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Urban Agglomeration, Capital Augmenting Technology, and Labor Market Equilibrium

by

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ABSTRACT

The objective of this paper is to measure the urban productivity using Japanese city-based cross-sectional data of 1980. The result of the labor-demand OLS regression analysis suggested two kinds of possible model specifications: capital augmenting and demand-supply equilibrium. The average effect of population density on labor productivity was 4.3% in a capital augmenting model while 8.0% in an equilibrium model.

1. INTRODUCTION

Most of the developed countries have experienced a remarkable decrease in net in-migration to big cities after 1970 (Vining, Pallone and Plane, 1981) in accordance with economic development and social integration. Observing the same one may infer that the postwar macro trend in the distribution of labor and capital seems to have stabilized apparently implying a factor market equilibrium due to interregional movements. Further, one may also infer that regions are now experiencing simultaneous relative growth in accordance with the increase in intra-organizational linkages among multilocational firms (Pred, 1977). Nevertheless, differences in wage rate between regions still persist, and there are no symptoms of such differences to converge either in the United States for 1958-78 (Clark and Ballard, 1981) or in Japan for 1955-1979 (Tabuchi, 1983).

Various arguments have been listed for the persisting differences in interregional wages from the viewpoint of the supply of and demand for labor. On the supply side of labor, it is attributed to the differences in the mixture of human-capital-related demographic characteristics (Scully, 1969), the cost of living (Coelho and Ghali, 1971), and the amenity or the quality of life (Liu, 1975). On the other hand, it has been discussed from the labor-demand side that the reason is due to the difference in production technology, viz., the existence of urban agglomeration economies which is considered to affect the production function favorably (Shefer, 1973; Kawashima, 1975; Sveikauskas, 1975; Segal, 1976; Carlino, 1979; Moomaw, 1981 and

1983; Nakamura, 1984), and hence affect the wage rate.

The supply-side argument implicitly assumes that high wage rate compensates for laborer's disamenity which is often expressed as a function of city size as a surrogate for rent, commuting cost, air pollution, and so forth. The demand-side discussion assumes large city size is associated with high labor productivity and with high wage rate. City size here is regarded as firm's 'amenity' or 'business climate'. Both of these two approaches, needless to say, are of importance and should be jointly considered in an equilibrium context.

This paper attempts to measure the urban productivity generated by urbanization economy. Following but criticizing Moomaw's (1981) model, in the next section, emphasis is placed on functional forms of the production function and the wage rate function. Section 3 then slightly generalizes Moomaw's model and estimates the Hicks-neutral urban productivity by the ordinary least squares regression of the labor demand equation, using Japanese cross-sectional city-based manufacturing data of 1980.

It was however revealed that suspicion falls on the assumption of the model and and the result indicates two kinds of modifications: relaxation of the Hicks-neutral technology and incorporation of the labor-supply equation. The former is modeled and estimation is conducted in Section 4, and the latter is analyzed in Section 5. Section 6 concludes the paper.

2. MOOMAW'S MODEL

Consider a country consisting of infinite variety of city sizes. For mathematical operationality, it is assumed that any function appearing below can be differentiable with respect to city size N. Following Moomaw's (1981) formulation, a firm in a competitive industry maximizes its profit with respect to capital, labor and city size as

$$\max.\ V - w(N)L - rK = g(N)f(L,K) - w(N)L - rK\ , \tag{1}$$

where V = the value added,

w(N) = the wage rate as a function of city size,

L = the labor input,

r = the price of capital,

K = the capital input including land, and

g(N) = the Hicks-neutral productivity as a function of city size.

A subscript referring to a city is omitted throughout this paper for legibility. It is hypothesized that both g(N) and w(N) are functions of city size while the rate of return r is constant among cities.

Differentiating equation (1) with respect to K, L and N, the following first-order conditions for profit maximization are obtained:

$$g(N)f_K = r\ , \tag{2}$$

$$g(N)f_L = w(N)\ , \tag{3}$$

$$g'(N)f = w'(N)L\ , \tag{4}$$

where the subscripts denote the partial derivative, and ' signifies the partial derivative with respect to N. If f is the CES production function $g[dK^{-p}+(1-d)L^{-p}]^{-1/p}$, $g(N)=aN^{b}$, and $w(N)=hN^{j}$, then (3) and (4) are written respectively as

$$\frac{V}{L}=\frac{a^{1-s}h^{s}}{(1-d)^{s}}N^{(1-s)b+sj}\ , \tag{3'}$$

$$\frac{V}{L}=\frac{jh}{b}N^{j}\ , \tag{4'}$$

where s is the elasticity of substitution defined as $1/(1+p)$. Equations (3') and (4') are the same as equations (13a) and (15a) in Moomaw(1981, p.680). So far as those assumptions are met, both of these two equilibrium conditions should be consistent. Comparing the coefficients and the exponents, the following conditions for parameters are obtained:

$$\frac{a^{1-s}h^{s}}{(1-d)^{s}}=\frac{jh}{b}\ , \tag{5}$$

$$(1-s)b+sj=j\ . \tag{6}$$

Two cases can be classified to the value of s.

