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Using a flexible translog production function

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Empirical Analysis of Agglomeration Economies in Japanese Assembly-type Manufacturing Industry for 1985-2000: Using a flexible translog production function

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Abstract

For Japan's assembly-type manufacturing industry which is composed of general machinery, electrical machinery, equipment and suppliers, and transportation equipment for 1985-2000, we estimate flexible translog production function based on Kim (1992) and Tokunaga and Kageyama (2008) using four-digit standard industrial classification (SIC) industry panel data and Ellison and Glaeser's (1997) agglomeration and co-agglomeration indices (with different industry groups) panel data, and obtain theoretically appropriate and significant results without the homotheticity restriction. From these results, we find evidence of positive and weak agglomeration economies on production in Japanese assembly-type manufacturing industry for 1985-2000.

Keywords: Agglomeration economies, Japanese assembly-type Manufacturing industry, Flexible translog production function
JEL classification: R11, R12, R30

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1. Introduction

In Tokunaga, Kageyama and Akune (2006), we calculated Ellison and Glaeser's (1997) agglomeration index using plant-level four-digit SIC data for Japan's manufacturing industry and examined how agglomeration in Japanese manufacturing industry affects production. We found a slightly positive agglomeration effect.[2] Furthermore, we estimated the agglomeration and co-agglomeration indices in five-year intervals for 1985, 1990, 1995, and 2000, and found positive agglomeration and co-agglomeration effects on production in Japanese manufacturing industry using a flexible translog production function and cost share equation.[3] Having found evidence of agglomeration for a sector representing one-third of Japanese manufacturing industry, especially assembly-type manufacturing industry, which is composed of general machinery, electrical machinery, equipment and suppliers, and transportation equipment, we examine how agglomeration and co-agglomeration affect production in that sector using four-digit SIC data for 1985–2000. According to METI's definitions, we use three industries, machine, electrical and electronics, and transportation machinery, as representatives of Japanese assembly-type manufacturing industry.[4]

This paper is organized as follows. Section 2 reviews agglomeration and co-agglomeration in Japanese assembly-type manufacturing industry for 1985–2000. Section 3 shows the estimation model of a flexible translog production function based on Kim (1992), Tokunaga, Kageyama, and Akune (2006), Tokunaga and Kageyama (2008), and other data sources. Section 4 shows estimation results of the flexible translog production function for 1985–2000. Section 5 concludes.

2. Review of Agglomeration and Co-agglomeration in Japan's Assembly-type Manufacturing Industry

Before reviewing the degree of agglomeration among Japanese industries, we survey the geographical distribution of assembly-type manufacturing industry in Figure 1 and Table 1. We find evidence of weak agglomeration in assembly-type manufacturing industry, which is composed of general machinery; electrical machinery, equipment, and suppliers; transportation equipment; and precision instruments and machinery in the Kaantou, Chubu, and Kansai areas.

<Figure 1 Geographical Distribution of Japan's Assembly-Type Manufacturing Industry (2007)>

<Table 1 Number of Plants by Prefecture 2007>

Next, we review Ellison and Glaeser's (1997) agglomeration index (γEG) as shown in equation (1),[5] using

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[2] See Tokunaga and Akune (2004, 2005) and Tokunaga, Kageyama, and Akune (2006).
[3] See Tokunaga and Kageyama (2008) and Kageyama and Tokunaga (2005).
[4] According to the METI's definition, we ought to use the four industries of machine, electrical and electronics, transport machine, and precision instruments and machinery to represent assembly-type manufacturing industry, however, due to data unavailability we use only three industries.
[5] For a detailed explanation on how this index was derived, see Ellison and Glaeser (1997) p.899.

plant-level two-digit and four-digit SIC data for Japanese manufacturing industry.[6]

$$\gamma_{EG} \equiv \frac{G-(1-\sum_{k=1}^{K} x_k^2)H}{(1-\sum_{k=1}^{K} x_k^2)(1-H)}. \quad (1)$$

Figure 2 shows the results of our agglomeration measurements from 1980, 1990, and 2000 using Ellison-Glaeser agglomeration index based on employment.[7] As shown in the figure, the industry with the highest degree of agglomeration in 2000 within the two-digit classifications was "Publishing and printing" (0.163), followed by "Leather, leather products, and fur" (0.123), "Textiles" (0.117), "Precision machinery" (0.078), "Metal products" (0.068), "Clothing and other textiles" (0.061), and "Ceramic, stone, and clay products" (0.051). While higher degrees of agglomeration appeared in these industries in 2000, we found evidence of weak agglomeration for assembly-type manufacturing industry in general machinery, electrical machinery, equipment and suppliers, transportation equipment, and precision instruments and machinery, although the degree decreases annually.

<Figure 2 Agglomeration in Japanese Manufacturing Industries (γEG, 1980, 1990, 2000)>

We could not conduct a detailed analysis of industrial agglomeration trends using two-digit industrial classification data. Therefore, we examine agglomeration by industry using four-digit Japanese Standard Industrial Classifications.[8] Table 2 ordinates the top 10 agglomerated industries for 1980, 1990, and 2000 based on four-digit classifications for Japanese assembly-type manufacturing industry. In 2000, the industry with the highest agglomeration was "Boilers" (0.233), followed by "Piston rings" (0.154); "Steam engines, turbines, and water wheels, except marine engines" (0.15) among manufacturers of general machinery, the industry with the highest agglomeration was "Medical electronic instruments and equipment" (0.167), followed by "Primary batteries (dry and wet)" (0.094); "Industrial process controlling instruments" (0.076) among manufacturers of electrical machinery, equipment, and supplies, and the industry with the highest agglomeration was "Hull blocks" (0.170); followed by "Bicycles and parts" (0.160) and "Aircraft engines" (0.157) among manufacturers of transportation equipment. Even comparison of results in 1980 and 1990 for these industries reveals that their degree decreases annually, but the top 10 industries remain nearly identical.

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[6] $G = \sum_{k=1}^{K} (s_k - x_k)^2$ is the squared form of an index which is a simple measure of an industry's geographical concentration (a proxy variable for regionally specialized economies). s_k is the employment percentage per industry within region k; x_k is the employment percentage by manufacturing industry within region k. H is the Herfindahl Index (a variable showing intra-industry diversity), defined as $\sum_{p=1}^{P} (z_p)^2$, for plant size distribution of plant p within a particular industry, and z_p,(p=1,...,P) is the industry employment percentage for a plant p, obtained by dividing total employment within the industry by the number of employees per factory.

[7] According to Ellison and Glaeser (1997), we use the median as an index and define industries with annual medians above 0.05 (for middle classifications) or 0.06 (for detailed classifications) on average as having a high degree of agglomeration.

[8] For more detailed results of these measurements of agglomeration, see Akune and Tokunaga (2005) or Tokunaga and Akune (2005). For results on co-agglomeration, see Kageyama, Tokunaga, and Akune (2006) and Tokunaga, Kageyama, and Akune (2006).

In addition, these results show a higher degree of agglomeration in Japanese assembly-type manufacturing industry.

<Table 2 Agglomeration Index (γEG) of Assembly-type Manufacturing industry (1980, 1990, 2000)
<Table 3 Co-agglomeration Index (Ellison and Glaeser, 1997) of Assembly Industry (1985, 1990, 1995, 2000)>

Because co-agglomeration showing the production linkage among different industries is important, we review Ellison and Glaeser's (1997) co-agglomeration index as shown in equation (2) using four-digit SIC data for Japanese manufacturing industry.

$$\gamma_{EG}^{c} = \frac{[G/(1-\sum_{i=1} X_i^2)] - \sum_j w_j^2 H_j - \sum_{j=1}^{r} \hat{\gamma}_{EGj}\, w_j^2 (1-H_j)}{1-\sum_{j=1}^{r} w_j^2}, \qquad (2)$$

where, w_j is the ratio of employees within an industry group and $\hat{\gamma}_{EG}$ is the calculated value of Ellison-Glaeser agglomeration index.

