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Urban Agglomeration Economies in Consumption and Production

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Abstract

In this paper, we estimated the net agglomeration economies in the consumption side as well as the production side using Japanese city-based data of 1992, when interregional net migration nearly ceased. We showed that doubling city size increases the nominal wage by approximately 10% but decreases the real wage by approximately 5%-9%. A 10% increase of the nominal wage is attributed to the productivity increase in production activities while a 5%-9% decrease of the real wage is a compensation for the net agglomeration economies, which are the benefits from product variety minus the costs of congestion. In other words, city bigness not only enhances the productivity of firms but also brings net agglomeration economies to households. In this way, we separated the net agglomeration economies in the production side from those in the consumption side.

JEL Classification Number: R00, R10

Keywords: agglomeration, urban productivity, product variety, congestion, interregional differential

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1 Introduction

The conventional neoclassical theory tells us that there should not exist price differentials between regions when production factors and/or products are perfectly mobile. According to the Heckscher-Ohlin theorem, even if production factors are immobile, as in the case with land, no price differentials occur between regions in the end.

In reality, however, per capita income, per area rent and the consumer price index do differ between regions. There are spatial regularities causing price levels to become higher as city size gets larger, as will be seen in Section 3. However, these price differences are not proportional. In fact, the consumer price index in large cities is slightly higher than the national average, but the land rent in large cities is much higher than the national average. Due to these variations in price differentials, it is not certain whether the real income in larger cities is higher or lower.

The real income level is affected by urban agglomeration economies and diseconomies. Urban agglomeration economies exert an influence on firms' profits and household utility both directly and indirectly. For example, on the production side, the urban agglomeration of firms increases their productivity. This increases the demand for labor and raises the wage rate, which leads to an increase in the demand for land and its rent. There are many empirical studies showing that agglomeration raises labor productivity in the manufacturing industries.[1] Such agglomeration economies prevail not only in the manufacturing industries but also in the total industries (Kanemoto, Ohkawara and Suzuki, 1996).

Urban agglomeration plays a role on the consumption side as well. Agglomeration of households brings about various kinds of congestion such as long-distance commuting and insufficient housing space, which decrease the level of household utility. These are urban agglomeration diseconomies.

On the other hand, there are agglomeration economies, which are called economies of variety, on the consumption side. Consumers can choose more suitable goods and services from a larger variety in larger cities. They can also enjoy the "city lights" effects there, as demonstrated by Kelley (1977). Agglomeration economies also play a role in job search. Since there are diverse job types and numerous workers with various skills and knowledge

[1]Labor productivity increases by several percent by doubling city size in manufacturing industries in the United States, Japan and Sweden. For more details, see Tabuchi (1986) and Kim (1997).

in larger cities, jobs and workers tend to match more easily there.

Our major question is whether the above agglomeration economies or agglomeration diseconomies dominate for households in large cities. If agglomeration diseconomies dominate, then we may say that large cities are overpopulated and in-migration to large cities should be restricted. On the contrary, if agglomeration economies are dominant, then further in-migration should be encouraged. In order to answer the question, we conduct an empirical analysis to measure the above agglomeration economies *in the consumption side* using Japanese city-based data.

In Section 2, we explain our model framework briefly and discuss estimation biases in conducting the empirical analysis. In Section 3, we describe the city-based data used in this paper and examine interregional variations in the price data. We then estimate net agglomeration economies for households as well as for firms in Section 4 and report the main results in Section 5.

2 Intercity Equilibrium Model

Roback (1982) developed a general equilibrium model of interregional land and labor markets. In order to answer the above question, we conduct an empirical analysis based on Roback's model.