(i) $s\neq 1$

From equation (6), $b=j$. Putting this relation into equation (4'), $V=wL$ is derived. This means that the aggregate income share of labor is 100% which is unreasonable.

(ii) $s=1$

From equation (5), $b=(1-d)j$. Putting this relation into equation (4'), it is derived that $(1-d)V=wL$. This implies that the aggregate income share of labor is $1-d$. Since $0<d<1$, it is not inconsistent.

Consequently, the Sveikauskas' (1975) estimate of b^* from $\log(V/L)=a+b^*\log(N)+(\text{other variables})$ is nothing but the estimate of j, not of b. b should be calculated by the formula $b=(1-d)j$ as Moomaw(1981) demonstrated. The estimate of b^* must be equal to j which is from $\log(w)=\log(h)+j\log(N)+(\text{other variables})$ although Moomaw (1981) argued that the estimate of b^* on average is greater than that of j.

Statistically, however, it can be shown that b^* is <u>not</u> significantly different from j using the Sveikauskas' estimates of b^* and j which are respectively listed in Tables I and II of Sveikauskas(1975) and reappeared in Table I of Moomaw(1981). Suppose populations of the regression estimates b^* and j be normally distributed, then the decision rule for the hypothesis H_0: $b^*=j$ is to reject H_0 if the following t-value is greater than the critical value:

$$t = \frac{E(b^*)-E(j)}{\sqrt{\frac{S(b^*)+S(j)}{n}}} \qquad \text{with d.f.} = \frac{(n-1)[S(b^*)+S(j)]^2}{[S(b^*)]^2+[S(j)]^2},$$

where n is the number of observations, E means expectation, and S means variance.[1] The t-value computed by the estimates in those Tables was only 0.858, and the degree of freedom was approximately 24. It thus follows that the values of b^* and j are statistically the same.

However, $s=1$ means the CES production function boils down to the Cobb-Douglas production function of homogeneous of degree one, and the distribution parameter is just the exponent of K in the Cobb-Douglas function. Consequently, what Moomaw computed was the Hicks-neutral productivity for the Cobb-Douglas production function. It should be noted that although there is no reason to confine the CES to the Cobb-Douglas production function, it is the result from the equilibrium conditions.

One of the crucial reasons is attributed to the functional forms of g(N) and w(N) which are sure to generate a constant elasticity. Manipulating equation (4), one obtains

$$w = \frac{g'/g}{w'/w}\frac{V}{L} = n\frac{V}{L}\,, \tag{4''}$$

where n may be called the <u>wage rate elasticity of productivity</u> having the property $0<n<1$. One may alternatively interpret n as the share of labor income. Provided n be constant across cities, then $g'/g=nw'/w$. Integration will yield

$$g = c\,w^{n}\,, \tag{7}$$

where c is a constant. Again assuming the CES production function, equation (3) is rewritten by

$$\frac{V}{L} = \frac{g^{1-s}w^{s}}{(1-d)^{s}} = \frac{c^{1-s}}{(1-d)^{s}}\,w^{n+s-ns}\,. \tag{3''}$$

Since both equation (3") and equation (4") should hold simultaneously, one gets

$$\frac{c^{1-s}}{(1-d)^s} = \frac{1}{n}, \qquad (8)$$

$$n+s-ns = 1. \qquad (9)$$

The set of equations (5) and (6) is a special case of the set of equations (8) and (9).

Examining (9), because $n \neq 1$, s becomes unity which boils down the CES to the Cobb-Douglas production function. Examining (8), on the other hand, $n=1-d$ is obtained. These are the same conclusions as before, but further generalization is obtained without specifying the functional forms of g(N) and w(N). The conclusions unchanged so far as the functional forms of g(N) and w(N) satisfy equation (7): for example, $g(N)=ae^{bN}$ and $w(N)=he^{jN}$.