Table 3 shows the top 10 co-agglomerated industries for 1985, 1990, 1995, and 2000 based on four-digit classifications of Japanese assembly-type manufacturing industry. In 2000, the industry with the highest co-agglomeration was "Piston rings and tableware (occidental-type)" (0.400), followed by "Steam engines and hand saws" (0.129), "Woolen yarn hand knitting and secondary forgings" (0.090) among manufacturers of general machinery, the industry with the highest co-agglomeration was "Primary batteries (dry and wet) and rolling of lead and alloys, including extruding" (0.069), followed by "Primary batteries (dry and wet) and secondary smelting and refining of zinc, including zinc alloys" (0.065), "X-ray equipment and stamped and pressed aluminum and aluminum alloy products" (0.062) among manufacturers of electrical machinery, and the industry with the highest co-agglomeration was "Hull blocks and safes" (0.149), followed by "Steel shipbuilding and files" (0.138), and "Marine engines and hand saws" (0.120) among manufacturers of transportation equipment. Comparing the results for 1985, 1990, 1995 and 2000 for these industries indicates that the top 20 industries have almost remained unchanged. These results indicate greater co-agglomeration in Japanese assembly-type manufacturing industry.

3 Model

3.1 A flexible translog production function

Having found evidence of agglomeration and co-agglomeration (with different industry groups) for assembly-type manufacturing industry, we examine how agglomeration and co-agglomeration in Japan's assembly-type manufacturing industry affect that sector's production using data based on four-digit SIC levels[9]—i.e., the degree of agglomeration economy for this industry. According to METI's definitions, we use

[9] Many studies are based on two-digit or three-digit industrial level data because of data constraints (Nakamura, 1985; Feser, 2001). In Nakamura (2008), the estimated results of agglomeration economies vary significantly among two-digit industries.

machine, electrical, and electronics, and transport machinery as sectors representing assembly-type manufacturing industry in this section. In the following application of the flexible translog function, agglomeration ($Agglo$) and co-agglomeration ($Coagglo$) with different industry groups' indices are used instead of traditional conceptualization of localization and urbanization economies.[10]

Because the flexible translog function does not impose a priori restrictions on elasticities of substitution and returns to scale, it has become a useful tool for analyzing production structures of many firms and industries (Christensen, Jorgenson, and Lau, 1973). Kim (1992) extends Chan and Mountain (1983) and suggests more flexible production functions based on the inverse input demand function. Here, we use the flexible translog production function without introducing restrictions such as homotheticity (Tokunaga and Kageyama, 2008).[11] The following production function and its cost share equation are estimated jointly.

The translog production function is as follows:

$$\begin{aligned}\ln Y = {} & \alpha_0 + \alpha_K \ln K + \alpha_L \ln L + \alpha_M \ln M + \frac{1}{2}\beta_{KK}(\ln K)^2 + \frac{1}{2}\beta_{LL}(\ln L)^2 + \frac{1}{2}\beta_{MM}(\ln M)^2 \\ & + \beta_{KL} \ln K \ln L + \beta_{KM} \ln K \ln M + \beta_{LM} \ln L \ln M \\ & + \delta_A \ln Agglo + \frac{1}{2}\delta_{AA}(\ln Agglo)^2 + \delta_C \ln Coagglo + \frac{1}{2}\delta_{CC}\left(\ln Coagglo\right)^2 \\ & + \gamma_{KA} \ln K \ln Agglo + \gamma_{LA} \ln L \ln Agglo + \gamma_{MA} \ln M \ln Agglo \\ & + \gamma_{KC} \ln K \ln Coagglo + \gamma_{LC} \ln L \ln Coagglo + \gamma_{MC} \ln M \ln Coagglo + \delta_{AC} \ln Agglo \ln Coagglo\end{aligned} \quad . \tag{3}$$

Cost share equations are as follows:

$$S_i = \frac{\alpha_i + \sum_j \beta_{ij} \ln X_j + \gamma_{iA} Agglo + \gamma_{iC} Coagglo}{\sum_i \alpha_i + \sum_i \sum_j \beta_{ij} \ln X_j + \sum_i \gamma_{iA} Agglo + \sum_i \gamma_{iC} Coagglo}, \tag{4}$$

where Y , K , L , E , M , $Agglo$, and $Coagglo$ represent output, capital, labor, materials, industrial agglomeration, and co-agglomeration for assembly-type manufacturing industry, respectively. In equation (4), subscript i denotes the i th input, and S_i denotes the i th input's share of costs. X_j is the input vector—capital, labor, and materials. α_i , β_{ij} , δ_A , $\delta_{AA}, \delta_C, \delta_{CC}, \delta_{AC}$, γ_{ij} are the parameters to be estimated. For estimation, we test two cases: (A) impose no restriction, (B) impose homotheticity ($\sum_j \beta_{ij} = 0$). We conduct the estimation using seemingly unrelated regression method (SUR) as suggested by Zellner (1962) taking serial correlation into account.

3.2 Data

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[10] See Krugman (1991), Fujita, Krugman, and Venables (1999) , Fujita and Thisse (2002), and Hanson (2005) for details about economics of agglomeration.

[11] Feser (2001) uses Kim's production function and analyzes the agglomeration economies for farm and garden machinery industry (SIC 352) and for measuring and controlling devices industry (SIC 382).

All panel data for estimation are sub-industries (four-digit industrial SIC) for assembly-type manufacturing industry, excluding data missing in the Census of Manufactures.[12] Required data are output, capital, labor, material, agglomeration, and costs. Output is shipment of manufactured goods. Data are from the Census of Manufactures. The value is realized using the output's deflator by type of economic activities (1995 = 100) from the Annual Report on National Accounts (NA) by the Economic and Social Research Institute. We utilize private capital stock data at the two-digit SIC level compiled by the Central Research Institute of the Electric Power Industry (CRIEPI). We divide this data proportionally by the sub-industry share (four-digit SIC) of tangible fixed assets per establishment (end of year) from the Census of Manufactures and use it as data for private capital stock. In regard to private labor, we consider employees. Employee data are from the Census of Manufactures. Materials are also from the Census of Manufactures. The value is realized by deflators on inputs by type of economic activity (1995 = 100) reported by NA. Capital cost is calculated by $p_k(r+d)/(1-\tau)$, where p_K is price of capital, r is the interest rate, d is the depreciation rate, and τ is the corporate tax rate. Price of capital is from the gross domestic capital formation deflator of plant and equipment reported by NA. The interest rate is the average contracted rate on loans and discounts reported by the Bank of Japan. For the depreciation rate, we divide depreciation by previous year's capital stock. Corporation tax rate is from the National Tax Agency Report. Total labor costs include total cash wages and salaries, available from the Census of Manufactures. We use the deflator for inputs by type of economic activity reported from NA as cost of materials.[13] Industrial agglomeration and co-agglomeration datasets are taken from Tokunaga and Akune (2004, 2005) and Tokunaga, Kageyama, and Akune (2005), which are the employment-based agglomeration index (γ_{EG}) and the employment-based co-agglomeration index (γ_{EG}^{C}) in Table 4.

<Table 4. Descriptive Statistics>

4. Estimation Results

First, we estimate the agglomeration effect on production from 1985–2000. Table 5 shows the estimation results of employment-based agglomeration (γ_{EG}). From the Wald test results, the restriction of homotheticity is rejected at 5% significance level. Hence from the results of non-homotheticity for γ_{EG}, almost all estimated parameters are significant at 1% or 5% level except for $\delta_{AA}, \gamma_{KA}, \gamma_{LA}$. The sign conditions of most parameters are theoretically appropriate. Thus, we estimate output elasticities of input, returns to scale, and the agglomeration effects on production. Results are shown in Table 6.[14] From this results, we found that the elasticity of capital is 0.110, elasticity of labor is 0.220, and elasticity of intermediate goods is 0.674, and output elasticity of intermediate goods exceeds the other two inputs. Very slight increasing returns to scale are suggested for this case. Elasticity of agglomeration on production is estimated to be 0.007 and is significant at 1% level.

[12] See Nakamura (1985, 2004) and Otuka (2003) for details about construction of the dataset.
[13] Deflator data are not published by four-digit levels. We substitute two-digit data for sub-industry data.
[14] Elasticities are evaluated at their sample means.