There are many homogeneous office firms located at the center of each city. Firms use land and labor as inputs and produces a numéraire good with constant returns to scale in production. Intercity migration and entry of firms are assumed to be free. The land rent and the wage rate in each city are determined endogenously within the model. Each firm maximizes its profit given the land rent, the wage rate and the urban amenities. Solving the first-order conditions for optimum, we obtain the following cost function:

$$C(w_f, r_f; \mathbf{z}) = C_o, \tag{1}$$

where w_f is the wage rate, r_f is the office rent per area, $\mathbf{z}$ is the amenity vector, and C_o is a constant cost. Subscripts denoting city numbers are omitted unless necessary. While these variables differ between cities, the cost function should be equal to one in each city under the free migration of firms.

Next, there are many homogeneous households. Each household resides outside the central city, works at an office in the central city, and earns the wage income and rental income.

Given the income and the housing rent, each household consumes the numéraire good and the housing services. Similarly to firms, the intercity migration of households is assumed to be costless. Maximizing household utility, we derive the following indirect utility function:

$$U(w_h, r_h; \mathbf{z}) = U_o, \tag{2}$$

where w_h is the per capita income comprising the wage and rental income, and r_h is the housing rent per area, or the price of the housing services per unit area. The values of r_h and w_h are different between cities and are determined endogenously as are the values of r_f and w_f. U_o is an equilibrium utility level determined by the entire system of cities. Each household chooses a city by considering factors such as housing rent, consumer price index, congestion, and environmental quality. Under the free migration of households, the utility level becomes equal between cities in equilibrium.

The amenity vector $\mathbf{z}$ affects not only the utility function but also the production function, and hence shifts the indirect utility function and the cost function. The urban amenities affecting production activities include the agglomeration of firms and the level of infrastructure. These would be positively associated with city size. On the other hand, the urban amenities affecting the utility level include traffic congestion and product variety, which are related to city size as well. To simplify the subsequent analysis, we regard city size as the most important proxy for urban amenities. City size is thus an endogenous variable in our framework.

The cost function of equation (1) is called the factor price frontier. It is represented in Figure 1, where the horizontal axis is the wage rate w_f and the vertical axis is the office rent. Normally, the cost function C_o is monotonically decreasing. In Figure 1, we can also show the indirect utility function of (2). Now, the horizontal axis is the income w_h and the vertical one is the housing rent r_h. The indirect utility function U_o is a locus of a constant utility level similar to an indifference curve showing the trade-off between the income and the housing rent. U_o should be monotonically increasing.

The equilibrium wage rate and the equilibrium housing rent are determined by the intersection E of C_o and U_o. In reality, however, data of point E can hardly be obtained.

