The productivity improvement effect of surrounding firms in the Japanese manufacturing industry

— industrial agglomeration and international trade —

製造業において周辺事業所が生産性に与える効果

— 産業集積と国際分業 —

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Abstract：This paper aims to show that the productivity improvement effect of industrial agglomeration in the manufacturing industry in Japan is decreasing, while industrial infrastructure is maintained and international trade continues to advance. Industrial mesh data from 1990 to 2010 were used for the analysis. Because mesh data were used, it was possible to analyze the data by latitude and longitude. We found that the productivity improvement effect of industrial agglomeration was not clear in every case during the period studied and the effect of the agglomeration of firms was found to be decreasing in the manufacturing industry year by year. It is thought that increases in importing and exporting that result from the formation of the global value chain have influenced the gradual decrease in the effect of agglomeration. This decreasing productivity improvement effect associated with industrial agglomeration affects the creation of industrial clusters in Japan.

要旨：産業インフラが整備され，産業の国際分業が進む中で，製造業事業所が集積することによる生産性向上効果を分析した。分析には1990年から2010年までの工業メッシュデータを用いた。メッシュごとのデータを用いたので市区町村の行政単位の再編の問題を避け，緯度経度での区割りで分析を行うことができた。その結果，製造業においては事業所が集中することの効果は明確ではなく，周辺事業所の生産性に対する効果は年々減少していることが明らかとなった。周辺事業所効果の減少には，国際分業による輸出入の増加が影響していると考えられる。

Keywords：Industrial agglomeration, Manufacturing industry, Productivity, International trade

1. Introduction

Not only large enterprises but also small and medium enterprises have relocated some of their factories to China and Southeast Asia from Japan in recent years, leaving numerous industrial estates in Japan inactive. This behavior has expanded the value chain globally. Conversely, in Japan some domestic manufacturing environments are improving. For example, the communications network has been expanded by the internet and transport infrastructure has been improved by expressways, bullet trains and home delivery systems. These changes seem to affect the productivity of manufacturing firms, especially in relation to the effect of industrial agglomeration. Hence we analyze the productivity improvement effect of manufacturing firm agglomeration in this paper.

Fujita, Krugman, and Venables (1999) and Sato, Tabuchi, and Yamamoto (2011) note the following four advantages of industrial agglomeration. Of these, (1), (2) and (3) are known as Marshall's three reasons for localization. (1) Technological external economy: it is possible to gain access to new technology earlier as a result of technology spillover. (2) Economies of scale in the intermediate goods market: the intermediate goods market expands when numerous related firms are relocated near existing firms. (3) Formation of a skilled labor market: workers with relevant skills gather, and both the demand and supply of specific industry workers increases. (4) Decrease in trading costs: it becomes easier for firms to cooperate with each other in the search for appropriate partners. These advantages improve the productivity of firms, and they contribute to what Porter (2000) describes as the 'cluster theory.' However, it seems that these advantages of industrial agglomeration are weakened by the development of technology, as argued by Krugman (2011). For instance, new technology can now be obtained almost simultaneously regardless of where a firm is located as a result of developments in information and communication technology. Moreover, the range of markets that can be accessed for the same financial and time costs has broadened as a result of developments in transportation and decreased transportation costs. The total transportation costs incurred by major manufacturing firms in Japan relative to their total sales value is decreasing since 1990, according to data from the Japan Logistic System Association (2015). Skilled workers can relocate over a wide area, even to foreign countries, as shown in the consumer electronic equipment industry and the semiconductor industry as we can see in the 'IT human resources white paper (2015)'. Additionally, matching of firms for business and matching of workers can be done using the Internet. Therefore, the effect of industrial agglomeration seems to be decreasing. The purpose of this paper is to clarify the decreasing effect of industrial agglomeration on productivity and the reasons of this effect. To do this, we examined the effect of industrial agglomeration on productivity improvement in the manufacturing industry and the relationship between productivity change and international trade using a Japanese inter-industry relations table and Japanese industrial mesh data from the Ministry of Economy, Trade and Industry.[1]

We found that the effect of manufacturing industrial agglomeration on productivity improvement is positive, but not significant in every case in Japan.[2] Additionally, it became clear that the productivity improvement effect of manufacturing industrial agglomeration is decreasing year by year. Moreover, the increases in importing and exporting as a result of global value chain and international specialization can be seen as one reason for this decreasing effect of manufacturing industrial agglomeration.

The rest of this paper is organized as follows. Section 2 presents a literature review and the current state of industrial agglomeration. On the basis of this background information, the purpose of this study is explained and our hypotheses are presented. Section 3 describes the data obtained for analysis. Section 4 presents the methods used for the regression analysis and the panel analysis. Section 5 presents and discusses the results. Section 6 concludes and proposes topics for future research.