<Table 5. Estimation of the Flexible Translog Production Function (Agglomeration Effect)>
<Table 6. Output Elasticities, Scale Economies, and Agglomeration, Case of γEG>

Next, we estimate the co-agglomeration effect (with different industry groups) on production. Table 7 shows the estimation results. From the results of Wald test, the restriction of homotheticity is rejected at the 5% significance level. From the results of non-homotheticity for γ_{EG}, almost all estimated parameters are significant at 1% or 5% level except for δ_{CC}, and sign conditions of almost all parameters are theoretically appropriate. From results of elasticity for each input, we found that elasticity of capital is 0.111, elasticity of labor is 0.217, and elasticity of intermediate goods is 0.641. There are very slight increasing returns to scale for this case. Elasticity of co-agglomeration with different industry groups is 0.017 and significant at 1% in Table 8.

<Table 7. Estimation of Flexible Translog Production Function (Co-agglomeration Effect)>
<Table 8. Output Elasticities, Scale Economies, and Co-agglomeration, Case of γEG>

Finally, we estimate the agglomeration and co-agglomeration effects (with different industry groups) on production. Table 9 shows the estimation results. From the Wald test results, the restriction of homotheticity is rejected at 5% level of significance. Hence, in Table 9, from the results of non-homotheticity for γ_{EG}, almost all estimated parameters are significant at 1% or 5% level except for $\delta_{AA}, \gamma_{KA}, \gamma_{LA}$, δ_{CC}, γ_{KC}, and γ_{MC}. Sign conditions of almost all parameters are theoretically appropriate. Thus, we calculate output elasticities of input, returns to scale, and agglomeration and co-agglomeration effects on production (Table 10).[15]

From results of elasticity for each input, we found that elasticities of capital, labor, and intermediate goods are 0.112, 0.218, and 0.673, respectively. Output elasticity of intermediate goods far exceeds the other two inputs. Economy of scale is about 1.0 and significant at 5% level. Very slight increasing returns to scale are suggested for this case.

Elasticities of agglomeration and co-agglomeration (with different industry groups) on production are estimated at 0.006 and 0.013, respectively, and are significant at 1% level. This results with four-digit SIC data suggest the presence of positive and weak agglomeration economies on production in Japan's assembly-type manufacturing industry. Compared to Tokunaga et al. (2008), the agglomeration effect for Japanese manufacturing industry is 0.007. Therefore, the degree of the agglomeration effect in Japanese assembly-type manufacturing is the same as that of Japan's manufacturing industry. On the other hand, the co-agglomeration effect (with different industry groups) for Japanese manufacturing industry is 0.008; Japan's assembly-type manufacturing industry exceeds that of Japanese manufacturing generally industry. Therefore, externality as

[15] Elasticities are evaluated at the sample means. The impact of agglomeration on production is calculated by $\partial \ln Y / \partial \ln Agglo = \delta_A + \delta_{AA} \ln Agglo + \sum_i \gamma_{iA} \ln X_i$, and that of co-agglomeration is $\partial \ln Y / \partial \ln Coagglo = \delta_C + \delta_{CC} \ln Coagglo + \sum_i \gamma_{iC} \ln X_i$.

co-agglomeration effect contributed to the production side in Japan's assembly-type manufacturing industry during 1985–2000.

<Table 9. Estimation of Flexible Translog Production Function, (Agglomeration and Co-agglomeration Effects)>
<Table 10. Output Elasticities, Scale Economies, and Agglomeration and Co-agglomeration, Case of γEG>

5. Conclusion

We estimated the flexible translog production function in Japan's assembly-type manufacturing industry for 1985–2000 based on Kim (1992) and Tokunaga and Kageyama (2008) using four-digit SIC industry panel data and Ellison and Glaeser's (1997) agglomeration and co-agglomeration (co-agglomeration with different industry groups) indices panel data. We found positive and weak agglomeration economies on production and very slight increasing returns to scale in Japanese assembly-type manufacturing industry which is composed of general machinery, electrical machinery, equipment and suppliers, and transportation equipment.

Previous research into agglomeration effects measured the degree of agglomeration by indices such as the Location Quotient or Location Gini Coefficient. We used the Ellison and Glaeser's (1997) agglomeration and co-agglomeration indices (co-agglomeration with different industry groups) as agglomeration data measured by Tokunaga and Akune (2004, 2005) and Tokunaga, Kageyama, and Akune (2006) for this industry over this period. Then, using a flexible translog production function, we derived theoretically appropriate and significant results without the homotheticity restriction. From estimation results for Japanese assembly type manufacturing industry during 1985–2000, our influential finding is that there are positive and weak effects of agglomeration economies. Especially, externality as co-agglomeration effect contributes to production in Japan's assembly-type manufacturing over the examined period.

However, we examined the agglomeration economies in Japan's assembly-type manufacturing industry (four-digit SIC industry panel data) using employing macro data. As an extension of this model's framework, we hope to analyze the impact of agglomeration economies on production in all Japanese industries using micro panel data (*Kohyo*-data) in future studies (Nakajima, Saito, and Uesugi, 2010). In addition, there is need to investigate the potential endogenous relationship between agglomeration and spillovers.

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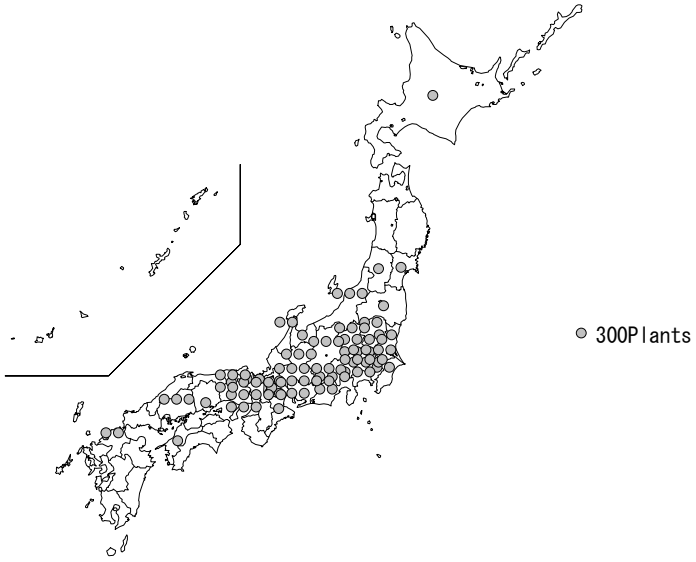
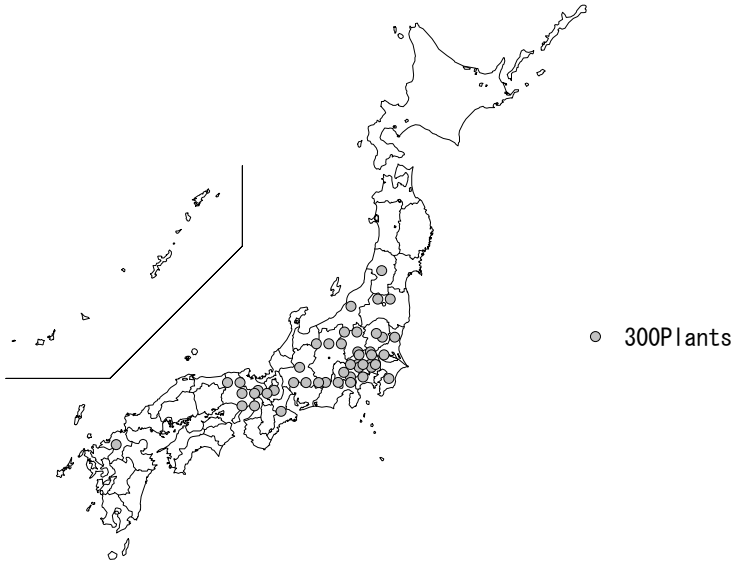
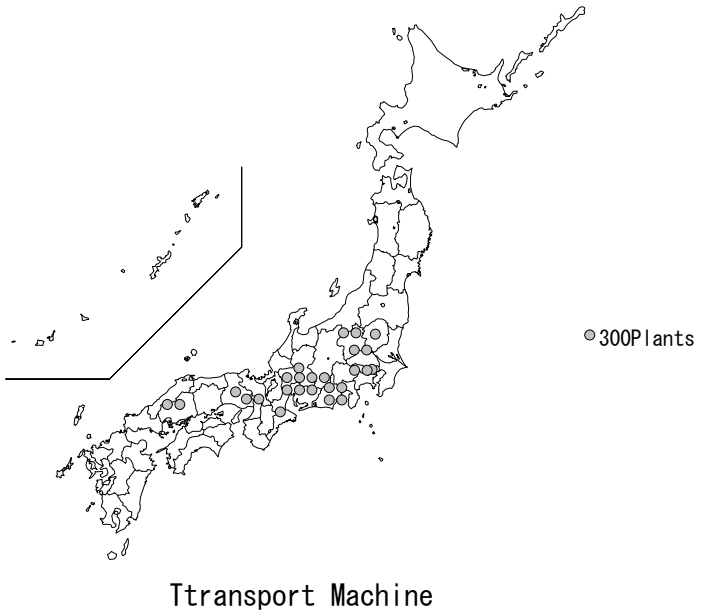