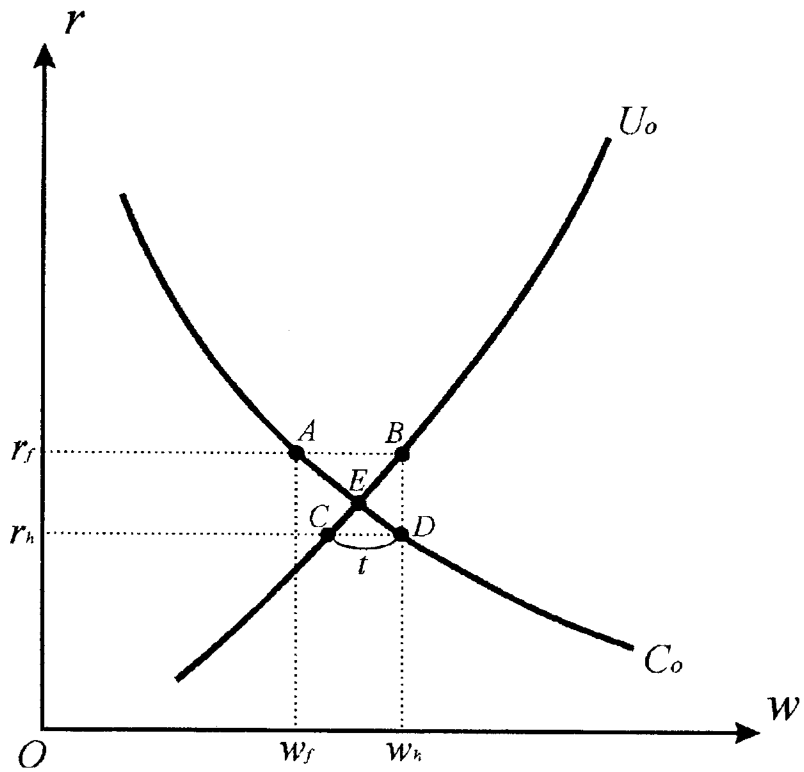

Figure 1: The Wage Rate, Office Rent and Housing Rent

Since r_f is the office rent in the central city, firms on C_o, would pay the rent r_f and the wage w_f at A. Households on U_o would pay the housing rent r_f in the central city out of the income w_h at B. By definition, the difference between w_h and w_f is the rental revenue of a household. Consider a household located at the average distance from the center. In Figure 1, such a household is on C, where the housing rent is r_h and the generalized costs of commuting including congestion are higher by t than those in the central city. Notice that B and C attain the same level of utility since they are on U_o. Finally, D is the point representing the average rent r_h and the per capita income w_h, which are the existing data. In other words, while the true equilibrium is given by E, the actual data is shown by D. The difference between E and D generates an estimation bias in the following analysis.

Figure 1 illustrates the equilibrium in a city of a certain size. What would be the consequences if the city size differed? When city size increases, the amenity level changes. Its net effect on the production side would be positive since agglomeration economies prevail. Otherwise, firms do not have an incentive to agglomerate in cities. Intercity equilibrium by the free migration of firms would be such that high productivity with high wages and high rent in large cities while low productivity with low wages and low rent in small cities. As shown in Figure 1, the cost function C_o should go up in large cities.

An increase in city size affects not only the production side but also the consumption side. So, it additionally shifts the indirect utility function U_o. This is due to agglomeration diseconomies of congestion and agglomeration economies of product variety. If the congestion (e.g., high commuting costs) dominates, then U_o goes down. On the other hand, if the product variety (e.g., diverse shops and restaurants) dominates, then U_o goes up. Whether the movement is upward or downward is an empirical question. If households regard the city bigness as a disamenity, then U_o goes down. If households consider the city bigness is an amenity, then U_o goes up. In this manner, we would be able to measure the net agglomeration dis/economies on the consumption side.

3 Data

Our analysis is cross-sectional using data of the Standard Metropolitan Employment Areas (SMEAs) of over 100,000 population.[2] The data set is listed in Table 1. Due to data availability, however, these data are not SMEA-based but city-based except for population (N). Although there were 118 SMEAs in Japan in 1990, our number of observations is 105 because some of the data are missing. We omitted results using the data of the wage rate in the manufacturing industry since the wage rate behaves very similarly to per capita income (w).

The first three prices (p, w, r) and the SMEA population (N) are endogenous variables, and the other eight variables are exogenous variables $\mathbf{z}$ as surrogates for urban environments. As discussed at the beginning of this paper, there should be no differentials in the first three prices in the absence of interregional transportation costs. However, the coefficients of variations of the first three price variables are different from zero, which may imply that interregional markets of labor, housing and consumer products are imperfect owing to the existence of transportation costs.

The coefficient of variations of the consumer price index is much lower than those of

[2]Japanese interregional migration became very small in 1990s while more than seven million people had migrated to the Tokyo Metropolitan Area from 1955 to 1989. Therefore, we may safely assume that intercity equilibrium has been attained in 1990s.

variable	year	mean	standard deviation	coefficient of variations
consumer price index (p)	1992	101.5	2.55	0.025
per capita income (w)	1992	1.42	0.238	0.168
average land price for housing (r)	1992	118974	172425	1.449
SMEA population (N)	1990	839711	2883303	3.434
nitric dioxide	1991*	16.6	5.29	0.319
time distance to Tokyo station	1995	4.93	3.29	0.667
average age	1990	37.6	1.46	0.039
hours of sunshine	1961-91	1896	154	0.081
snowfall days	1961-91	30.1	37.3	1.238
prefectural capital (dummy)		0.381	0.488	1.281
industrial city (dummy)		0.343	0.477	1.391
coast (dummy)		0.667	0.474	0.710

Note: Years with the asterisk are fiscal years.