2. Literature review and current state of industrial agglomeration

2.1 Review of the literature on agglomeration theory

New economic geography (NEG) is known as a branch of spatial economics and the theory of industrial agglomeration. Krugman (1991) demonstrated the basic theory of agglomeration using the model of two regions, two production sectors and two types of labor. Krugman's theory showed that agglomeration minimizes transport costs to realize scale economies. Krugman (1998) explained centripetal force and centrifugal force of agglomeration. The centripetal forces are market-size effects, thick labor markets and pure external economies, and the centrifugal forces are immobile factors, land rents and pure external diseconomies. We consider that productivity improvement by surrounding firms becomes a centripetal force. Because such areas are attractive for most firms. Krugman and Elizondo (1995) showed that when the economy is open to international trade, the centripetal force becomes weaker. We analyze the relationship between the productivity improvement effect realized by the surrounding firms and the international trade based on their theory. Tomiura (2003) showed that after the Plaza Accord (in 1985), import penetration affected Japanese internal economic geography by weakening input-output linkages among regional industries, and manufacturing industries became more geographically dispersed as a result of import penetration, especially after 1990. He also showed that Japanese manufacturing firms have become more evenly distributed across Japan in the same period. This means that trade (increasing import penetration) weakened the centripetal force of industrial areas in Japan. This paper differs from Tomiura's work in that in his model the explained variable (dependent variable) is labor demand, but in our model the dependent variable is productivity. Based on Tomiura's work, we show the productivity improvement effect of surrounding firms is weakened by the global value chain.

2.2 Literature review of empirical studies on productivity improvement by agglomeration

There have been several empirical studies on industrial agglomeration. Ciccone and Hall (1996) and Ciccone (2002) investigated whether industry agglomeration leads to productivity improvement. They showed that labor accumulation through industrial agglomeration increased labor productivity in the United States (Ciccone and Hall (1996)) and Europe (Ciccone (2002)). Melo, Graham, and Noland (2009) conducted a meta-analysis of 34 previous studies and confirmed the effect of industrial agglomeration on productivity improvement in numerous studies. These studies showed that in general, industrial agglomeration positively affects productivity improvement. Regarding industrial agglomeration in Japan, Yoshida and Ueda (1999) analyzed the advantages of agglomeration and the disadvantages of conglomeration and overcrowding. They divided Japan into three areas, Tokyo, Osaka, and other regions, and showed that the agglomeration effect was decreasing in Tokyo and Osaka, and increasing in other regions, because of the balance between centripetal and centrifugal forces. Hayashi (2012) analyzed the relationship between the distribution of firms and the advantages of agglomeration using a center density and density gradient of firms. He found that the spatial structures in Tokyo and Osaka generated disadvantages of agglomeration as a result of excessive density. In this paper, the different effects in the metropolitan areas, are not analyzed. In our analysis, the element of overcrowding was removed by the independent variable, which is 'population density', and the pure agglomeration advantage was analyzed. Our aim is not to compare industrial areas but to understand the time trend of productivity.

Brulhart and Mathys (2008) examined the endogeneity of productivity enhancement through industrial agglomeration and firm accumulation. They proved the effect of industrial agglomeration and endogeneity using a dynamic panel analysis of regional data from eastern and western European countries from 1980 to 2003 based on the research of Ciccone (2002). They also examined two types of industrial agglomeration effects. One is 'localization economies' in the same industry, which accompany agglomeration among the same kind of industries, and the other is 'urbanization economies', which occur when different kinds of industries agglomerate. They showed that the effects of localization economies are unclear, but urbanization economies exert clear effects on labor productivity. Regarding the self-selection problem of endogeneity, Graham et al. (2010) showed effects in both directions, i.e. industrial agglomeration improves the productivity of firms and high-productivity areas tend to encourage the aggregation of high-productivity firms, through a dynamic panel analysis using data based on British postcodes (ZIP codes). In a study based on statistics from the Ministry of Economy, Trade and Industry of Japan, Konishi and Saito (2012) analyzed the effect of industry agglomeration on firms' productivity in the manufacturing industry using total factor productivity (TFP) as the dependent variable. As for the results, urbanization-type agglomeration produced productivity improvement, but industrial specialization-type agglomeration had no effect in most industries, and the endogeneity of productivity was proved. Therefore, in this paper, we consider urbanization-type agglomeration.[3]

2.3 Current state of industrial agglomeration in Japan and theoretical background of this study

The number of manufacturing firms in Japan has been decreasing every year since the collapse of the bubble economy in 1990 according to data from the Ministry of Economy, Trade and Industry. Figure 1 shows the mean number of firms per unit area (1 km^2) counted on the basis of firms employing more than 3 people for each manufacturing industry.[4] These data are used for the analyses in this study. The industry classifications are the same as those used in the industrial statistical data of the Ministry of Economy, Trade and Industry, namely, the life-related industry (e.g., food manufacturing, textiles, and printing), the basic materials industry (e.g., wood and wood products, chemicals, iron, steel, and nonferrous products), and the processing and assembly industry (e.g., general machinery, electrical machinery, and precision machinery).[5] The numbers of manufacturing firms per unit of area are decreasing in all these industry groups, as are the numbers of workers, both of which trends are inconsistent with agglomeration.

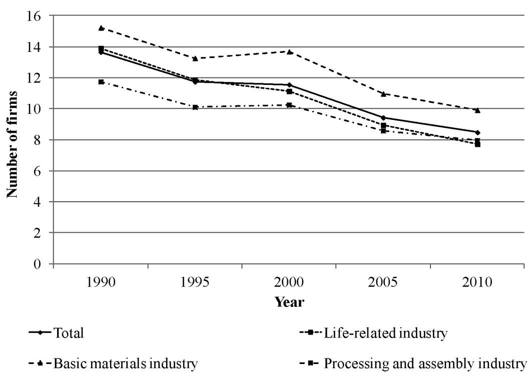

Fig. 1 Change in the number of firms per unit area (mean value per 1 km^2)

In Japan, some manufacturing firms have relocated to China and Southeast Asia, and the global value chain is strengthening. This means Japanese companies can get cheaper parts (intermediate materials) from China and Southeast Asia than from Japan. Decreasing transportation costs exert a similar effect in terms of decreasing agglomeration. This is consistent with our theoretical models, which we introduced in '2.1 Review of the literature on agglomeration theory' and '2.2 Literature review of empirical studies on productivity improvement by agglomeration'. So, this type of international trade (global value chain) produces centrifugal force on theoretical models.