It may be natural to think that the functional forms between productivity and the wage rate are different with respect to city size. For instance, the wage rate may be determined by marginal productivity of labor adjusted by other factors, such as degree of unionization, amenity, and cost of living including rent and commuting costs. On the other side, the productivity may be determined by urban agglomeration economies like urbanization and localization. Although in aggregate both the wage rate and the productivity are considered increasing functions of city size, it would be quite possible that the functional form is dissimilar.

Alternatively, modifying equation (4"), the elasticity is interpreted as the aggregate income share of labor, i.e., $n=wL/V$. One should thus remember that the foregoing can be justified if and only if n does not change systematically over city size.

3. GENERALIZATION AND OLS ESTIMATION

This section attempts to generalize the Moomaw's (1981) model represented by (2), (3) and (4) in the previous section. Firstly, the assumption of the Hicks neutral productivity is relaxed because city size as agglomeration economies may affect more on capital (capital saving technology), or more on labor (labor saving technology). The former would dominate if for instance social overhead capital is intensively utilized in big cities as Mera (1973) demonstrated, and the latter may dominate if "human capital" is positively associated with city size.

Secondly, the functional form of w(N) is not _a priori_ specified, which also generalizes the analysis. However, the CES production function of homogeneous of degree one is assumed. As the capital data including social overhead capital and land do not exist, one cannot use the VES production functions to compute the productivity of cities.

Based upon these things, the formulation becomes as follows:

$$\max.\ ([g_L(N)L]^{-p}+[g_K(N)K]^{-p})^{-1/p} - w(N)L - rK\ , \qquad (19)$$

where $g_L(N)$, $g_K(N)$, and p $(= \frac{1}{s} - 1)$ are parameters. The first-order conditions for profit maximization corresponding equations (2), (3) and (4) are

$$g_K^{-p}(\frac{V}{K})^{p+1} = r\ , \qquad (11)$$

$$g_L^{-p}(\frac{V}{L})^{p+1} = w\ , \qquad (12)$$

$$V^{p+1}(g_K' g_K^{-p-1} K^{-p} + g_L' g_L^{-p-1} L^{-p}) = w'L \ . \qquad (13)$$

Since the capital data is unavailable, (12) is the only equation that can be used for direct parameter estimation. Suppose $g_K(N)$ and $g_L(N)$ are specified respectively as

$$g_K(N) = a_K N^{b_K} \ , \qquad (14)$$

$$g_L(N) = a_L N^{b_L} \ , \qquad (15)$$

where a_K, b_K, a_L and b_L are parameters, then equation (12) can be written by

$$\frac{V}{L} = a_L^{1-s} \, w^s \, N^{b_L(1-s)}. \qquad (12')$$

Taking logarithm on both sides, one can estimate the parameters a_L^{1-s}, s and $b_L(1-s)$, and hence identify the "productivity" parameter b_L.

Using the 1980 Census of Manufactures in Japan (Japanese Ministry of International Trade and Industry, 1980), an attempt was made to estimate the urban productivity parameters of two-digit industry by use of city based data, the number of which is 646 in 1980. Unfortunately, since Japan does not have metropolitan based data, such as the United States' SMSA data, one cannot utilize city size (i.e., population) as an index for urban agglomeration economies. Thus, following Åberg(1973), population density would be suitable because in an integrated country like Japan population density is considered to be strongly related to population potential or accessibility measure which captures not only intraurban but also interurban agglomeration benefits as shown by Tabuchi (1982).

Utilizing Toyo Keizai's (1981) data of 1980, a preliminary study was conducted to compare population density with population. It was found in terms of correlation coefficient that wage rate was less associated with population than population density in <u>every</u> industry. The correlation coefficients between wage rate and population were from 0.016 to 0.382 whereas those between wage rate and population density ranged from 0.093 to 0.600. One can infer that this is ascribed to the existence of many suburbs and satellite cities in the samples. On the other hand, the validity of population density as the agglomeration economies is stated by Mera(1973, p.318): "the higher per capita income in high-density areas can be explained by both savings in social overhead capital cost and increased efficiency of inputs."

The computed result of the OLS regression in each industry is listed in Table 1. The number of observations (NOB) varies among industries and is less than the number of cities (i.e., 646) because some data are withheld from the public due to lack of sufficient number of firm establishments. The derived estimates of b_L were calculated and reported also in Table 1.