Table 1: Descriptive Statistics of the Data

the two other price variables. This is because interregional arbitrage takes place easily due to the low transportation costs of consumer products. On the other hand, the coefficient of variations of the land price is relatively high since housing services are non-traded.[3] Here, we assume that the land price is proportional to the land rent and the housing rent across regions. This is true if arbitrage takes place between the land market and the financial market, the interest rate is the same between regions, and a plot of land is relatively more expensive than a house.

Finally, in order to see the empirical regularities of prices, we computed the correlation coefficients between the endogenous variables of the SMEA population and the three price variables in Table 1. All values of the correlation coefficients are positive and large (between

[3]Tabuchi (1997) proved that the coefficient of variations of housing rent necessarily exceeds that of per capita income, which always exceeds that of traded good prices with normal consumer preference for housing and traded goods. The reason can be explained as follows. Suppose the housing rent in a big city is twice as large as that in a small city while the consumer price index is the same. If per capita income in a big city doubles, then a consumer is better off by reducing her housing expenditure while purchasing more consumer goods. Thus, to be on an equal level of utility, per capita income in a big city should be less than double.

0.44 and 0.93). In this way, we confirm the spatial regularities that these price variables are positively associated with city size.

4 Estimation

Using the data set in the previous section, let us now estimate the cost function (1) and the utility function (2). Since the wage, the rent and the population are endogenous variables, they should be simultaneously determined in equations (1) and (2). Furthermore, the errors in the equations may be heteroskedastic. In order to take into account the heteroskedasticity, we use the instrumental variables (IV) method in the estimation.

First of all, we shall explain an estimation method of the utility function. Let $\mathbf{y}$ be the endogenous variables and $\mathbf{z_1}$ be the exogenous variables of the models, and $\mathbf{z_2}$ be the exogenous variables used as instrumental variables only. The first moment condition used for the estimation is

$$E[f(y_i, z_{1i}; \theta)|\mathbf{z_{1i}}, \mathbf{z_{2i}}] = 0, \quad i = 1, \ldots, n, \tag{3}$$

where the functional form of $f(\cdot)$ is known. In this paper, it is either Cobb-Douglas or CES type, and θ is the parameter vector to be estimated. The second moment condition to be considered for the estimation is

$$E[f(y_i, z_{1i}; \theta)^2|\mathbf{z_{1i}}, \mathbf{z_{2i}}] = \sigma_i^2, \quad i = 1, \ldots, n. \tag{4}$$

The endogenous variables are logarithms of the nominal wage (w), the average land price (r), the consumer price index (p), and the SMEA population (N). The exogenous variables used as instrumental variables are the following: a logarithm of the hours of sunshine, the number of snowfall days, the dummy variable whether or not the SMEA has prefectural capital, the dummy variable whether or not part of the SMEA was designated as *Shinsangyō Toshi* (the New Industrial City) or *Kōgyō Seibi Tokubetsu Chiiki* (the Planned Industrial District) by the Ministry of International Trade and Industry in the early 1970s, and the dummy variable whether or not the SMEA is on the coast.

The models to be estimated are:

$$f(\theta) = \log \frac{w_i}{r_i^{\eta_1} p_i^{(1-\eta_1)}} - \alpha \log N_i - \mathbf{z_{1i}}\beta \tag{5}$$

for the Cobb-Douglas functional form and

$$f(\theta) = \log \frac{w_i}{[\eta_1 r_i^\rho + \eta_2 p_i^\rho]^{1/\rho}} - \alpha \log N_i - \mathbf{z_{1i}}\beta \tag{6}$$

for the CES functional form. The exogenous variables in both models are logarithms of the level of nitric dioxide (NO_2) and the average age and the constant term. Note that the first term of the RHS in each model is regarded as the "real wage" since the nominal wage w_i is adjusted by the rent r_i and the consumer price index p_i.

