variable has an unexpected sign.

Table 3 reports the effects of changing the social overhead capital variable. Among the four types of social overhead capital, the daily life type has the largest (White adjusted) *t*-value and adjusted *R*-squared, although the difference compared with all social overhead capital, which includes all four types ("All SOC") is small.

[Insert Table 3]

All the estimates so far assume that the income premium of college graduate is $H = 0.3$, i.e., college graduates earn 30% more income than others. Table 4 shows the effects of changing the premium. Reducing it to zero produces only a small change in the results. As noted in the preceding section, estimating (17) yields an extremely high value of $H = 2.3$. Although the coefficient for city size is not large, the coefficient for income is small, which yields an estimate of agglomeration economies about four times higher than previous ones.

[Insert Table 4]

Table 5 examines the effects of changing the definition of CBD workers. The column labeled 15 (60) minutes assumes that individuals whose commuting times exceed 15 (60) minutes are all CBD workers. The last column assumes that all residents are CBD workers. Changing the commuting time cut-off to 15 minutes or 60 minutes from 30 minutes does not significantly affect the estimates, but assuming that the percentage of CBD commuters is 100% doubles the coefficient of city size. This highlights the seriousness of this type of misspecification.

[Insert Table 5]

Our social overhead capital variable is per unit area, where the area of a municipality is taken as the habitable area that excludes mountains, rivers, lakes, etc. Table 6 compares the results of five different land area definitions. The second case subtracts agricultural land area from habitable land. The third case uses land that is subject to real estate taxation. The fourth is the city planning area that has zoning regulation. The last one is the urbanization promotion area where urban development is encouraged. Except for the taxable land area and urban promotion area cases where the adjusted R^2's are significantly smaller than other cases, the results are similar.

[Insert Table 6]

Finally, Table 7 reports the effects of changing the instrumental variables. Replacing the metropolitan population in 1920 by the number of workers in 1980 does not cause big differences. Adding a municipality-level variable changes the results significantly, however. For example, the last column uses the population density in each municipality in addition to two metropolitan-level variables. The city-size variable is insignificant and the value of social overhead capital is much larger than other cases.

[Insert Table 7]

5 Concluding Remarks

Using municipality-level data, we estimated the magnitude of agglomeration economies and the value of social overhead capital on the consumption side. According to our best estimates, doubling the metropolitan size increases the real income of a household by 9.3% (land price estimation) or 7.9% (housing rent estimation). These estimates are larger than most of the estimates of production side agglomeration economies[6], which shows the importance of consumption side agglomeration economies. The value of social overhead capital of the daily life type is much larger at 45.7% (land price estimation) or 24.4% (housing rent estimation).

Our approach has a number of limitations mainly because of data availability. First, our commuting time variable may not be a good proxy of commuting time to the CBD. Constructing a better commuting time data would yield more reliable estimates. Second, many municipalities include nonurban areas. The use of more disaggregated or micro data would be a fruitful direction for future research. Third, the search for better instrumental variables, especially for the social overhead capital variable, must be continued.

Acknowledgments

We thank Laurent Gobillon, Toru Kitagawa, Kamhon Kan, and participants at a faculty seminar at the University of Tsukuba, the 53rd Annual North American Meetings of the Regional Science Association

[6] For example, the estimate by Kanemoto et al. (2005) for the largest 29 metropolitan areas is 6.8%.

International, 2006, and 2007 Taipei Conference on Regional and Urban Economics for their useful comments.

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Table 1 MEA size and the number of sample municipalities

MEA	MEA size (Number of employed persons)	Sample size (Land price)	Sample size (Housing rent)
Tokyo	16,381,141	159	146
Osaka	5,997,167	65	53
Nagoya	2,832,816	41	35
Kyoto	1,269,592	9	6
Fukuoka	1,098,537	14	13
Sapporo	1,035,995	4	2
Kobe	1,010,009	6	5
Hiroshima	817,949	7	5
Sendai	760,717	11	7
Kitakyushu	657,500	8	3
Shizuoka	546,736	3	3
Hamamatsu	502,319	5	3
Niigata	487,833	6	3
Okayama	483,430	4	1
Kumamoto	480,610	8	6
Utsunomiya	460,970	5	3
Gifu	416,901	6	5
Kanazawa	389,844	3	3
Fukuyama	369,627	5	5
Himeji	357,683	4	3
Takamatsu	353,739	1	1
Toyohashi	344,458	4	2
Nagano	340,104	3	3
Oita	336,376	2	2
Mito	335,374	4	2
Kagoshima	328,274	3	3
Naha	319,666	5	5
Kofu	318,637	4	2
Yokkaichi	314,021	3	3
Toyama	296,490	3	2