The unweighted average elasticity of substitution s was 1.21 ranging from 0.72 (nonferrous metal industry) to 1.56 (apparel and related products industry), and these estimates were above unity in 16 out of 19 industries. The findings do not imply that the wage rate is in proportion to the labor productivity which is the case of Cobb-Douglas production function in which s=1.

Rather they simply imply that the aggregate income share of labor is low in high productivity cities and is high in low productivity cities in most of the industries. This result differs from Gallaway's (1963) finding in the United States for the year 1954. Assuming the Cobb-Douglas production function he concluded that there was no difference between the North and the South. Here, intercity wage differential is less than intercity productivity differential in proportion in most of the industries. As labor productivity is considered to be positively related to city size or density, one may say that if a firm changes its location from a low-density city to a high-density city, the percentage increase in the productivity is greater than that in the wage rate. Needless to say, firm's location is indifferent everywhere and its profit is null due to the assumption of perfect competition.

However, 7 out of 19 estimates of b_L were negative values. This casts suspicion on the model itself because the negative urban externality is unlikely to occur. One may consider the following two possible hypotheses.

The first hypothesis is that $g_L(N)$ is constant across cities but that $g_K(N)$ is increasing with respect to population density N. That is to say, population density is <u>capital augmenting</u> and not labor augmenting. While capital is considered to be augmenting with respect to N because of urban positive externalities such as urbanization economies, labor quality which would be related to city size (Sveikauskas, 1975) may be unimportant presumably due to automation and robotization technology. This argument may be justified by the fact that 16 out of 19 estimates of $b_L(1-s)$ were insignificant at the 5% level.

The second possibility is the introduction to a supply-side equation of labor since the previous discussion completely neglected the laborer's utility in terms of choosing a city. Labor supply was assumed perfectly elastic with respect to wage, and wage acceptance level was considered to be determined solely by city size or density index. If a flex-wage labor market under perfect competition could be assumed, then, the supply-side equation should be introduced. In this case, the parameters should be estimated simultaneously.

Taking account of the first argument Section 4 presents a capital augmenting model, and Section 5 presents an equilibrium model incorporating the labor supply and demand structure.

4. A CAPITAL AUGMENTING MODEL

The model of equations from (10) to (15) in the preceding section is slightly modified here. Since most of the estimated coefficients b_L were insignificantly different from zero, b_L in (15) is set to zero in each industry. This means that the larger cities are associated only with savings in capital cost and not with savings in labor cost.

(12') is then reduced to

$$\frac{V}{L} = a_L^{1-s} w^s . \tag{12''}$$

As the degree of homogeneity is unity, V is just exhausted, i.e., V=wL+rK. Using this with (11)and (13) to eliminate r and K, and using (12"), one obtains

$$\frac{w'}{a_L^{1-s} w^s - w} = \frac{g_K'}{g_K} . \tag{16}$$

Integrating both sides of (16) and using (15),

$$\int_{w_0}^{w} \frac{dw}{a_L^{1-s} w^s - w} = b_K * \log(N) + c_0 , \tag{17}$$

where w_0 and c_0 are arbitrary constants that do not affect the OLS estimate of b_K. Thus, after recalculating the estimates of a_L and s by (12"), one can compute the left hand side of (17) by numerical integration, and then conduct the OLS regression to get the estimate of b_K. As discussed before, instead of population, population density was used for N in the right hand side of (19) as a description of urban agglomeration. Ideally, it is desirable to include more variables to explain the cross-sectional variations of g_K, such as the total number of establishments (Carlino, 1979), the intercity network, the labor availability, and so forth. This was not done here because the major purpose of this paper is to investigate the effect of city size or density on productivity coefficients of g_K and g_L, and because emphasis is placed on the comparison with the previous works by Sveikauskas (1975) and Moomaw(1981).

The OLS estimates of b_K in respective industries are shown in Table 2 exhibiting large variation among industries. Material industries, such as chemical, nonferrous metal, and pulp and paper, tend to have low values of b_K while apparel, textile and machinery industries have high values. It follows in general than the latter group is capital augmenting in terms of population density while the former is not.

Holding capital and labor constant, let us next compute the implied effect of population density on labor productivity by use of

$$\frac{\partial V/L}{\partial N}\frac{N}{V/L} = \left(\frac{V}{L}\right)^{1+p} g_K^{-p-1} \frac{b_K g_K}{N} \left(\frac{K}{L}\right)^{-p} \frac{N}{V/L} \qquad (18)$$

$$= b_K \frac{V-wL}{V} .$$

The effect of population density on capital productivity V/K and on value added V are the same as equation (18). Using the average values of V and wL, in each industry this value was calculated and reported in Table 2. The unweighted average effect was 0.043 implying that doubling population density will cause 4.3% increase in the productivity on average.