We estimate the parameters using IV with moment conditions (3) and (4). Here, the instrumental variables consist of the exogenous explanatory variables and those used only for instrumental variables. The estimation has two steps. In the first step, estimates of the parameters are obtained as

$$\hat{\theta} = \text{argmin}_\theta f(\theta)' Z(Z'Z)^{-1} Z' f(\theta),$$

where Z is the matrix of the instrumental variables. In the second step, asymptotically more efficient estimates of the parameters can be obtained by

$$\tilde{\theta} = \text{argmin}_\theta f(\theta)' Z(Z'\hat{\Omega}Z)^{-1} Z' f(\theta),$$

where $\hat{\Omega}$ is a diagonal matrix with its j'th diagonal element being $\hat{\sigma}_j^2 = f(\mathbf{z_{1j}}, \hat{\theta})^2$. This estimation method is essentially equivalent to GMM developed by Hansen (1982).

The test of exogeneity of the instrumental variables are also conducted. The null hypothesis of the test is that the moment condition (3) holds. Under the null hypothesis,

$$f(\tilde{\theta})' Z(Z'\hat{\Omega}Z)^{-1} Z' f(\tilde{\theta})$$

converges to the χ^2 distribution with the degrees of freedom being the difference between the number of the instrumental variables and the parameters to be estimated. For example, the degrees of freedom is 3 for the Cobb-Douglas case, while it is 1 for the CES case.

Next, the cost function (1) is estimated in the same way. In this case, the functional form is linear as:

$$f(\theta) = \log w_i - \gamma \log r_i - \delta \log N_i - \mathbf{z}_{i1}\eta,$$

where γ and δ are parameters to be estimated. The exogenous explanatory variables are a logarithm of the time distance to Tokyo Station and the constant term. The variables used only as instrumental variables are the same as those in the indirect utility function (2). The estimation procedure has the same two steps as before. Because of the linearity of the model, we have an explicit form of the estimators as

$$\tilde{\theta} = \left(X'Z(Z'\hat{\Omega}Z)^{-1}Z'X\right)^{-1} X'Z(Z'\hat{\Omega}Z)^{-1}Z'\mathbf{y},$$

where $\mathbf{y}$ is the vector of $\log w_i$, X the explanatory matrix consisting of $\log N_i$, the time distance to Tokyo and the constant term, and Z the matrix of instrumental variables consisting of X and the other exogenous variables. In this case, the degrees of freedom of the test statistic for the exogeneity is 4.

The estimates of the indirect utility functions (Cobb-Douglas and CES types) are shown in the first two columns of Table 2 while those of the cost function are in the third column.

In the Cobb-Douglas model, η_1 denotes the ratio of the housing service expenditure to the total expenditure for an average household. The estimate implies 13% of the total expenditure is applied to housing services, which is a reasonable percentage. According to the Report of National Consumption Survey of 1989, the ratio of the housing expenditure inclusive of the imputed rent to the household income inclusive of the housing loan payment is 9.9%. On the other hand, the average price of new housing is 6.7 times as high as the average household annual income. Provided the average length of services is 35 years, then the lifetime ratio of the housing expenditure to the household income is approximately 19%. Incidentally, using a different data set, Watanabe (1996) estimated the marginal rate of housing expenditure to be between 15.6% and 20.5%.

In the CES model, the restriction of the constant returns to scale is not imposed. The elasticity of substitution ρ is larger than 0 although it is not statistically significant.[4] In the CES case, the expenditure ratio of the housing services is given by $\eta_1 r^\rho/(\eta_1 r^\rho + \eta_2 p^\rho)$, which depends on the prices and parameter values. Its mean and standard deviation are 16% and 10% respectively, which are also reasonable values.