Machine



Electrical and Electronics



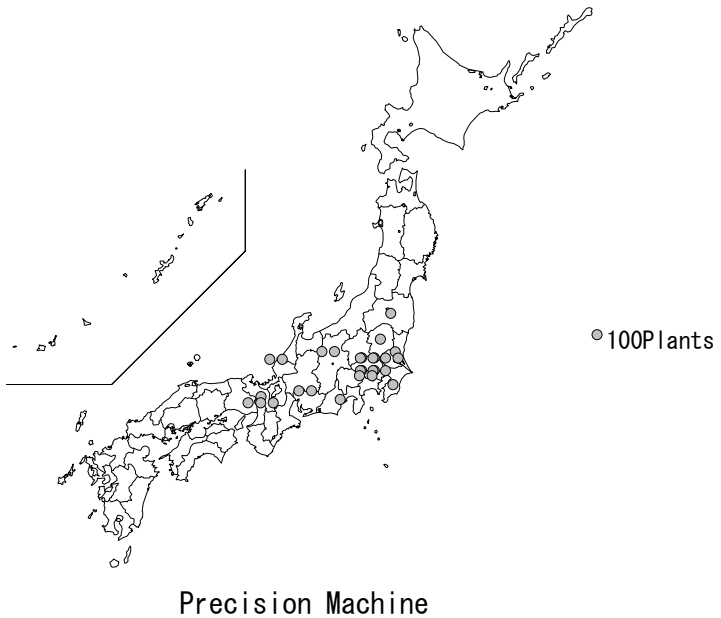


Figure 1 Geographical Distribution of Japan's Assembly-type Manufacturing Industry (2007)

Prefectures	Machine	Electrical and Electronics	Ttransport Machine	Precision Machine
Hokkaido	382	137	133	30
Aomori	82	159	31	34
Iwate	246	277	68	47
Miyagi	307	288	100	41
Akita	177	235	35	35
Yamagata	440	408	114	48
Fukushima	507	656	146	148
Ibaraki	741	670	280	137
Tochigi	651	432	383	164
Gunma	905	661	621	83
Saitama	2108	1278	710	406
Chiba	774	383	138	125
Tokyo	2352	1785	475	744
Kanagawa	2136	1589	751	259
Niigata	1006	530	176	93
Toyama	481	231	82	6
Ishikawa	639	206	89	16
Fukui	217	140	25	249
Yamanashi	328	343	91	54
Nagano	1100	1139	283	288
Gifu	900	375	382	36
Shizuoka	1736	1046	1438	118
Aichi	3968	1144	2225	202
Mie	565	488	362	14
Shiga	432	308	103	54
Kyoto	640	421	117	155
Osaka	3967	1560	613	308
Hyogo	1501	779	486	90
Nara	188	90	42	13
Wakayama	172	40	24	10
Tottori	91	196	17	8
Shimane	143	93	51	8
Okayama	447	222	263	18
Hiroshima	932	291	604	37
Yamaguchi	258	97	132	12
Tokushima	133	57	24	10
Kagawa	254	97	63	9
Ehime	331	88	95	10
Kochi	126	41	25	11
Fukuoka	779	345	165	39
Saga	157	81	49	4
Nagasaki	114	64	155	8
Kumamoto	170	166	104	16
Oita	150	133	102	16
Miyazaki	96	78	26	17
Kagoshima	114	135	21	18
Okinawa	12	10	7	6
Total	33955	19992	12426	4254

Table 1 Number of Plants by Prefectures 2007

Figure 2 Agglomeration of Japanese Manufacturing Industries (γ EG, 1980,1990,2000)

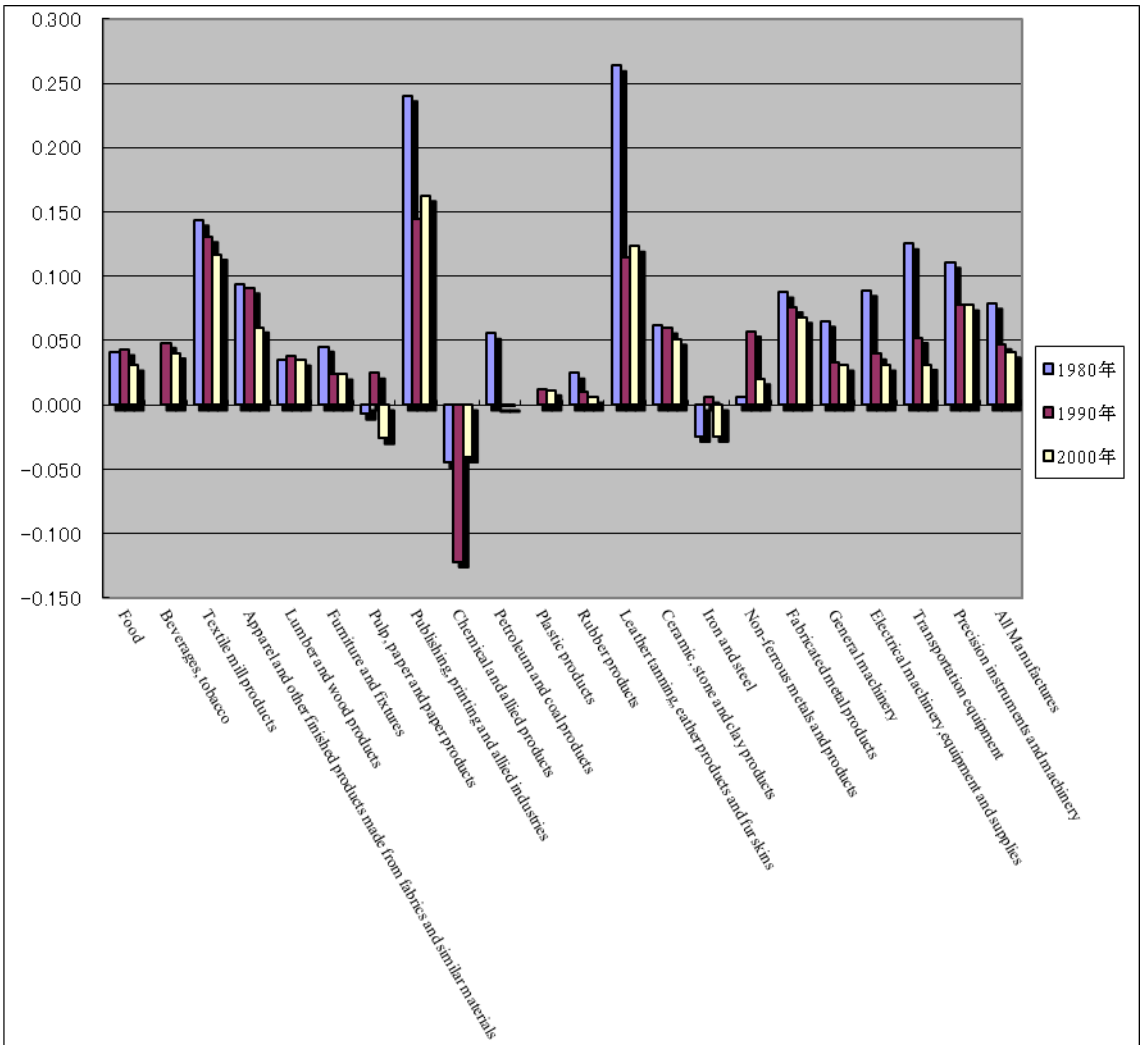


Table 2 Agglomeration Index (γ EG) of Assembly-type Manufacturing Industry (1980, 90, 2000)