On the other hand, applying the estimation method by Moomaw (1981) (i.e., log-linear regression of (4') and $\frac{\partial V/L}{\partial N} \frac{N}{V/L} = j * \frac{wL}{V}$, where the labor share wL/V is taken as an industry average) to the Japanese data, the computed value of the unweighted average effect was 4.0%.[2] Apparently one may say that the specification of the Hicks-neutral technology yields a downward bias in the estimate of the implied density effect on productivity.

5. AN EQUILIBRIUM MODEL

To describe the equilibrium labor market, a labor supply equation is introduced (Nordhaus and Tobin, 1972; Kelly, 1977). Although their labor-supply function consists of wage rate, population density, percent population urbanized, and population, the function in this section only includes wage rate and population density. Assuming multiplicativity for the sake of simplification, one may specify the labor-supply equation as

$$L = b_1 w^{b_2} N^{b_3}, \qquad (19)$$

where b_1, b_2 and b_3 are parameters to be estimated. This simplified specification avoids a collinearity problem pointed out by Fogarty and Garofalo(1980), and focuses the effect of population density on labor supply in particular.

Econometrically, equations (12') and (19) should simultaneously be estimated. Utilized was the two-stage least squares (2SLS) method of estimation which is equivalent to the indirect least squares or limited-information maximum likelihood, because the system of simultaneous equations in this model is exactly identified.

The first stage is to obtain the estimated values of labor L and wage rate w by regressing L on V and L, and by regressing w on V and L because L and w would be considered endogenous in labor market. The second stage is to regress equations (12') and (19) employing the estimated values of L and w. The 2SLS result is tabulated in Table 3 exhibiting large differences in the coefficient estimates of $\log(a_L^{1-s})$, s, and $b_L(1-s)$ as compared to the OLS estimates shown in Table 1.

In the first place, all signs of the 2SLS estimates were the same across industries whereas those of the OLS estimates were not. Moreover, the interindustry variations in the 2SLS respective estimates seem to be smaller presumably implying the necessity of demand-supply simultaneity relationship in labor market.

Secondly, only 4 out of 19 2SLS estimates of $b_L(1-s)$ were found to be insignificant at the level of 5% while 16 out of 19 OLS were insignificant. This clear contrast would also strengthen the importance of demand-supply simultaneity. Therefore, assuming the labor demand-supply equilibrium, one can measure the urban agglomeration effect whose existence was almost rejected by the labor-demand OLS regression in Section 3. Notice the difference that the capital augmenting technology (Solow neutrality) in Section 4 is not necessarily hypothesized here. One may still be able to hypothesize the Hicks neutrality in terms of population density if the equilibrium is introduced.[3]

Thirdly, the estimate s by 2SLS was larger than that by OLS in every industry. The following may be one explanation. Suppose the error terms in the log-linear regressions of (12') and (19) are e_1 and e_2 respectively, the OLS estimate of s is given by

$$s_{OLS} = \frac{S_{wy}S_{NN} - S_{Ny}S_{wN}}{S_{ww}S_{NN} - S_{wN}^2},$$

where $S_{AB} = \Sigma\,[\log(A)-\frac{1}{n}\Sigma\log(A)][\log(B)-\frac{1}{n}\Sigma\log(B)]$, $n =$ the number of observations, and $y=V/L$. Eliminating L in (12') and

(19), and substituting the value of y, it is obtained

$$\text{plim}(s_{OLS}) = s - (s+b_2)\frac{\sigma^2_{e_1}+\sigma_{e_1e_2}-\sigma_{Ve_1}}{\sigma^2_{e_1}+\sigma^2_{e_2}+\sigma^2_V(1-r^2_{VN})+2\sigma_{e_1e_2}-2\sigma_{Ve_1}-2\sigma_{Ve_2}}$$

$$= s - (s+b_2)\frac{\sigma^2_{e_1}}{\sigma^2_{e_1}+\sigma^2_{e_2}+\sigma^2_V(1-r^2_{VN})}, \qquad (20)$$

iff $\sigma_{e_1e_2}=\sigma_{Ve_1}=\sigma_{Ve_2}=0$, where σ^2_x is the variance of x, σ_{xy} is the covariance between x and y, and r_{xy} is the correlation coefficient between x and y (Maddala, 1977, p. 242). As s>0, b_2>0, and the fraction is also positive, $\text{plim}(s_{OLS})<s$. Thus, one may conclude that the OLS estimate of the elasticity of substitution s is negatively biased. Incidentally, the unweighted average 2SLS estimate of s is 2.31 while the unweighted average OLS estimate is 1.21. It should also be noted that every 2SLS estimate of s is greater than unity, which apparently reject the Cobb-Douglas production function.