Positive signs of other estimated coefficients imply that these variables are considered disamenities in net for households. This is because the disamenities should be compensated

[4]In addition, the AIC values are 10.3 for the Cobb-Douglas case and 21.0 for the CES case. These suggest that the Cobb-Douglas type is preferable in view of model selection measures. However, since we need robust results against different functional forms, we have kept the both types of the models.

by the higher real wage to keep the same utility level between cities.

The estimates of the elasticity of the SMEA population to the real wage are slightly different between the Cobb-Douglas and CES cases, being approximately -5% in the Cobb-Douglas case and -9% in the CES case. This means that doubling the population size of an SMEA decreases the real wage by 5%-9%. In other words, the urban agglomeration economies due to product varieties outweigh the agglomeration diseconomies due to congestion for households located in large cities. It should be noted however that the values of 5%-9% may be overestimated as pointed out in Figure 1 of Section 2. This is because we cannot observe the true values of E, but the available data of D instead.

Besides urban agglomeration, there are a demographic factor such as the average age and an environmental factor such as the nitric dioxide, both of which shift the indirect utility function. The average age is significant. Its economic interpretations are not straightforward partly because the true utility function may be very complex, and partly because they may be a proxy for unobservable environmental variables. On the other hand, the sign of the nitric dioxide is positive in the sense that air pollution must be compensated for by a higher real wage.

The results of the exogeneity tests are reported in the last two rows. According to the P values, the null hypothesis that the instrumental variables are exogenous is not rejected in each model.

Finally, we should check the residuals $f(\tilde{\theta})$ to see if the model specification is free from biases and heteroskedasticity. We plotted the residuals against a logarithm of population ($\log N$) in Figure 2 for the Cobb-Douglas case and in Figure 3 for the CES case. It would follow from these figures that these models are unbiasedly estimated and heteroskedasticity of the errors is properly adjusted.

The estimated coefficients of the cost function are given in the third column of Table 2. The estimated coefficient of the SMEA population is +0.10. The positive sign means that labor productivity will become larger for larger city size. This result is in accord with the empirical studies that doubling city size increases labor productivity in manufacturing industries in the United States, Japan and Sweden by several percent (Kim, 1997).

The negative sign of the distance to Tokyo means that it decreases the productivity of firms, or easy access to Tokyo raises their productivity. On the other hand, the negative sign

	Utility Function		Cost Function
	Cobb-Douglas	CES	Linear
ρ		1.06	
		(1.53)	
η_1	0.13	1.99	
	(4.04)	(2.90)	
η_2		11.73	
		(11.38)	
SMEA population	-0.05	-0.09	0.10
	(-2.71)	(-2.63)	(2.48)
average age	-1.31	-1.69	
	(-6.72)	(-5.00)	
nitric dioxide	0.13	0.10	
	(4.35)	(2.41)	
distance to Tokyo			-0.21
			(-6.05)
land price			-0.09
			(-1.13)
constant	9.62	8.81	4.63
	(12.33)	(3.06)	(22.52)
χ^2 value	0.85	0.03	4.88
P value	0.84	0.87	0.18