Based on previous studies, it is clear that industrial agglomeration has a positive relationship with productivity improvement in urbanization-type agglomeration, even if we consider endogeneity. So, we propose hypothesis 1. However, if the effect is decreasing in this study period, the result may become negative.

Hypothesis 1: Industrial agglomeration has a positive relationship with productivity improvement in manufacturing firms.

First, we would like to clarify the effect of agglomeration in Japan.

Next, hypothesis 2 is proposed based on the theoretical model and taking into account the development of industrial infrastructure and the influence of global value chains. We were unable to find any empirical studies showing a decrease in the industrial agglomeration effect.

Hypothesis 2: The effect of industrial agglomeration on productivity improvement in manufacturing firms is decreasing year by year.

This is based on Krugman (2011). Industrial infrastructure and international trade in these years may weaken the agglomeration economy.

Because we think that the effect of industrial infrastructure development is stronger across a larger area than a smaller area, hypothesis 3 is also proposed.

Hypothesis 3: The effect of industrial agglomeration on productivity improvement in manufacturing firms is decreasing less across larger areas than smaller areas.

Improvements in industrial infrastructure and communication technology are causing transportation and communication costs to decrease more across larger areas than smaller areas. The result of this has been to improve productivity in larger areas relative to smaller areas, and recently the productivity decreasing effect has been less in larger areas.

The last hypothesis relates to the global value chain and international trade.

Hypothesis 4: International trade decreases the effect of industrial agglomeration on productivity improvement in manufacturing firms.

This hypothesis is based on the models of Krugman and Elizondo (1995) and Tomita (2003).

We show the empirical evidence of these hypotheses on the basis of these models and theories, considering the effects on the productivities of core firms (firms in core area). The differences were analyzed based on the surrounding distance and industries to verify the hypotheses and increase the reliability of the results. Hypothesis 1 and hypothesis 2 relate to the productivity of the core firm, and hypothesis 3 and hypothesis 4 relate to the reasons for productivity decreasing. To the best of our knowledge, no previous studies have attempted to prove hypotheses 2, 3 and 4.

3. Data

Industrial longitudinal data is now available. We used industrial statistical mesh data from the Statistics and Information Department of the Research Institute of the Ministry of Economy, Trade and Industry of Japan to analyze manufacturing industry productivity. These data are based on a grid divided into 1 km^2 units according to latitude and longitude coordinates. Since 1990, there has been ongoing amalgamation of municipalities in Japan, creating problems in terms of the comparison of data for municipal towns and villages. The use of mesh data avoids these problems and enables analysis of the effects of surrounding firms. Mesh data for 1990, 1995, 2000, 2005, and 2010 are used.[6] There are three types of tables in the industrial statistical mesh data. These are 'table by scale,' 'table by industry,' and the 'Kou table.'[7] 'Table by scale' and 'table by industry' contain data for firms employing more than 3 people. The 'Kou table' contains data for firms employing more than 29 people. These tables are connected by mesh ID. When labor productivity is a dependent variable, the 'table by scale' data are used. When TFP is a dependent variable, the data from the 'Kou table' are used.[8] Data for periods prior to 1982 were not used, because the methods used to summarize the data prior to 1982 differed from those used after 1990.[9] In the 'Kou table,' the manufacturing industry is divided into three categories: the life-related industry, the basic materials industry, and the processing and assembly industry. We use these categories in this paper for comparison. The 'table by scale' does not include industry-related data, but the 'table by industry' does. Therefore, the categories in the 'table by industry' were used as the industry categories in the 'table by scale.' These industry categories were used to analyze labor productivity and TFP by industry in each mesh.

Financial data are unavailable when there are only one or two firms in a mesh. These data are concealed. These firms represent about 12% of firms employing more than 3 people (in the 'table by scale') and about 43% of firms employing more than 29 people (in the 'Kou table'). Although the number of firms we analyzed only represent a portion of the entire number of manufacturing firms, the effect of the unavailable data was reduced by comparing the results from 'table by scale,' which includes firms of more than 3 people, and the results from the 'Kou table,' which includes firms of more than 29 people, in addition to the comparison between industries.

The number of firms in the surrounding area was used as the measure of agglomeration. This is the total number of firms within a given distance and is the same as the density of firms. The number of firms within 1 km of a mesh is called the number of firms in 1 km surrounding; that is, it is the number of firms in a 9 km^2 area, with four borders comprising straight lines of 3 km in length, surrounding the core mesh. Similarly, the number of firms in 5 km surrounding is the number of firms in a 121 km^2 area, with four borders of 11km each, surrounding the core mesh. The firms included in 1 km surrounding are also included in 5 km surrounding. When labor productivity is used as a dependent variable, the firms listed in the 'table by scale' are used as the firms in surrounding, and when TFP is used as a dependent variable, the firms listed in the 'Kou table' are used as the firms in surrounding.[10]

The international trade effect was analyzed using import and export data from the Japanese inter-industry relations table contained in the annual national economic accounting by the Cabinet Office of Japan. The import and export data for manufacturing industry were obtained from this table.