Manufacture of general machinery (34), 1980

	code	Industry	γ_{EG}
1	3451	Machinery for man-made fiber and spinning machinery	0.318
2	3495	Piston rings	0.267
3	3491	Fire extinguishing equipment and its apparatus	0.200
4	3463	Pulp and paper industrial machinery	0.090
5	3462	Woodworking machinery	0.087
6	3453	Dyeing and finishing machinery	0.071
7	3473	Elevators and escalators	0.063
8	3411	Boilers	0.061
9	3476	Industrial furnaces and ovens	0.060
10	3483	Refrigerators and air conditioning apparatus	0.055

Manufacture of electrical machinery, equipment and supplies (35), 1980

	code	Industry	γ_{EG}
1	3562	Video recording and duplicating equipment	0.153
2	3542	Radio communication equipment	0.147
3	3515	Electrical welding equipment	0.115
4	3552	Electronic data processing machines, digital and analog computers, equipment and accessories	0.106
5	3561	Electric measuring instruments, except otherwise classified	0.099
6	3545	Railway signal and safety appliances	0.099
7	3591	Storage batteries	0.085
8	3541	Communication equipment (wired)	0.083
9	3551	X-ray equipment	0.083
10	3592	Primary batteries (dry and wet)	0.077

Manufacture of transportation equipment (36),1980

	code	Industry	γ_{EG}
1	3652	Aircraft engines	0.564
2	3651	Aircraft	0.275
3	3642	Hull blocks	0.215
4	3659	Miscellaneous aircraft parts and auxiliary equipment	0.159
5	3631	Bicycles and parts	0.132
6	3612	Motor vehicle bodies and trailers	0.057
7	3643	Wooden shipbuilding and repairing	0.050
8	3641	Steel shipbuilding and repairing	0.050
9	3613	Motor vehicle parts and accessories	0.042
10	3644	Small watercraft building and repairing	0.039

Manufacture of general machinery (29), 1990

	code	Industry	γ_{EG}
1	2995	Piston rings	0.157
2	2963	Pulp and paper industrial machinery	0.153
3	2912	Steam engines, turbines and water wheels, except marine engines	0.108
4	2983	Refrigerators and air conditioning apparatus	0.098
5	2951	Machinery for man-made fiber and spinning machinery	0.091
6	2962	Woodworking machinery	0.081
7	2991	Fire extinguishing equipment and its apparatus	0.078
8	2973	Elevators and escalators	0.062
9	2953	Dyeing and finishing machinery	0.052
10	2911	Boilers	0.049

Manufacture of electrical machinery, equipment and supplies (30), 1990

	code	Industry	γ_{EG}
1	3045	Railway signal and safety appliances	0.154
2	3042	Radio communication equipment	0.140
3	3072	Industrial process controlling instruments	0.106
4	3092	Primary batteries (dry and wet)	0.090
5	3015	Electrical welding equipment	0.070
6	3071	Electric measuring instruments, except otherwise classified	0.070
7	3091	Storage batteries	0.059
8	3061	X-ray equipment	0.051
9	3051	Electronic data processing machines, digital and analog computers, equipment and accessories	0.039
10	3016	Auxiliary equipment for internal combustion engines	0.035

Manufacture of transportation equipment (31), 1990

	code	Industry	γ_{EG}
1	3152	Aircraft engines	0.547
2	3142	Hull blocks	0.187
3	3131	Bicycles and parts	0.163
4	3159	Miscellaneous aircraft parts and auxiliary equipment	0.104
5	3112	Motor vehicle bodies and trailers	0.092
6	3145	Marine engines	0.056
7	3141	Steel shipbuilding and repairing	0.055
8	3113	Motor vehicle parts and accessories	0.043
9	3144	Small watercraft building and repairing	0.036
10	3122	Railroad car parts	0.026

Manufacture of general machinery (29), 2000

	code	Industry	γ_{EG}
1	2911	Boilers	0.233
2	2995	Piston rings	0.154
3	2912	Steam engines, turbines and water wheels, except marine engines	0.150
4	2963	Pulp and paper industrial machinery	0.142
5	2919	Miscellaneous engines and turbines	0.126
6	2973	Elevators and escalators	0.060
7	2962	Woodworking machinery	0.059
8	2955	Sewing machinery and equipment	0.045
9	2954	Textile machinery parts, attachments and accessories	0.038
10	2994	Ball and roller bearings	0.036

Manufacture of electrical machinery, equipment and supplies (30), 2000

	code	Industry	γ_{EG}
1	3063	Medical electronic instruments and equipment	0.167
2	3092	Primary batteries (dry and wet)	0.094
3	3072	Industrial process controlling instruments	0.076
4	3043	Radio and television receivers	0.072
5	3061	X-ray equipment	0.068
6	3091	Storage batteries	0.056
7	3015	Electrical welding equipment	0.055
8	3071	Electric measuring instruments, except otherwise classified	0.047
9	3045	Railway signal and safety appliances	0.045
10	3084	Resistors, capacitors, transformers and composite parts	0.043

Manufacture of transportation equipment (31), 2000

	code	Industry	γ_{EG}
1	3142	Hull blocks	0.170
2	3131	Bicycles and parts	0.160
3	3152	Aircraft engines	0.157
4	3145	Marine engines	0.075
5	3112	Motor vehicle bodies and trailers	0.059
6	3141	Steel shipbuilding and repairing	0.058
7	3113	Motor vehicle parts and accessories	0.054
8	3159	Miscellaneous aircraft parts and auxiliary equipment	0.053
9	3122	Railroad car parts	0.036
10	3144	Small watercraft building and repairing	0.033

Table 3 Co-agglomeration Index (Ellison and Glaeser, 1997) of Assembly-type Manufacturing Industry (1985, 90, 95, 2000)

year : 1985

Manufacture of general machinery (29)

Code	Downstream Industry	Code	Upstream Industry	CA
2995	Piston rings	2821	Tableware (occidental-type)	0.373
2991	Fire extinguishing equipment and its apparatus	2732	Rolling of lead and alloys, including extruding	0.152
2991	Fire extinguishing equipment and its apparatus	2662	Malleable iron castings	0.111
2941	Metal machine tools	2982	Woolen yarn hand knitting machines	0.110
2962	Woodworking machinery	2963	Pulp and paper industrial machinery	0.100
2963	Pulp and paper industrial machinery	2962	Woodworking machinery	0.100
2911	Boilers	2825	Files	0.095
2965	Foundry equipment	2982	Woolen yarn hand knitting machines	0.092
2982	Woolen yarn hand knitting machines	2661	Iron castings, except cast iron pipes and malleable iron casting	0.090
2991	Fire extinguishing equipment and its apparatus	2829	Miscellaneous hardware	0.087
2912	Steam engines, turbines and water wheels, except marine eng	2826	Hand saws and saw blades	0.077
2944	Machinists' precision tools, except powder metallurgy produ	2982	Woolen yarn hand knitting machines	0.076
2982	Woolen yarn hand knitting machines	2944	Machinists' precision tools, except powder metallurgy products	0.076
2965	Foundry equipment	3015	Electrical welding equipment	0.070
2991	Fire extinguishing equipment and its apparatus	2692	Iron and steel shearing and slitting	0.062
2971	Pumps and pumping equipment	2991	Fire extinguishing equipment and its apparatus	0.061
2964	Printing, bookbinding and paper covering machinery	2891	Safes	0.056
2991	Fire extinguishing equipment and its apparatus	2994	Ball and roller bearings	0.056
2994	Ball and roller bearings	2991	Fire extinguishing equipment and its apparatus	0.056
2991	Fire extinguishing equipment and its apparatus	2731	Rolling and drawing copper and copper alloys	0.053

year : 1985

Manufacture of electrical machinery, equipment and supplies (30)