Table 2 Estimation of the bid rent function: Main results

	ln (Land price)			ln (Rent)		
	OLS	IV	Random effect + IV	OLS	IV	Random effect + IV
Income	0.256***	0.249***	0.306***	0.143***	0.142***	0.176***
	(0.050)	(0.051)	(0.052)	(0.045)	(0.045)	(0.048)
ln（City size）	0.051***	0.059***	0.091**	0.029*	0.031**	0.045**
	(0.016)	(0.016)	(0.045)	(0.015)	(0.016)	(0.022)
ln（SOC）	0.467***	0.465***	0.444***	0.145***	0.144***	0.138***
	(0.022)	(0.022)	(0.021)	(0.020)	(0.020)	(0.021)
Commuting time	–0.0005	–0.001	–0.006***	–0.001	–0.001	–0.004*
	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)
ln（1 + Number of days of snow cover）	–0.097***	–0.094***	–0.097***	0.021	0.022	0.017
	(0.024)	(0.025)	(0.037)	(0.018)	(0.019)	(0.020)
Constant	6.533***	6.452***	6.241***	6.082***	6.064***	5.941***
	(0.239)	(0.236)	(0.568)	(0.200)	(0.206)	(0.268)
Value of agglomeration						
in million yen	0.199**	0.238**	0.297*	0.205	0.221	0.254*
	(0.086)	(0.098)	(0.159)	(0.142)	(0.151)	(0.151)
Elasticity	0.063**	0.075**	0.093*	0.064	0.069	0.079*
	(0.027)	(0.031)	(0.050)	(0.044)	(0.047)	(0.047)
Value of SOC						
in million yen	1.825***	1.865***	1.452***	1.010***	1.018***	0.786***
	(0.401)	(0.424)	(0.284)	(0.384)	(0.390)	(0.277)
Elasticity	0.575***	0.587***	0.457***	0.313***	0.316***	0.244***
	(0.126)	(0.134)	(0.089)	(0.119)	(0.121)	(0.086)
Sample size	424	424	424	333	333	333
Adjusted R^2	0.808	0.808	0.810	0.406	0.406	0.418
Sargan's J statistic	–	9.182	1.433	–	0.000	2.982
Breush-Pagan test (LM statistic)	7.463	41.795	–	0.013	0.015	–