Besides fluctuations in the productivity of firms, the entry and exit of firms is also thought to increase and decrease overall productivity. The number of firms in a mesh is clear, but it is difficult to specify the entry and exit of individual firms in the industrial mesh data used in this study. Therefore, it is difficult to distinguish between the effects of changes in the productivity of individual firms and those of entry and exit. Kim, Kwon, and Fukao (2007) note that "The sluggish productivity increases after the 1990s originated chiefly in a decrease in the internal effect (the productivity change in each firm), although there was also an effect through the entry and exit of firms."

4. Methods and models

4.1 Relative labor productivity and relative TFP

Relative labor productivity and relative TFP are used as the dependent variables. The relationship between the dependent variable of the targeted mesh and the number of firms in the surrounding area was analyzed for each year using regression analysis and panel analysis. Relative labor productivity and relative TFP are calculated using the financial data for each mesh. Equations (1), (2), (3), and (4), which were developed by Good, Nadiri, and Sickles (1996) and used by Kim, Kwon, and Fukao (2008), were used for our calculations. Relative value provides a more accurate basis for comparisons than does absolute value. First, relative labor productivity is calculated using equations (1) and (2).

If t = SY

$$\ln RLP_f(t) = (\ln V_f(t) - \overline{\ln V(t)}) - (\ln L_f(t) - \overline{\ln L(t)}) \quad (1)$$

If t > SY

$$\ln RLP_f(t) = (\ln V_f(t) - \overline{\ln V(t)}) + \sum_{s=SY+1}^{t} (\overline{\ln V(s)} - \overline{\ln V(s-1)})$$
$$- \left[(\ln L_f(t) - \overline{\ln L(t)}) + \sum_{s=SY+1}^{t} (\overline{\ln L(s)} - \overline{\ln L(s-1)})\right] \quad (2)$$

Here, $\ln RLP_f(t)$ is relative labor productivity, meaning the labor productivity of the firms in year t in mesh f compared with the labor productivity of a standard mesh (a virtual mesh for which each variable takes the mean value of the meshes analyzed in the first year (SY)). In the above equation, $V_f(t)$ is the "value added"[11] of the firms in mesh f in year t. The domestic corporate goods price index of the Bank of Japan was used as a deflator. $L_f(t)$ is a labor input, which was calculated by multiplying "number of workers" by the number of working hours in each year from the Annual Report on National Accounts (Cabinet Office of Japan). The upper bar shows the average of each variable. The monetary unit is 10,000 Yen. The labor productivity transitions, which were calculated using mesh data for firms employing more than 3 people, are shown in Figure 2.[12] Relative labor productivity is lowest in all years in the life-related industry, and is lower in 2010 than in 2005 in all categories as a result of the Lehman shock.

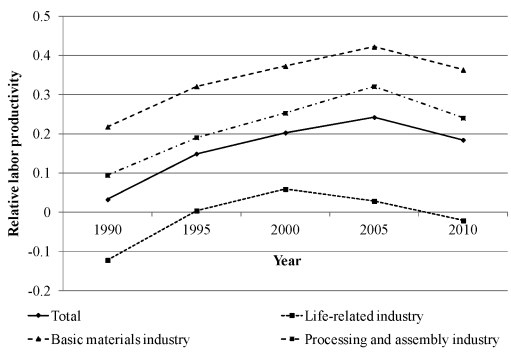

Fig. 2 Change in relative labor productivity (mean value per unit area)

Next, relative TFP is calculated using equations (3) and (4).

If t = SY

$$\ln RTFP_f(t) = (\ln Y_f(t) - \overline{\ln Y(t)}) - \sum_{i=1}^{n} \frac{1}{2} (S_{if}(t) + \overline{S_i(t)})(\ln X_{if}(t) - \overline{\ln X_i(t)}) \quad (3)$$

If t > SY

$$\ln RTFP_f(t) = (\ln Y_f(t) - \overline{\ln Y(t)}) + \sum_{s=SY+1}^{t} (\overline{\ln Y(s)} - \overline{\ln Y(s-1)}) - [\sum_{i=1}^{n} \frac{1}{2} (S_{if}(t) + \overline{S_i(t)})(\ln X_{if}(t) - \overline{\ln X_i(t)}) + \sum_{s=SY+1}^{t} \sum_{i=1}^{n} \frac{1}{2} (\overline{S_i(s)} + \overline{S_i(s-1)})(\overline{\ln X_i(s)} - \overline{\ln X_i(s-1)})] \quad (4)$$