Code	Downstream Industry	Code	Upstream Industry	CA
3015	Electrical welding equipment	3092	Primary batteries (dry and wet)	0.099
3092	Primary batteries (dry and wet)	2732	Rolling of lead and alloys, including extruding	0.085
3042	Radio communication equipment	1941	Plate making for printing	0.073
3081	Electron tubes	2732	Rolling of lead and alloys, including extruding	0.064
3092	Primary batteries (dry and wet)	1497	Coated, water-proof fabrics	0.062
3015	Electrical welding equipment	2662	Malleable iron castings	0.060
3043	Radio and television receivers	2991	Fire extinguishing equipment and its apparatus	0.059
3091	Storage batteries	2729	Miscellaneous secondary smelting and refining of non-ferrous meta	0.059
3042	Radio communication equipment	1951	Bookbinding	0.054
3042	Radio communication equipment	3091	Storage batteries	0.052
3092	Primary batteries (dry and wet)	2829	Miscellaneous hardware	0.051
3015	Electrical welding equipment	2829	Miscellaneous hardware	0.048
3043	Radio and television receivers	3092	Primary batteries (dry and wet)	0.046
3021	Household electric appliances	2991	Fire extinguishing equipment and its apparatus	0.043
3092	Primary batteries (dry and wet)	2692	Iron and steel shearing and slitting	0.040
3042	Radio communication equipment	3083	Integrated circuits	0.040
3092	Primary batteries (dry and wet)	2722	Secondary smelting and refining of zinc, including zinc alloys	0.040
3081	Electron tubes	2513	Glass processing materials	0.039
3042	Radio communication equipment	1991	Service industries related to printing trade	0.038
3092	Primary batteries (dry and wet)	2721	Secondary smelting and refining of lead, including lead alloys	0.038

year : 1985

Manufacture of transportation equipment (31)

Code	Downstream Industry	Code	Upstream Industry	CA
3142	Hull blocks	2891	Safes	0.106
3141	Steel shipbuilding and repairing	2825	Files	0.103
3145	Marine engines	2826	Hand saws and saw blades	0.077
3121	Railroad cars	3121	Railroad cars	0.067
3143	Wooden shipbuilding and repairing	2825	Files	0.056
3121	Railroad cars	2121	Lubricating oils, except petroleum refined ones	0.052
3111	Motor vehicles, including motorcycles	3112	Motor vehicle bodies and trailers	0.051
3111	Motor vehicles, including motorcycles	3113	Motor vehicle parts and accessories	0.042
3112	Motor vehicle bodies and trailers	3113	Motor vehicle parts and accessories	0.041
3143	Wooden shipbuilding and repairing	1612	Veneer wood	0.040
3113	Motor vehicle parts and accessories	3016	Auxiliary equipment for internal combustion engines	0.040
3121	Railroad cars	2054	Paints	0.038
3141	Steel shipbuilding and repairing	3145	Marine engines	0.037
3142	Hull blocks	3145	Marine engines	0.035
3141	Steel shipbuilding and repairing	2891	Safes	0.035
3111	Motor vehicles, including motorcycles	3016	Auxiliary equipment for internal combustion engines	0.035
3145	Marine engines	2827	Agricultural tools, except agricultural machinery	0.033
3121	Railroad cars	2832	Gas and oil appliances	0.031
3143	Wooden shipbuilding and repairing	1617	Flooring mills	0.028
3145	Marine engines	2823	Edge tools, artisans' tools and hand tools, except files, saws a	0.028

year : 1990

Manufacture of general machinery (29)

Code	Downstream Industry	Code	Upstream Industry	CA
2995	Piston rings	2821	Tableware (occidental-type)	0.370
2911	Boilers	2825	Files	0.140
2991	Fire extinguishing equipment and its apparatus	2732	Rolling of lead and alloys, including extruding	0.097
2919	Miscellaneous engines and turbines	2891	Safes	0.093
2965	Foundry equipment	2982	Woolen yarn hand knitting machines	0.086
2962	Woodworking machinery	2963	Pulp and paper industrial machinery	0.081
2963	Pulp and paper industrial machinery	2962	Woodworking machinery	0.081
2941	Metal machine tools	2982	Woolen yarn hand knitting machines	0.080
2919	Miscellaneous engines and turbines	2391	Rubber coated fabric and its products	0.073
2964	Printing, bookbinding and paper covering machinery	2891	Safes	0.062
2982	Woolen yarn hand knitting machines	2661	Iron castings, except cast iron pipes and malleable iron casting	0.062
2991	Fire extinguishing equipment and its apparatus	2662	Malleable iron castings	0.059
2991	Fire extinguishing equipment and its apparatus	2829	Miscellaneous hardware	0.055
2912	Steam engines, turbines and water wheels, except ma	2826	Hand saws and saw blades	0.055
2913	Internal combustion engines	2392	Medical and sanitary rubber products	0.053
2973	Elevators and escalators	2662	Malleable iron castings	0.052
2944	Machinists' precision tools, except powder metallu	2982	Woolen yarn hand knitting machines	0.047
2982	Woolen yarn hand knitting machines	2944	Machinists' precision tools, except powder metallurgy products	0.047
2911	Boilers	2826	Hand saws and saw blades	0.047
2978	Chemical machinery and its equipment	1941	Plate making for printing	0.044

year : 1990				
Manufacture of electrical machinery, equipment and supplies (30)				
Code	Downstream Industry	Code	Upstream Industry	CA
3015	Electrical welding equipment	3092	Primary batteries (dry and wet)	0.114
3092	Primary batteries (dry and wet)	2732	Rolling of lead and alloys, including extruding	0.091
3049	Miscellaneous communication equipment and related p	3478	Thermos bottles	0.086
3042	Radio communication equipment	1941	Plate making for printing	0.074
3015	Electrical welding equipment	2662	Malleable iron castings	0.069
3092	Primary batteries (dry and wet)	1497	Coated, water-proof fabrics	0.057
3015	Electrical welding equipment	2829	Miscellaneous hardware	0.056
3081	Electron tubes	2732	Rolling of lead and alloys, including extruding	0.052
3042	Radio communication equipment	3091	Storage batteries	0.051
3092	Primary batteries (dry and wet)	2829	Miscellaneous hardware	0.049
3042	Radio communication equipment	1991	Service industries related to printing trade	0.049
3091	Storage batteries	2719	Miscellaneous primary smelting and refining of non-ferrous metals	0.048
3061	X-ray equipment	2851	Stamped and pressed aluminum and aluminum alloy products	0.048
3045	Railway signal and safety appliances	3083	Integrated circuits	0.044
3041	Communication equipment (wired)	2392	Medical and sanitary rubber products	0.043
3042	Radio communication equipment	1951	Bookbinding	0.043
3083	Integrated circuits	2719	Miscellaneous primary smelting and refining of non-ferrous metals	0.041
3092	Primary batteries (dry and wet)	2722	Secondary smelting and refining of zinc, including zinc alloys	0.041
3043	Radio and television receivers	2991	Fire extinguishing equipment and its apparatus	0.038
3042	Radio communication equipment	3083	Integrated circuits	0.038

year : 1990				
Manufacture of transportation equipment (31)				
Code	Downstream Industry	Code	Upstream Industry	CA
3142	Hull blocks	2891	Safes	0.146
3141	Steel shipbuilding and repairing	2825	Files	0.109
3145	Marine engines	2826	Hand saws and saw blades	0.066
3111	Motor vehicles, including motorcycles	3112	Motor vehicle bodies and trailers	0.059
3141	Steel shipbuilding and repairing	2891	Safes	0.056
3112	Motor vehicle bodies and trailers	3113	Motor vehicle parts and accessories	0.048
3121	Railroad cars	2121	Lubricating oils, except petroleum refined ones	0.041
3111	Motor vehicles, including motorcycles	3113	Motor vehicle parts and accessories	0.040
3145	Marine engines	2827	Agricultural tools, except agricultural machinery	0.033
3144	Small watercraft building and repairing	1617	Flooring mills	0.032
3113	Motor vehicle parts and accessories	3016	Auxiliary equipment for internal combustion engines	0.031
3121	Railroad cars	2881	Bolts, nuts, rivets, machine screws, wood screws, etc.	0.030
3141	Steel shipbuilding and repairing	3145	Marine engines	0.030
3145	Marine engines	2691	Iron powder	0.029
3143	Wooden shipbuilding and repairing	1612	Veneer wood	0.028
3142	Hull blocks	3145	Marine engines	0.027
3121	Railroad cars	2054	Paints	0.025
3191	Industrial trucks and parts and accessories	3113	Motor vehicle parts and accessories	0.025
3144	Small watercraft building and repairing	1612	Veneer wood	0.025
3191	Industrial trucks and parts and accessories	2661	Iron castings, except cast iron pipes and malleable iron casting	0.024