Notes: Significance level ***1% **5% *10%

Table 3　Comparison of four types of social overhead capital

	Daily life	**National land preservation**	**Industry**	**Agriculture and fishery**	**All SOC**
Income	0.306^{***}	0.606^{***}	0.533^{***}	0.576^{***}	0.322^{***}
	(0.052)	(0.066)	(0.067)	(0.069)	(0.053)
ln（City size）	0.091^{**}	0.133^{**}	0.192^{***}	0.171^{***}	0.098^{**}
	(0.045)	(0.058)	(0.052)	(0.054)	(0.046)
ln（SOC）	0.444^{***}	0.381^{***}	0.172^{***}	-0.261^{***}	0.472^{***}
	(0.021)	(0.046)	(0.020)	(0.028)	(0.024)
Commuting time	-0.006^{***}	-0.009^{***}	-0.009^{***}	-0.010^{***}	-0.005^{*}
	(0.002)	(0.003)	(0.003)	(0.003)	(0.002)
ln（1 + Number of days of snow cover）	-0.097^{***}	-0.180^{***}	-0.171^{***}	-0.184^{***}	-0.112^{***}
	(0.037)	(0.048)	(0.041)	(0.044)	(0.037)
Constant	6.241^{***}	6.347^{***}	7.095^{***}	9.983^{***}	5.646^{***}
	(0.568)	(0.707)	(0.635)	(0.750)	(0.577)
Value of agglomeration					
in million yen	0.297^{*}	0.220^{**}	0.360^{***}	0.296^{***}	0.305^{**}
	(0.159)	(0.102)	(0.115)	(0.104)	(0.155)
Elasticity	0.093^{*}	0.069^{**}	0.113^{***}	0.093^{***}	0.096^{**}
	(0.050)	(0.032)	(0.036)	(0.033)	(0.049)
Value of SOC					
in million yen	1.452^{***}	0.628^{***}	0.323^{***}	-0.453^{***}	1.466^{***}
	(0.284)	(0.113)	(0.065)	(0.072)	(0.286)
Elasticity	0.457^{***}	0.198^{***}	0.102^{***}	-0.143^{***}	0.462^{***}
	(0.089)	(0.036)	(0.020)	(0.023)	(0.090)
Sample size	424	424	424	422	424
Adjusted R^2	0.810	0.681	0.694	0.642	0.799
Sargan's J statistic	1.433	0.472	1.853	1.778	1.951

Notes: Significance level　***1%　**5%　*10%

Table 4 The effects of changing the income premiums of college graduates, *H*

	H = 0.3	**H = 0**	**H = 2.3**
Income	0.306***	0.286***	0.059
	(0.052)	(0.044)	(0.094)
ln（City size）	0.091**	0.097**	0.076
	(0.045)	(0.044)	(0.048)
ln（SOC）	0.444***	0.435***	0.504***
	(0.021)	(0.022)	(0.020)
Commuting time	–0.006***	–0.007***	0.0003
	(0.002)	(0.002)	(0.002)
ln（1 + Number of days	–0.097***	–0.096***	–0.071*
of snow cover）	(0.037)	(0.037)	(0.038)
Constant	6.241***	6.284***	6.377***
	(0.568)	(0.560)	(0.608)
Value of agglomeration			
in million yen	0.297*	0.337**	1.294
	(0.159)	(0.167)	(2.317)
Elasticity	0.093*	0.106**	0.408
	(0.050)	(0.053)	(0.730)
Value of SOC			
in million yen	1.452***	1.517***	8.604
	(0.284)	(0.279)	(13.714)
Elasticity	0.457***	0.478***	2.711
	(0.089)	(0.088)	(4.321)
Sample size	424	424	424
Adjusted R^2	0.810	0.813	0.795
Sargan’s J statistic	1.433	1.486	1.858

Notes: Significance level ***1% **5% *10%

Table 5 The definitions of CBD workers

	30 min	**15 min**	**60 min**	**CBD 100%**
Income	0.306***	0.296***	0.329***	0.302***
	(0.052)	(0.053)	(0.050)	(0.042)
ln（City size）	0.091**	0.078*	0.106**	0.183***
	(0.045)	(0.043)	(0.045)	(0.048)
ln（SOC）	0.444***	0.450***	0.430***	0.359***
	(0.021)	(0.021)	(0.022)	(0.026)
Commuting time	–0.006***	–0.005**	–0.007***	–0.023***
	(0.002)	(0.002)	(0.002)	(0.003)
ln（1 + Number of days	–0.097***	–0.095**	–0.102***	–0.119***
of snow cover）	(0.037)	(0.037)	(0.037)	(0.037)
Constant	6.241***	6.314***	6.046***	6.894***
	(0.568)	(0.565)	(0.575)	(0.526)
Value of agglomeration				
in million yen	0.297*	0.264*	0.321**	0.606***
	(0.159)	(0.159)	(0.151)	(0.196)
Elasticity	0.093*	0.083*	0.101**	0.191***
	(0.050)	(0.050)	(0.048)	(0.062)
Value of SOC				
in million yen	1.452***	1.522***	1.305***	1.189***
	(0.284)	(0.308)	(0.234)	(0.215)
Elasticity	0.457***	0.480***	0.411***	0.375***
	(0.089)	(0.097)	(0.074)	(0.068)
Sample size	424	424	424	424
Adjusted R^2	0.810	0.810	0.811	0.817
Sargan's J statistic	1.433	1.378	1.692	3.071