Here, $\ln RTFP_f(t)$ is relative TFP, which represents the TFP value of mesh f in year t compared with the standard mesh (a virtual mesh for which each variable has the mean value of the meshes analyzed in the first year (SY)). $Y_f(t)$ is the output (sales) of mesh f in year t, $X_{if}(t)$ is production factor i (input), and $S_{if}(t)$ is the cost share of production factor i. The upper bar represents the average of each variable. The arithmetic mean is used for the cost share. The geometric mean is calculated for the production factors and the outputs, because of the logarithmic form. Intermediate input, labor input, and capital stock are used as production factors. "Amount of raw materials used," "amount of fuel used," and "amount of electricity used" are totaled to provide intermediate input. The domestic corporate goods price index of the Bank of Japan was used as a deflator in the production factors and output. The labor input was calculated by multiplying "number of workers" by the number of working hours per year. Capital stock was calculated by multiplying "amount of tangible fixed assets at the end of the year" by the actual book value ratio and the operation rate. The ratio between the private company capital stocks of the Economic and Social Research Institute and the tangible fixed assets shown in the Business Corporation Statistics was used for the actual book value ratio. The operation rate was obtained from the mining and manufacturing industry index of the Ministry of Economy, Trade and Industry. The cost share was calculated using the intermediate input cost, the labor input cost, and the capital input cost. "Annual salary" was used as the labor input cost. The capital input cost was calculated by multiplying "amount of tangible fixed assets at the end of the year" by the depreciation rate plus the interest rate. The depreciation rate was obtained from the Statistics of Business Corporations time series data, and the interest rate was obtained from the Bank of Japan time series data. The change in relative TFP, which was calculated using the 'Kou table' that included data for firms employing more than 29 people, is shown in Figure 3. Relative TFP is low in 2005 and 2010 because of the Japanese recession and the Lehman shock.

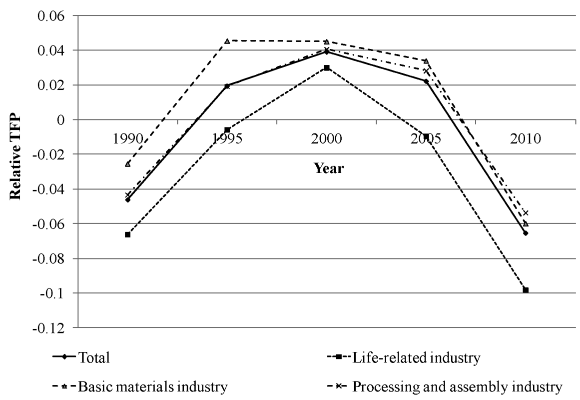

Fig. 3 Change in relative TFP (mean value per unit area)

4.2 Regression analysis by year

Multiple regression analysis was performed using equation (5) to analyze the effect of agglomeration on productivity in each year. The relative labor productivity (lnRLP) of each mesh is the dependent variable (explained variable), and the number of firms in the surrounding area (lnNJN) is the main explanatory variable. The effect of agglomeration is an improvement in labor productivity.

$$\ln RLP_f = a \ln HCPF_f + b \ln SALPHC_f + c \ln FASPHC_f + d \ln POP_f + e \ln NJN_f + g\ PRED_f + C + \varepsilon_f \quad (5)$$

where f represents the mesh. $HCPF_f$ is the number of workers in a firm. $SALPHC_f$ is the salary per year per person. $FASPHC_f$ is the tangible fixed assets per person. POP_f is the population density of the city to which the mesh belongs (people/km^2). NJN is the number of firms within N km, which is the main explanatory variable.[13] PRED is the prefecture dummy, and a, b, c, d, e, and g are coefficients. C is the constant term and ε is the error term. Though international trade improves the productivity of firms, we cannot get the trade data for each mesh. However, we think that the effect of surrounding firms (coefficient e) is not influenced much directly by the international trade in this case. Regarding independent variables, we use the number of people per firm to control the firm scale of each mesh.[14] The salary per person controls the quality of workers. Tangible fixed assets per person[15] controls the feature of the industry in each mesh. Population density is used to control the negative effect of overcrowding of each industrial area.[16]

There is a possibility not only that the effect of agglomeration on the productivity of a firm rises in an agglomerated area, but also that there is a 'self-selection' endogeneity problem, whereby originally high-productivity firms gather in an area that is appropriate for production. To overcome this self-selection endogeneity problem, we used the instrumental variable method, in which the number of firms in the surrounding area was assumed to be an endogenous variable, and the number of firms in the same surrounding area and the number of workers in the mesh in the previous period were used as instrumental variables.

4.3 Panel analysis

Panel analysis was conducted using equation (6), in which the relative labor productivity (lnRLP) or relative TFP (lnRTFP) of each mesh is the dependent variable and the number of firms in the surrounding area (lnNJN) is the main explanatory variable.

$$lnRLP_f(t) \text{ or } lnRTFP_f(t) = a\ lnHCPF_f(t) + b\ lnSALPHC_f(t) + c\ lnFASPHC_f(t) + d\ lnPOP_f(t) + e\ lnNJN_f(t) + g\ YTD(t) + h\ JNT_f(t) + i\ YD(t) + j\ PRED_f(t) + C + \varepsilon_f(t) \quad (6)$$

where t represents the year (1990, 1995, 2000, 2005, or 2010). YTD(t) is the year trend, and YD(t) is the year dummy. YTD(t) is 1 for the first year (1990), 2 for the second year (1995), and so on. $JNT_f(t)$ is the cross-term of $lnNJN_f(t)$ and YTD(t). Other variables

Table 1 Summary statistics for the mesh data (firms of more than 3 people)[19]