Table 2: Estimation Results of the Utility and Cost Functions

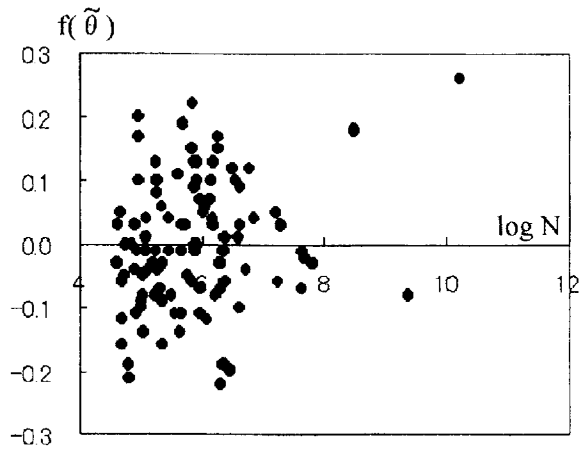

Figure 2: Residuals for the Cobb-Douglas Case

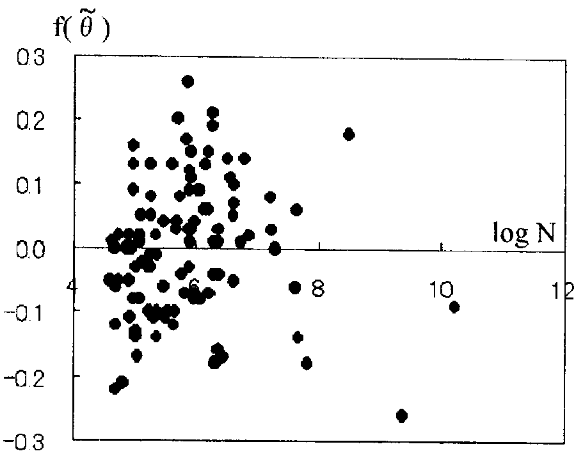

Figure 3: Residuals for the CES Case

of the land price implies that the factor price frontier (1) is negatively sloped as depicted in Figure 1. This is consistent with Roback's intercity equilibrium model explained in Section 2.

The result of the exogeneity test in the last two rows shows that the instrumental variables are exogenous. This result is the same as that in the indirect utility function. The adjusted R^2 is 0.52. In Figure 4, the observed and predicted nominal wages are plotted. The horizontal axis is the observed nominal wage and the vertical one is the predicted nominal wage. The solid line is 45-degree line. We observe from the figure that the model is unbiasedly estimated, and the heteroskedasticity of the errors is properly adjusted.

It should be noted that firms are interested un the nominal wage, while households care for the real one. The regression of the cost function (1) expresses the behavior of firms whereas the regression of the indirect utility function (2) describes the behavior of households. Thus, the 10% increase of the nominal wage is attributable to the productivity increase for firms. On the other hand, the 5%-9% decrease of the real wage is compensated for by the net agglomeration economies, which are the benefits from product variety minus the costs of congestion for households. We thus confirm that while city bigness enhances the productivity of firms, it brings net agglomeration economies to households as well.

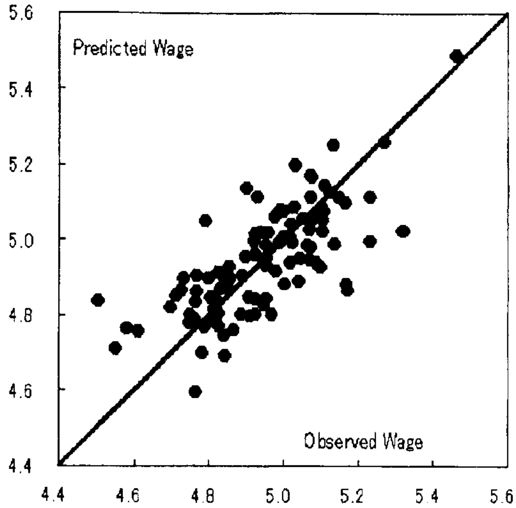

Figure 4: Observed versus Predicted Wages

5 Conclusion

In this paper, we attempted to quantify agglomeration economies and agglomeration diseconomies both on the production side and on the consumption side. We showed that when the city size doubles, the nominal wage goes up by approximately 10% whereas the real wage goes down by approximately 5%-9%.

Our conclusion is shown by a schematic diagram in Figure 5. The 10% difference on the production side is reflected in the nominal wage differential, while the 5%-9% difference on the consumption side is captured by the real wage differential. In this way, the net agglomeration economies in production and in consumption can be econometrically separated.[5]

[5] It should be noted that these conclusions are with reservations because urban hierarchical systems, where different goods and services are produced between large and small cities, are out of the reach of this paper. Furthermore, recently increasing intercity division of labor has not been considered here. When production processes are divided into several plants located in various cities, the notion of urban agglomeration economy may be extended to that of network economy or international increasing returns to scale (Ethier, 1982).