Fourthly, compared with the derived OLS estimates of b_L, the derived 2SLS's b_L were all positive and had less variation among industries. The minimum was 0.025 (chemicals industry), the maximum was 0.143 (clay, stone and glass industry), and the unweighted simple average was 0.080. However, b_k cannot be estimated in the absence of capital data. Extending equation (18), the effect of population density on labor productivity is computed as

$$\frac{\partial V/L}{\partial N}\frac{N}{V/L} = b_K\frac{V-wL}{V} + b_L\frac{wL}{V} . \tag{18'}$$

If, unlike Section 4, the Hicks-neutral technology is assumed with respect to population density so that b_K equals b_L, then doubling population density will cause 8.0% increase in the labor productivity on average. This increase is nearly twice as large as the capital-augmenting case in Section 4.

Fifthly, it is observed that the estimate of b_2 was much greater than that of s in every industry. As b_2 is regarded as the elasticity of labor supply and s is the elasticity of labor demand provided V and N held constant, one can say that labor supply is elastic relative to labor demand. This situation is depicted in Figure 1. S denotes the supply curve; D denotes the demand curve; and the subscripts 1 and 2 indicate low and high density cities respectively. Note that the OLS case (i.e., labor demand regression) implicitly assumes supply is perfectly elastic and hence the supply curve is horizontal. From Table 3,

$$\frac{\partial L_D}{\partial w} < 0 \quad \text{since } s > 0 ,$$

$$\frac{\partial L_D}{\partial N} > 0 \quad \text{since } b_L(1-s) < 0 ,$$

$$\frac{\partial L_S}{\partial w} > 0 \quad \text{since } b_2 > 0 , \text{ and}$$

$$\frac{\partial L_S}{\partial N} < 0 \quad \text{since } b_3 > 0 .$$

The effect of population density N on wage rate w is then shown to be positive both in the demand equation and in the supply equation. Hence, the equilibrium wage rate should always be an increasing function of population density. The effect of N on labor L at the equilibrium point, on the other hand, is indeterminate in general. In each industry, the effect should be calculated by the reduced form of the model eliminating the endogenous variable w from (12') and (19) as

$$\log(L) = \frac{b_2(s-1)}{b_2+s}\log(a_L) + \frac{s}{b_2+s}\log(b_1) + \frac{b_2}{b_2+s}\log(V) + \frac{b_3 s-b_2 b_L(1-s)}{b_2+s}\log(N), \quad (21$$

which means

$$\frac{\partial L}{\partial N} = \frac{b_3 s-b_2 b_L(1-s)}{b_2+s}\,\frac{L}{N}\,. \quad (22)$$

According to numerical calculation substituting the estimates in Table 3 for the right-hand side, it was found that the values of (22) were positive in seven industries (SICs 24, 26, 28, 29, 30, 32 and 39) and negative in the other twelve industries.

Finally, the elasticity between labor supply and population density, expressed by b_3 in Table 3, was negative in every industry ranging from -2.043 to -0.043, and the unweighted average value was -0.652. This is the very reverse of Kelly's (1977) result possibly due to the exclusion of percent urbanized population and population variables here. The negative signs of b_3 may be interpreted that population density is a disamenity and is compensated by high wage rate. Population density would be regarded as a surrogate for an index of congestion, rent, and so on.

6. CONCLUSIONS

Assuming the CES production function and perfect competition, the labor-demand regression by OLS was conducted in each industry using 1980 Census of Manufactures in Japan. The result reported in Table 1 however did not show the statistical significance in urban productivity coefficient, b_L.

In Section 4, it was then hypothesized that the urban agglomeration economy affects only capital and not labor. Setting $b_L=0$, b_K was computed in each industry. It was found that the implied unweighted average effect of population density on labor productivity computed in this paper (4.3%) was slightly larger than that by Moomaw's (1981) method (4.0%).

Section 5, on the other hand, introduced a labor-supply equation, and conducted the simultaneous estimation by 2SLS. As compared with the OLS result, the 2SLS estimates of b_L were significantly different from zero implying the importance of demand-supply structure in labor market. The unweighted average effect of population density on labor productivity was 8.0% provided the technology was Hicks neutral. One may therefore conclude that the urban agglomeration effect is higher than expected.