	Mean value	Standard deviation	Minimum value	Maximum value	Mean value of Life-related industry	Mean value of Basic materials industry	Mean value of Processing and assembly industry
Relative labor productivity (logarithm)	0.1562	0.6215	-8.1064	4.2947	-0.0156	0.3352	0.2173
Number of person per firm (logarithm)	2.9566	0.8299	1.3863	8.9041	2.7603	3.0437	3.1355
Salary of year per person (10k Yen)(logarithm)	5.6903	0.3810	1.3606	8.2223	5.5519	5.7990	5.7725
Tangible fixed assets per person (10k Yen)(logarithm)	3.3364	3.0385	-5.3823	10.6400	2.9499	3.7685	3.4463
Population density (Head count/km^2)(logarithm)	6.6024	1.4476	0.9163	9.9934	6.5402	6.5803	6.7055
Number of firms in target mesh (logarithm)	1.9986	0.7807	1.0986	6.3953	2.0241	2.0424	1.9240
Number of firms in 1km (3km square) (logarithm)	3.7168	1.0431	1.0986	8.0408	-	-	-
Number of firms in 5km (11km square) (logarithm)	5.8283	1.2499	1.0986	9.7495	-	-	-
Number of firms in 10km (21km square) (logarithm)	6.8674	1.3152	1.0986	10.4468	-	-	-
Number of firms in 20km (41km square) (logarithm)	7.9466	1.3502	1.3863	10.9547	-	-	-
Number of firms in 40km (81km square) (logarithm)	8.7943	1.3376	2.1972	11.3378	-	-	-
Number of samples (number of total meshes for five years)		124,417			50,632	35,571	38,214
Number of meshes		37,421			18,838	16,072	18,177

Table 2 Correlation matrix for the mesh data (firms of more than 3 people)

N=124,417	[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]	[9]	[10]
[1] Relative labor productivity (logarithm)	1.0000									
[2] Number of person per firm (logarithm)	0.4185	1.0000								
[3] Salary of year per person (10k Yen)(logarithm)	0.7016	0.4821	1.0000							
[4] Tangible fixed assets per person (10k Yen)(logarithm)	0.3743	0.5024	0.4113	1.0000						
[5] Population density (Head count/km^2)(logarithm)	0.2134	0.0053	0.3209	0.2047	1.0000					
[6] Number of firms in target mesh (logarithm)	0.2186	0.0547	0.2555	0.5540	0.4283	1.0000				
[7] Number of firms in 1km (3km square) (logarithm)	0.2188	0.0038	0.3025	0.3633	0.6726	0.7212	1.0000			
[8] Number of firms in 5km (11km square) (logarithm)	0.2356	-0.0184	0.3359	0.2584	0.8286	0.5495	0.8293	1.0000		
[9] Number of firms in 10km (21km square) (logarithm)	0.2365	-0.0197	0.3364	0.2231	0.8335	0.4826	0.7303	0.9440	1.0000	
[10] Number of firms in 20km (41km square) (logarithm)	0.2301	-0.0212	0.3215	0.1854	0.7759	0.4088	0.6246	0.8357	0.9354	1.0000
[11] Number of firms in 40km (81km square) (logarithm)	0.2140	-0.0255	0.2933	0.1509	0.6897	0.3520	0.5405	0.7369	0.8383	0.9344

Table 3 Summary statistics for the mesh data (firms of more than 29 people)[20]

	Mean value	Standard deviation	Minimum value	Maximum value	Mean value of Life-related industry	Mean value of Basic materials industry	Mean value of Processing and assembly industry
Relative TFP (logarithm)	-0.0071	0.2363	-2.1011	2.2479	-0.0293	0.0078	-0.0035
Relative labor productivity (logarithm)	0.1724	0.7771	-14.5447	3.4890	-0.0091	0.3114	0.1837
Number of person per firm (logarithm)	4.6043	0.6403	3.4232	8.2646	4.4700	4.5854	4.7404
Salary of year per person (10k Yen)(logarithm)	5.9622	0.3242	3.6545	7.3651	5.8365	6.0265	6.0036
Tangible fixed assets per person (10k Yen)(logarithm)	6.4708	0.8132	0.7285	9.9960	6.1978	6.7257	6.4396
Population density (Head count/km^2)(logarithm)	7.1326	1.3951	1.5261	9.9934	7.1348	7.2036	7.0563
Number of firms in target mesh (logarithm)	1.5294	0.4697	1.0986	4.0604	1.4510	1.5974	1.5259
Number of firms in 1km (3km square) (logarithm)	2.7717	0.7634	1.0986	5.3230	-	-	-
Number of firms in 5km (11km square) (logarithm)	4.5983	1.0027	1.0986	7.0630	-	-	-
Number of firms in 10km (21km square) (logarithm)	5.5560	1.0838	1.0986	7.9828	-	-	-
Number of firms in 20km (41km square) (logarithm)	6.5327	1.1266	1.3863	8.5329	-	-	-
Number of firms in 40km (81km square) (logarithm)	7.2973	1.1143	1.9459	9.1580	-	-	-
Number of samples (number of total meshes for five years)		26,423			7,842	9,508	9,073
Number of meshes		10,147			3,816	4,221	4,600

Table 4 Correlation matrix for the mesh data (firms of more than 29 people)