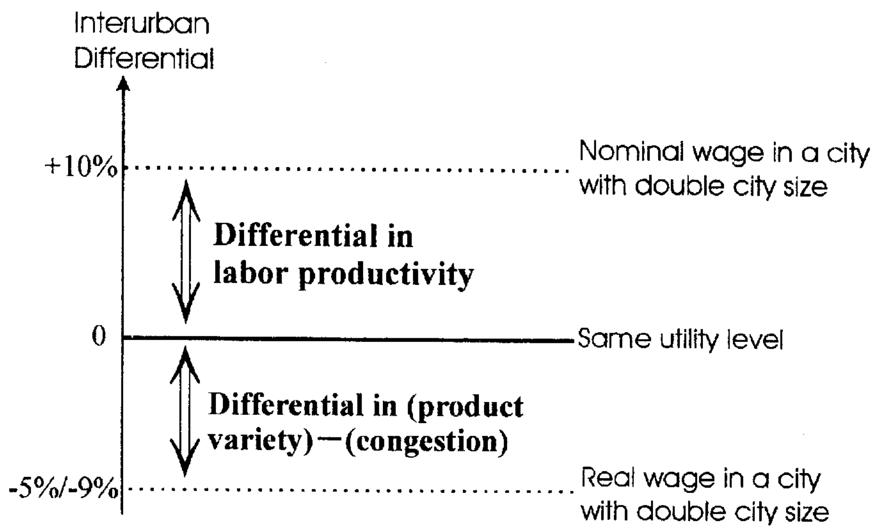

Figure 5: Nominal Wage Differential and Real Wage Differential

Data Sources

- Consumer price index (p): consumer price index excluding the housing rent, *Zenkoku Bukka Tōkei Chōsa Hōkoku* (National Survey of Prices), Volume 1, Management and Coordination Agency, Statistics Bureau, 1992.
- Per capita income (w): tax-based income divided by population in million yen, *Shichōsonzei Kazei Jōkyō tou no Sirabe* (Survey of Municipal Taxation), Ministry of Home Affairs, 1992.
- Average land price (r): average price of land per m^2 in a residential area, *Chika Kōji* (Official Posted Land Price), National Land Agency, 1992.
- SMEA population (N): population in the Standard Metropolitan Employment Area (SMEA) derived from Tokuoka (1991) using the National Census, Statistics Bureau, 1990.
- Nitric dioxide (z_1): $0.001ppm$, *Nippon no Taiki Osen Jōkyō* (Air Pollution in Japan), Environment Agency, *Gyōsei*, 1991.
- Time distance to Tokyo station (z_2): Shortest time to the Tokyo station by train, *Eki Supāto Zenkokuban*, Val Kenkyūsho, 1995.
- Average age (z_3): National Census, Statistics Bureau, 1990.
- Hours of sunshine (z_4): total number of hours of sunshine in a year, *Rika Nenpyō* (Chronological Scientific Tables), National Astronomical Observatory, *Maruzen*, average from 1961 to 1991.
- Snowfall days (z_5): total number of snowfall days in a year, *Rika Nenpyō* (Chronological Scientific Tables), National Astronomical Observatory, *Maruzen*, average from 1961 to 1991.
- Prefectural capital (z_6): dummy variable, 1 if the SMEA is a prefectural capital, 0 otherwise.
- Industrial city (z_7): dummy variable, 1 if the SMEA is designated as *Shin Sangyō Toshi* (the New Industrial City) or *Kogyō Seibi Tokubetsu Chiiki* (the Planned Industrial District), 0 otherwise.
- Coast (z_8): dummy variable, 1 if the SMEA is on the coast, 0 otherwise.

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