year : 1995				
Manufacture of general machinery (29)				
Code	Downstream Industry	Code	Upstream Industry	CA
2995	Piston rings	2821	Tableware (occidental-type)	0.370
2919	Miscellaneous engines and turbines	2391	Rubber coated fabric and its products	0.133
2965	Foundry equipment	2982	Woolen yarn hand knitting machines	0.124
2911	Boilers	2825	Files	0.108
2912	Steam engines, turbines and water wheels, except ma	2826	Hand saws and saw blades	0.102
2941	Metal machine tools	2982	Woolen yarn hand knitting machines	0.102
2962	Woodworking machinery	2963	Pulp and paper industrial machinery	0.086
2963	Pulp and paper industrial machinery	2962	Woodworking machinery	0.086
2919	Miscellaneous engines and turbines	2891	Safes	0.084
2964	Printing, bookbinding and paper covering machinery	2891	Safes	0.080
2919	Miscellaneous engines and turbines	2799	Non-ferrous metal products, n.e.c.	0.073
2982	Woolen yarn hand knitting machines	2661	Iron castings, except cast iron pipes and malleable iron casting	0.068
2913	Internal combustion engines	2392	Medical and sanitary rubber products	0.065
2991	Fire extinguishing equipment and its apparatus	2732	Rolling of lead and alloys, including extruding	0.058
2944	Machinists' precision tools, except powder metallu	2982	Woolen yarn hand knitting machines	0.057
2982	Woolen yarn hand knitting machines	2944	Machinists' precision tools, except powder metallurgy products	0.057
2991	Fire extinguishing equipment and its apparatus	2662	Malleable iron castings	0.053
2961	Food processing machinery	2825	Files	0.046
2982	Woolen yarn hand knitting machines	2664	Secondary forgings	0.045
2913	Internal combustion engines	2739	Miscellaneous rolling of non-ferrous metals and alloys, including	0.043

year : 1995				
Manufacture of electrical machinery, equipment and supplies (30)				
Code	Downstream Industry	Code	Upstream Industry	CA
3081	Electron tubes	2732	Rolling of lead and alloys, including extruding	0.135
3043	Radio and television receivers	3092	Primary batteries (dry and wet)	0.116
3015	Electrical welding equipment	3092	Primary batteries (dry and wet)	0.109
3061	X-ray equipment	3081	Electron tubes	0.084
3043	Radio and television receivers	2991	Fire extinguishing equipment and its apparatus	0.080
3091	Storage batteries	2719	Miscellaneous primary smelting and refining of non-ferrous metals	0.073
3092	Primary batteries (dry and wet)	2732	Rolling of lead and alloys, including extruding	0.071
3015	Electrical welding equipment	2662	Malleable iron castings	0.065
3045	Railway signal and safety appliances	3049	Miscellaneous communication equipment and related products	0.064
3049	Miscellaneous communication equipment and related p	3045	Railway signal and safety appliances	0.064
3041	Communication equipment (wired)	2392	Medical and sanitary rubber products	0.059
3061	X-ray equipment	2851	Stamped and pressed aluminum and aluminum alloy products	0.055
3092	Primary batteries (dry and wet)	2829	Miscellaneous hardware	0.054
3042	Radio communication equipment	1991	Service industries related to printing trade	0.054
3092	Primary batteries (dry and wet)	2722	Secondary smelting and refining of zinc, including zinc alloys	0.053
3015	Electrical welding equipment	2829	Miscellaneous hardware	0.052
3092	Primary batteries (dry and wet)	2721	Secondary smelting and refining of lead, including lead alloys	0.049
3083	Integrated circuits	2729	Miscellaneous secondary smelting and refining of non-ferrous meta	0.046
3081	Electron tubes	2516	Glass tableware and kitchenware	0.045
3042	Radio communication equipment	1951	Bookbinding	0.042

year : 1995				
Manufacture of transportation equipment (31)				
Code	Downstream Industry	Code	Upstream Industry	CA
3142	Hull blocks	2891	Safes	0.144
3141	Steel shipbuilding and repairing	2825	Files	0.112
3145	Marine engines	2826	Hand saws and saw blades	0.096
3143	Wooden shipbuilding and repairing	1612	Veneer wood	0.068
3141	Steel shipbuilding and repairing	2891	Safes	0.060
3111	Motor vehicles, including motorcycles	3112	Motor vehicle bodies and trailers	0.056
3143	Wooden shipbuilding and repairing	2825	Files	0.054
3112	Motor vehicle bodies and trailers	3113	Motor vehicle parts and accessories	0.050
3111	Motor vehicles, including motorcycles	3113	Motor vehicle parts and accessories	0.045
3145	Marine engines	2391	Rubber coated fabric and its products	0.044
3143	Wooden shipbuilding and repairing	1617	Flooring mills	0.033
3143	Wooden shipbuilding and repairing	1622	Plywood	0.031
3191	Industrial trucks and parts and accessories	3113	Motor vehicle parts and accessories	0.031
3141	Steel shipbuilding and repairing	3145	Marine engines	0.030
3145	Marine engines	2827	Agricultural tools, except agricultural machinery	0.030
3143	Wooden shipbuilding and repairing	1611	General sawing and planning mills	0.029
3143	Wooden shipbuilding and repairing	3145	Marine engines	0.028
3121	Railroad cars	2919	Miscellaneous engines and turbines	0.026
3145	Marine engines	2823	Edge tools, artisans' tools and hand tools, except files, saws a	0.026
3143	Wooden shipbuilding and repairing	1711	Wooden furniture and furnishings, except Japanese lacquered ones	0.025

year : 2000				
Manufacture of general machinery (29)				
Code	Downstream Industry	Code	Upstream Industry	CA
2995	Piston rings	2821	Tableware (occidental-type)	0.400
2912	Steam engines, turbines and water wheels, except ma	2826	Hand saws and saw blades	0.129
2982	Woolen yarn hand knitting machines	2664	Secondary forgings	0.090
2911	Boilers	2825	Files	0.085
2964	Printing, bookbinding and paper covering machinery	2891	Safes	0.079
2919	Miscellaneous engines and turbines	2391	Rubber coated fabric and its products	0.076
2919	Miscellaneous engines and turbines	2799	Non-ferrous metal products, n.e.c.	0.060
2962	Woodworking machinery	2963	Pulp and paper industrial machinery	0.050
2963	Pulp and paper industrial machinery	2962	Woodworking machinery	0.050
2991	Fire extinguishing equipment and its apparatus	2732	Rolling of lead and alloys, including extruding	0.048
2912	Steam engines, turbines and water wheels, except ma	2827	Agricultural tools, except agricultural machinery	0.046
2977	Hydraulic equipment and pneumatic equipment	2919	Miscellaneous engines and turbines	0.043
2912	Steam engines, turbines and water wheels, except ma	2823	Edge tools, artisans' tools and hand tools, except files, saws a	0.040
2961	Food processing machinery	2825	Files	0.040
2913	Internal combustion engines	2739	Miscellaneous rolling of non-ferrous metals and alloys, includin	0.040
2971	Pumps and pumping equipment	2919	Miscellaneous engines and turbines	0.039
2976	Industrial furnaces and ovens	2551	Fire bricks	0.039
2982	Woolen yarn hand knitting machines	2663	Steel castings	0.037
2913	Internal combustion engines	2392	Medical and sanitary rubber products	0.036
2941	Metal machine tools	2982	Woolen yarn hand knitting machines	0.036