N=26,423	[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]	[9]	[10]	[11]
[1] Relative TFP (logarithm)	1.0000										
[2] Relative labor productivity (logarithm)	0.7304	1.0000									
[3] Number of person per firm (logarithm)	0.2159	0.2303	1.0000								
[4] Salary of year per person (10k Yen)(logarithm)	0.5078	0.5487	0.3420	1.0000							
[5] Tangible fixed assets per person (10k Yen)(logarithm)	0.2850	0.4446	0.2371	0.5556	1.0000						
[6] Population density (Head count/km^2)(logarithm)	0.2663	0.2739	0.0620	0.4692	0.2199	1.0000					
[7] Number of firms in target mesh (logarithm)	0.1257	0.1570	0.0953	0.1940	0.1573	0.2782	1.0000				
[8] Number of firms in 1km (3km square) (logarithm)	0.2531	0.2561	0.1055	0.4112	0.1699	0.6548	0.5163	1.0000			
[9] Number of firms in 5km (11km square) (logarithm)	0.2911	0.2893	0.0744	0.5051	0.1955	0.8449	0.3281	0.7861	1.0000		
[10] Number of firms in 10km (21km square) (logarithm)	0.2823	0.2889	0.0684	0.5016	0.1981	0.8547	0.2832	0.7019	0.9504	1.0000	
[11] Number of firms in 20km (41km square) (logarithm)	0.2743	0.2903	0.0704	0.4942	0.2030	0.8123	0.2507	0.6257	0.8608	0.9451	1.0000
[12] Number of firms in 40km (81km square) (logarithm)	0.2614	0.2918	0.0712	0.4816	0.2123	0.7521	0.2343	0.5741	0.7840	0.8581	0.9443

are the same as in equation (5).[17] The next equation is the same as equation (6) whereby the part of equation (6) is represented by the number of firms in the surrounding area.

$$\ln RLP_f(t) = a \ln HCPF_f(t) + b \ln SALPHC_f(t) + c \ln FASPHC_f(t) + d \ln POP_f(t) + (e + h\ YTD(t)) \ln NJN_f(t) + g\ YTD(t) + i\ YD(t) + j\ PRED_f(t) + C + \varepsilon_f(t)$$

Therefore, coefficient h can be considered the trend coefficient of industrial agglomeration. If coefficient h is significantly negative, it means that the effect on the explained variable decreases every year. Because labor productivity and TFP appear to be endogenous variables, the instrumental variable method was used. The number of firms in the surrounding area ($\ln NJN_f(t)$) was assumed to be an endogenous variable,[18] and the number of firms in the same surrounding area and the number of workers in the mesh in the previous period were used as instrumental variables.

The basic statistics calculated from the data used for the abovementioned analyses are shown in Table 1 and Table 3, and the correlation coefficients are shown in Table 2 and Table 4.

The productivity of the basic materials industry is highest in terms of labor productivity and TFP. The correlation coefficients between population density ([5] in Table 2 and [6] in Table 4) and the other variables are a little high. However, multicollinearity with other variables was not recognized in our analysis.

5. Results

5.1 Regression analysis results by year

The influence of surrounding firms on labor productivity was analyzed using equation (5) for each year and each surrounding distance. Here, the results of the analysis of data relating to firms employing more than 3 people are shown. Not all results are shown because of the complexity. The coefficient e used in equation (5) is shown in Figure 4,[21] which summarizes the results of our analysis of five surrounding distances in each of the five years. It means that Figure 4 is the result of 25 times calculating equation (5). It can be seen that most of the coefficients are greater than 0, although in 2010 most of them are negative. Although the effect of agglomeration can be seen, it is decreasing.

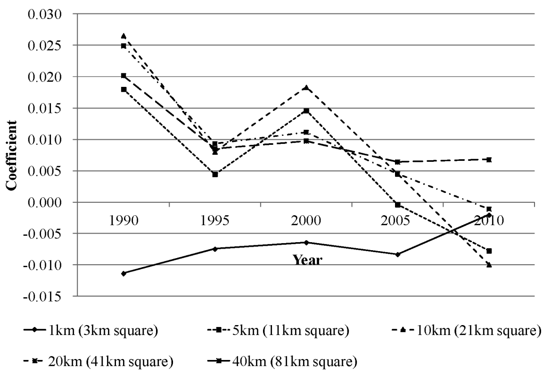

Fig. 4 Changes in the effect of surrounding firms according to distance (labor productivity)

The effect of agglomeration can be seen to be decreasing everywhere other than within a 1 km radius. As for the effect of agglomeration within a 1 km radius, the significance of the result in each year is low, and the coefficient is often near 0. Although this phenomenon is particularly evident in firms employing more than 3 people, this requires further study, because it is beyond the scope of this study and seems to be related to the agglomeration of low-productivity small firms. For example, Drucker and Feser (2012) showed that the productivities of small firms are low because big firms reduce their costs by using surrounding small firms as affiliate companies.

Based on analysis on an annual basis, though we can see the time trend the low significance of the results means it is difficult to confirm support for the hypotheses. Next, the results of the panel analysis are presented.

5.2 Panel analysis results

The results of the analysis of the effect of agglomeration based on the surrounding distance in accordance with equation (6) are shown in Table 5 and Table 6. Table 5 shows the results for firms employing more than 3 people. Relative labor productivity was analyzed as a dependent variable. Table 6 shows the results for firms employing more than 29 people. Relative TFP was analyzed as a dependent variable.[22]

It can be seen from the figures in the 'All data' column in Table 5 (first 5 columns) that the signs of the coefficients of the number of surrounding firms (top 5 rows) vary and their significance is low. In Table 6, where relative TFP is the dependent variable, the signs of the coefficients of the number of surrounding firms are positive. Thus, it seems that the number of surrounding firms has a positive effect. When we compare Table 5 and Table 6, the effect of agglomeration is small for the small firms. Drucker and Feser (2012) explained this phenomenon in terms of larger firms having a broader supply chain and hence being affected by broader trade. Small firms also get only small effects from knowledge spillover, because they are developing different and old field technology. Moreover, as large firms reduce the cost from surrounding small firms as subcontract firms, the productivities of small firms are low.