FOOTNOTE

1) Strictly speaking, one should conduct the analysis of covariance (Chow, 1960), but that cannot be done here in the absence of the original U.S. data.

2) The estimation method here differs from that of Moomaw (1981) in that the educational variable is not included and population density is used as an index of urban externality, rather than population.

The unweighted average effect was 3.4% using the population variable, but t-values were much lower. Remember that Moomaw's estimate of the effect by use of the U.S. SMSA data in 1967 was 2.7%.

3) Neutrality is usually defined in terms of time since technological development is considered as an increasing function of time. It should be noted, however, that neutrality is defined in terms of population density in this paper.

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Table 1

OLS Regression of $\log(V/L)=\log(a_L^{1-s})+s*\log(w)+b_L(1-s)*\log(N)$ [a]

SIC Industry	$\log(a_L^{1-s})$	s	$b_L(1-s)$	b_L	NOB
18 Food	-1.01	1.39	-0.008	0.021	499
	(3.1)	(21.4)	(0.5)		
20 Textile mill	-0.00	1.14	0.002	-0.014	260
	(0.0)	(14.0)	(0.1)		
21 Apparel	-2.21	1.56	0.019	-0.034	328
	(5.7)	(19.1)	(1.4)		
22 Lumber and wood	2.01	0.76	0.029	0.121	240
	(4.1)	(7.9)	(2.0)		
23 Furniture and fixtures	-0.79	1.29	0.010	-0.034	157
	(1.3)	(10.4)	(0.4)		
24 Pulp and paper	0.30	1.12	-0.006	0.050	212
	(0.6)	(12.3)	(0.3)		
25 Printing and publishing	-0.97	1.31	0.020	-0.065	204
	(2.5)	(17.2)	(1.4)		
26 Chemicals	-1.44	1.49	-0.033	0.067	179
	(1.0)	(6.0)	(0.8)		
28 Rubber	-0.43	1.27	-0.076	0.281	61
	(0.5)	(8.3)	(2.2)		
29 Leather and furs	-0.15	1.17	-0.019	0.112	34
	(0.1)	(5.2)	(0.5)		
30 Clay, stone and glass	-0.81	1.37	-0.083	0.224	399
	(2.1)	(18.6)	(5.5)		
31 Iron and steel	-1.08	1.38	-0.018	0.047	166
	(1.5)	(10.3)	(0.6)		
32 Nonferrous metal	2.60	0.72	-0.007	-0.025	93
	(2.3)	(3.6)	(0.2)		
33 Fabricated metal	-0.14	1.18	-0.010	0.056	368
	(0.3)	(14.8)	(0.8)		
34 Machinery except SICs 35,36 and 37	0.91	0.98	0.006	0.300	411
	(2.4)	(13.7)	(0.5)		
35 Electrical machinery	-1.31	1.41	-0.015	0.037	403
	(4.0)	(21.8)	(0.9)		
36 Transportation equipment	-0.05	1.14	0.011	-0.079	242
	(0.1)	(11.2)	(0.5)		
37 Precision machinery	0.05	1.12	0.006	-0.050	142
	(0.1)	(10.0)	(0.3)		
39 Others	-0.45	1.26	-0.022	0.085	240
	(0.9)	(12.6)	(1.1)		

[a] t-values are in parentheses.

Table 2

The effect of population density on productivity in a capital augmenting model

SIC	b_K	t-value of b_K	$\frac{\partial V/L}{\partial N} \frac{N}{V/L}$
18 Food	.075	15.1	.051
20 Textile mill	.107	10.5	.060
21 Apparel	.131	11.9	.065
22 Lumber and wood	.071	10.5	.040
23 Furniture and fixtures	.104	9.7	.057
24 Pulp and paper	.027	3.0	.017
25 Printing and publishing	.107	11.3	.064
26 Chemicals	.004	0.9	.003
28 Rubber	.047	2.0	.028
29 Leather and furs	.093	3.9	.051
30 Clay, stone and glass	.054	11.5	.036
31 Iron and steel	.049	5.1	.035
32 Nonferrous metal	.017	1.8	.012
33 Fabricated metal	.060	11.1	.035
34 Machinery except SICs 35,36 and 37	.077	12.2	.042
35 Electrical machinery	.099	10.9	.062
36 Transportation equipment	.096	8.3	.058
37 Precision machinery	.108	7.5	.059
39 Others	.054	6.2	.033