year : 2000				
Manufacture of electrical machinery, equipment and supplies (30)				
Code	Downstream Industry	Code	Upstream Industry	CA
3092	Primary batteries (dry and wet)	2732	Rolling of lead and alloys, including extruding	0.069
3092	Primary batteries (dry and wet)	2722	Secondary smelting and refining of zinc, including zinc alloys	0.065
3061	X-ray equipment	2851	Stamped and pressed aluminum and aluminum alloy products	0.062
3081	Electron tubes	2732	Rolling of lead and alloys, including extruding	0.058
3015	Electrical welding equipment	3092	Primary batteries (dry and wet)	0.056
3042	Radio communication equipment	1991	Service industries related to printing trade	0.056
3091	Storage batteries	3092	Primary batteries (dry and wet)	0.050
3092	Primary batteries (dry and wet)	3091	Storage batteries	0.050
3092	Primary batteries (dry and wet)	2829	Miscellaneous hardware	0.041
3081	Electron tubes	2582	Artificial aggregate	0.041
3042	Radio communication equipment	1941	Plate making for printing	0.039
3032	Electric lighting fixtures	3031	Electric bulbs	0.037
3091	Storage batteries	2713	Primary smelting and refining of zinc	0.036
3045	Railway signal and safety appliances	3049	Miscellaneous communication equipment and related products	0.036
3049	Miscellaneous communication equipment and related p	3045	Railway signal and safety appliances	0.036
3042	Radio communication equipment	1951	Bookbinding	0.035
3091	Storage batteries	2719	Miscellaneous primary smelting and refining of non-ferrous metals	0.032
3041	Communication equipment (wired)	2392	Medical and sanitary rubber products	0.032
3092	Primary batteries (dry and wet)	1497	Coated, water-proof fabrics	0.029
3081	Electron tubes	2513	Glass processing materials	0.028

year : 2000				
Manufacture of transportation equipment (31)				
Code	Downstream Industry	Code	Upstream Industry	CA
3142	Hull blocks	2891	Safes	0.149
3141	Steel shipbuilding and repairing	2825	Files	0.138
3145	Marine engines	2826	Hand saws and saw blades	0.120
3141	Steel shipbuilding and repairing	2891	Safes	0.079
3143	Wooden shipbuilding and repairing	2825	Files	0.071
3121	Railroad cars	2919	Miscellaneous engines and turbines	0.059
3111	Motor vehicles, including motorcycles	3112	Motor vehicle bodies and trailers	0.055
3112	Motor vehicle bodies and trailers	3113	Motor vehicle parts and accessories	0.052
3111	Motor vehicles, including motorcycles	3113	Motor vehicle parts and accessories	0.051
3145	Marine engines	2827	Agricultural tools, except agricultural machinery	0.045
3121	Railroad cars	3121	Railroad cars	0.045
3145	Marine engines	2391	Rubber coated fabric and its products	0.035
3145	Marine engines	2823	Edge tools, artisans' tools and hand tools, except files, saws a	0.035
3191	Industrial trucks and parts and accessories	3113	Motor vehicle parts and accessories	0.032
3145	Marine engines	2691	Iron powder	0.030
3142	Hull blocks	2974	Conveyers and conveying equipment	0.030
3121	Railroad cars	2054	Paints	0.029
3113	Motor vehicle parts and accessories	2661	Iron castings, except cast iron pipes and malleable iron casting	0.028
3144	Small watercraft building and repairing	1612	Veneer wood	0.027
3121	Railroad cars	2881	Bolts, nuts, rivets, machine screws, wood screws, etc.	0.026

Table 4. Descriptive statistics

Variables	Variable description
Y	Output (millions of 1995 Yen)
K	Capital (millions of 1995 Yen)
L	Labor (manhours)
M	Materials (millions of 1995 Yen)
S_K	Capital cost share
S_L	Labor cost share
S_M	Material cost share
Agglo	Agglomeration (Employment based)
Coagglo	Co-agglomeration(Employment based)

Source: Census of Manufacture, dataset offered by CRIEPI, Tokunaga, Kageyama, and Akune(2005).

Table 5. Estimation of flexible translog production function (agglomeration effect)

Case of γ_{EG}

	Nonhomotheticity		
	Coeff.	S.E.	t-stat.
α_0	1.024	0.268	3.816***
α_K	0.082	0.018	4.475***
α_L	0.635	0.019	33.60***
α_M	0.409	0.036	11.239***
β_{KK}	0.023	0.003	9.314***
β_{LL}	0.097	0.004	23.191***
β_{MM}	0.153	0.004	34.247***
β_{KL}	0.016	0.002	7.164***
β_{KM}	-0.034	0.003	-11.967***
β_{LM}	-0.126	0.003	-38.262***
δ_A	0.084	0.049	1.731**
δ_{AA}	-0.005	0.005	-0.974
γ_{KA}	0.0008	0.002	0.253
γ_{LA}	0.001	0.002	0.597
γ_{MA}	-0.008	0.004	-2.198**
Sample	360		
Adj.R^2		0.990	

Note: *** significant at 1% level, ** significant at 5% level, and * significant at 10% level.
Source: Authors' calculation

Table 6. Output elasticities, scale economies, and agglomeration
Case of γEG

		Coeff.	S.E.	t-stat.
Output elasticities				
	Capital	0.110	0.001	90.3***
	Labor	0.220	0.004	62.4***
	Intermediate goods	0.674	0.004	175.3***
Returns to scale		1.004	0.208	4.8***
Agglomeration effects		0.007	0.001	11.7***

Note: *** significant at 1% level, ** significant at 5% level, and * significant at 10% level.
Source: Authors' calculation

Table 7. Estimation of flexible translog production function (co-agglomeration effect)

Case of γEG

	Nonhomotheticity		
	Coeff.	S.E.	t-stat.
α_0	2.217	0.516	4.378***
α_K	0.064	0.027	2.351***
α_L	0.587	0.026	22.579***
α_M	0.362	0.049	7.335***
β_{KK}	0.025	0.003	9.256***
β_{LL}	0.095	0.005	20.680***
β_{MM}	0.152	0.005	31.427***
β_{KL}	0.014	0.002	5.893***
β_{KM}	-0.035	0.003	-10.949***
β_{LM}	-0.121	0.004	-34.143***
δ_c	0.261	0.104	2.520***
δ_{cc}	0.005	0.016	0.315
γ_{KC}	-0.005	0.004	-1.359*
γ_{LC}	-0.007	0.003	-2.127**
γ_{MC}	-0.007	0.006	-1.279**
Sample	296		
Adj.R^2		0.990	

Note: *** significant at 1% level, ** significant at 5% level, and * significant at 10% level.
Source: Authors' calculation

Table 8. Output elasticities, scale economies, and co-agglomeration
Case of γEG

		Coeff.	S.E.	t-stat.
Output elasticities				
	Capital	0.111	0.002	73.6***
	Labor	0.217	0.004	56.2***
	Intermediate goods	0.641	0.004	151.7***
Returns to scale		1.001	0.697	1.40*
Co-Agglomeration effects		0.017	0.002	10.5***

Note: *** significant at 1% level, ** significant at 5% level, and * significant at 10% level.
Source: Authors' calculation

Table 9. Estimation of flexible translog production function
(agglomeration and co-agglomeration effects)

Case of γ_{EG}

	Nonhomotheticity		
	Coeff.	S.E.	t-stat.
α_0	2.370	0.516	4.598***
α_K	0.070	0.028	2.494***
α_L	0.587	0.026	22.520***
α_M	0.373	0.049	7.599***
β_{KK}	0.025	0.003	8.956***
β_{LL}	0.097	0.005	20.171***
β_{MM}	0.150	0.005	30.699***
β_{KL}	0.014	0.002	5.699***
β_{KM}	-0.034	0.003	-10.732***
β_{LM}	-0.123	0.004	-33.712***
δ_A	0.167	0.068	2.436***
δ_{AA}	-0.003	0.006	-0.600
γ_{KA}	0.001	0.002	0.523
γ_{LA}	-0.001	0.002	-0.425
γ_{MA}	-0.010	0.004	-2.401***
δ_C	0.265	0.105	2.530***
δ_{CC}	0.006	0.017	0.361
γ_{KC}	-0.004	0.004	-1.178
γ_{LC}	-0.006	0.003	-1.957**
γ_{MC}	-0.005	0.006	-0.862
δ_{AC}	0.012	0.009	1.292*
Sample	296		
Adj.R^2		0.990	

Note: *** significant at 1% level, ** significant at 5% level, and * significant at 10% level.
Source: Authors' calculation

Table 10. Output elasticities, scale economies, and agglomeration and co-agglomeration
Case of γEG

		Coeff.	S.E.	t-stat.
Output elasticities				
	Capital	0.112	0.001	76.0***
	Labor	0.218	0.004	55.7***
	Intermediate goods	0.673	0.004	156.4***
Returns to scale		1.002	0.544	1.8**
Agglomeration effects		0.006	0.001	6.2***
Co-agglomeration effects		0.013	0.002	6.9***

Note: *** significant at 1% level, ** significant at 5% level, and * significant at 10% level.
Source: Authors' calculation