Notes: Significance level ***1% **5% *10%

Table 6 Land area definitions

	Habitable areas	**Habitable – Cultivated land areas**	**Evaluated land tract [building]**	**City planning areas**	**Urbanization promotion areas**
Income	0.306***	0.419***	0.612***	0.426***	0.774***
	(0.052)	(0.052)	(0.062)	(0.045)	(0.073)
ln（City size）	0.091**	0.092**	0.160***	0.115***	0.247***
	(0.045)	(0.042)	(0.047)	(0.039)	(0.051)
ln（SOC）	0.444***	0.507***	0.444***	0.391***	0.108**
	(0.021)	(0.029)	(0.048)	(0.018)	(0.049)
Commuting time	–0.006***	–0.009***	–0.014***	–0.008***	–0.019***
	(0.002)	(0.002)	(0.003)	(0.002)	(0.003)
ln（1 + Number of days of snow cover）	–0.097***	–0.123***	–0.159***	–0.118***	–0.206***
	(0.037)	(0.032)	(0.037)	(0.029)	(0.042)
Constant	6.241***	5.344***	4.183***	6.207***	6.146***
	(0.568)	(0.545)	(0.708)	(0.471)	(0.750)
Value of agglomeration in million yen	0.297*	0.219**	0.262***	0.269***	0.319***
	(0.159)	(0.108)	(0.087)	(0.097)	(0.079)
Elasticity	0.093*	0.069**	0.082***	0.085***	0.100***
	(0.050)	(0.034)	(0.028)	(0.031)	(0.025)
Value of SOC in million yen	1.452***	1.212***	0.726***	0.918***	0.139**
	(0.284)	(0.186)	(0.121)	(0.118)	(0.064)
Elasticity	0.457***	0.382***	0.229***	0.289***	0.044**
	(0.089)	(0.058)	(0.038)	(0.037)	(0.020)
Sample size	424	423	424	424	376
Adjusted R^2	0.810	0.792	0.702	0.813	0.551
Sargan’s J statistic	1.433	3.359	2.227	5.436	2.910

Notes: Significance level ***1% **5% *10%

Table 7 Instrument variables

IV for city size	None	ln (MEA population 1920) ln (MEA ratio of habitable area)	ln (MEA workers 1980) ln (MEA ratio of habitable area)	ln (MEA population 1920) ln (MEA ratio of habitable area)
IV for SOC				**City population density**
Income	0.305***	0.306***	0.305***	0.107*
	(0.052)	(0.052)	(0.052)	(0.061)
ln（City size）	0.075*	0.091**	0.074*	0.027
	(0.043)	(0.045)	(0.043)	(0.058)
ln（SOC）	0.445***	0.444***	0.445***	0.629***
	(0.021)	(0.021)	(0.021)	(0.027)
Commuting time	–0.006**	–0.006***	–0.006**	–0.002
	(0.002)	(0.002)	(0.002)	(0.003)
ln（1 + Number of days of snow cover）	–0.096***	–0.097***	–0.096***	–0.055
	(0.037)	(0.037)	(0.037)	(0.047)
Constant	6.441***	6.241***	6.444***	5.892***
	(0.554)	(0.568)	(0.551)	(0.674)
Value of agglomeration in million yen	0.245	0.297*	0.244	0.247
	(0.149)	(0.159)	(0.149)	(0.518)
Elasticity	0.077	0.093*	0.077	0.078
	(0.047)	(0.050)	(0.047)	(0.163)
Value of SOC in million yen	1.458***	1.452***	1.459***	5.868*
	(0.286)	(0.284)	(0.286)	(3.471)
Elasticity	0.460***	0.457***	0.460***	1.849*
	(0.090)	(0.089)	(0.090)	(1.094)
Sample size	424	424	424	418
Adjusted R^2	0.809	0.810	0.809	0.781
Sargan’s J statistic	–	1.433	1.104	0.581

Notes: Significance level ***1% **5% *10%