Table 3

2SLS Regressions of

$$\begin{cases} \log(V/L)=\log(a_L^{1-s})+s*\log(w)+b_L(1-s)*\log(N) \\ \log(L)=\log(b_1)+b_2*\log(w)+b_3*\log(N) \end{cases}$$ [a]

SIC Industry	$\log(a_L^{1-s})$	s	$b_L(1-s)$	$\log(b_1)$	b_2	b_3	b_L	NOB
18 Food	-9.42	3.09	-0.229	-42.5	9.84	-1.018	0.110	499
	(7.1)	(11.5)	(5.7)	(6.9)	(8.0)	(5.6)		
20 Textile mill	-5.10	2.18	-0.120	-52.4	11.92	-1.171	0.102	260
	(4.4)	(9.3)	(3.6)	(6.6)	(7.4)	(5.1)		
21 Apparel	-6.91	2.57	-0.078	-40.5	9.88	-0.714	0.050	328
	(7.6)	(13.2)	(3.4)	(8.3)	(9.5)	(5.8)		
22 Lumber and wood	-7.77	2.67	-0.136	-79.7	16.69	-1.217	0.081	240
	(2.8)	(4.9)	(2.6)	(4.1)	(4.4)	(3.4)		
23 Furniture and fixtures	-6.13	2.36	-0.123	-81.8	17.55	-2.043	0.090	157
	(2.3)	(4.5)	(1.7)	(3.2)	(3.4)	(3.0)		
24 Pulp and paper	-2.77	1.69	-0.026	-28.5	6.32	-0.043	0.038	212
	(3.0)	(10.0)	(1.1)	(7.6)	(9.2)	(0.5)		
25 Printing and publishing	-2.50	1.60	-0.015	-42.5	9.31	-0.774	0.025	204
	(4.0)	(13.2)	(0.8)	(9.5)	(10.7)	(5.9)		
26 Chemicals	-16.54	4.11	-0.077	-59.9	11.54	-0.116	0.025	179
	(5.0)	(7.2)	(1.4)	(7.5)	(8.3)	(0.9)		
28 Rubber	-3.09	1.76	-0.104	-35.4	7.71	-0.235	0.137	61
	(2.1)	(6.4)	(2.6)	(4.3)	(5.0)	(1.1)		
29 Leather and furs	-7.90	2.73	-0.162	-58.1	12.74	-0.755	0.094	34
	(2.1)	(3.6)	(1.9)	(2.6)	(2.8)	(1.5)		
30 Clay, stone and glass	-4.69	2.11	-0.159	-36.8	8.03	-0.562	0.143	399
	(5.1)	(12.1)	(6.9)	(8.0)	(9.2)	(4.9)		
31 Iron and steel	-6.72	2.40	-0.106	-45.4	9.27	-0.450	0.076	166
	(5.0)	(9.8)	(2.7)	(8.7)	(9.8)	(2.9)		
32 Nonferrous metal	-3.94	1.89	-0.043	-43.4	8.76	-0.047	0.048	93
	(1.8)	(4.7)	(1.1)	(5.9)	(6.7)	(0.4)		
33 Fabricated metal	-9.05	2.88	-0.142	-91.5	18.45	-1.000	0.076	368
	(4.4)	(7.3)	(4.1)	(5.4)	(5.8)	(3.5)		
34 Machinery except	-3.52	1.80	-0.069	-48.1	10.01	-0.462	0.086	411
SICs 35,36 and 37	(4.5)	(12.3)	(3.8)	(11.5)	(12.9)	(4.7)		
35 Electrical machinery	-4.92	2.13	-0.107	-20.5	5.32	-0.351	0.095	403
	(9.1)	(19.9)	(5.0)	(12.5)	(16.3)	(5.4)		
36 Transportation equipment	-3.58	1.81	-0.062	-38.3	8.36	-0.512	0.077	242
	(4.3)	(11.5)	(2.2)	(12.1)	(14.1)	(4.8)		
37 Precision machinery	-3.19	1.76	-0.063	-29.1	6.96	-0.708	0.083	142
	(3.3)	(9.2)	(2.1)	(7.5)	(9.1)	(6.0)		
39 Others	-6.44	2.43	-0.111	-31.8	7.26	-0.205	0.078	240
	(5.1)	(9.8)	(3.6)	(6.8)	(8.0)	(1.8)		

[a] t-values are in parentheses.

Figure 1

Demand curve and elastic supply curve