When coefficients e and h are incorporated, e.g., (e + h× year trend), the results become negative when the year trend is 5 (year 2010) or more, i.e., the effect seems to diminish after several years. Therefore, Hypothesis 1, industrial agglomeration has a positive relationship with productivity improvement in manufacturing firms, is not supported in every case, though there are positive effects in most cases.

The sign of the coefficient of the cross-term of the year trend and the number of firms in the surrounding area is negative in all cases (rows 7 to 11) in Table 5 and Table 6, and significance levels are high in almost all cases. Thus, Hypothesis 2, the effect of industrial agglomeration on productivity improvement in manufacturing firms is decreasing year by year, is supported. As this phenomenon can be seen in the data relating to both firms employing more than 3 people and those employing more than 29 people, the results do not seem to be affected by the concealed data.

Regarding the other independent variables, the positive relationship between the number of people

Table 5 Agglomeration effect results (firms of more than 3 people, the dependent variable is relative labor productivity)

	All data					Life-related industry					Basic material industry					Processing and assembly industry				
	1km	5km	10km	20km	40km	1km	5km	10km	20km	40km	1km	5km	10km	20km	40km	1km	5km	10km	20km	40km
Number of firms in 1km (3km square) (logarithm)	-0.0049					0.0261					-0.0239					0.0079				
	(-0.35)					(1.09)					(-0.66)					(0.21)				
Number of firms in 5kn (11km square) (logarithm)		-0.0005					0.0636 **					-0.0499					-0.0502			
		(-0.02)					(2.04)					(-1.02)					(-0.92)			
Number of firms in 10km (21km square) (logarithm)			-0.0039					0.0530					-0.0675					-0.0664		
			(-0.15)					(1.37)					(-1.15)					(-1.00)		
Number of firms in 20km (41km square) (logarithm)				0.0197					0.0715					-0.1551 **					0.0813	
				(0.59)					(1.52)					(-2.01)					(0.90)	
Number of firms in 40km (81km square) (logarithm)					-0.0428					0.0841					-0.1653 *					-0.0975
					(-1.09)					(1.54)					(-1.75)					(-0.90)
Year trend	-0.0191 ***	-0.0039	-0.0007	0.0043	-0.0017	-0.0138 *	-0.0005	-0.0005	0.0035	0.0017	-0.0265 ***	-0.0189 *	-0.0114	-0.0057	0.0011	-0.0070	0.0050	0.0058	0.0157	-0.0052
	(-4.28)	(-0.80)	(-0.12)	(0.74)	(-0.27)	(-1.92)	(-0.08)	(-0.07)	(0.41)	(0.19)	(-2.85)	(-1.82)	(-1.01)	(-0.45)	(0.08)	(-0.62)	(0.39)	(0.42)	(1.05)	(-0.33)
Cross term	-0.0014					-0.0006					-0.0004					-0.0047 **				
Number of firms in 1km surrounding and year trend	(-1.51)					(-0.41)					(-0.21)					(-2.05)				
Cross term		-0.0035 ***					-0.0017					-0.0023					-0.0065 ***			
Number of firms in 5km surrounding and year trend		(-4.64)					(-1.49)					(-1.48)					(-3.34)			
Cross term			-0.0035 ***					-0.0018 *					-0.0035 **					-0.0060 ***		
Number of firms in 10km surrounding and year trend			(-4.81)					(-1.68)					(-2.14)					(-3.12)		
Cross term				-0.0032 ***					-0.0018					-0.0056 ***					-0.0035	
Number of firms in 20km surrounding and year trend				(-4.17)					(-1.63)					(-3.01)					(-1.64)	
Cross term					-0.0033 ***					-0.0011					-0.0061 ***					-0.0041 *
Number of firms in 40km surrounding and year trend					(-4.03)					(-0.99)					(-2.84)					(-1.73)
Number of persons par firm (logarithm)	0.0498 ***	0.0505 ***	0.0506 ***	0.0506 ***	0.0504 ***	0.0546 ***	0.0553 ***	0.0550 ***	0.0549 ***	0.0546 ***	0.0384 ***	0.0390 ***	0.0394 ***	0.0399 ***	0.0401 ***	0.0420 ***	0.0421 ***	0.0422 ***	0.0419 ***	0.0420 ***
	(15.542)	(15.70)	(15.73)	(15.74)	(15.68)	(9.56)	(9.73)	(9.68)	(9.67)	(9.63)	(5.08)	(5.20)	(5.25)	(5.32)	(5.34)	(6.38)	(6.42)	(6.43)	(6.39)	(6.40)
Salary of year per person (logarithm)	0.9189 ***	0.9168 ***	0.9168 ***	0.9169 ***	0.9177 ***	0.8879 ***	0.8860 ***	0.8863 ***	0.8867 ***	0.8871 ***	0.9203 ***	0.9191 ***	0.9182 ***	0.9174 ***	0.9179 ***	0.8874 ***	0.8861 ***	0.8865 ***	0.8864 ***	0.8882 ***
	(141.59)	(141.30)	(141.36)	(141.53)	(141.75)	(90.56)	(90.38)	(90.43)	(90.57)	(90.65)	(56.95)	(56.81)	(56.74)	(56.70)	(56.80)	(60.32)	(60.21)	(60.28)	(60.31)	(60.47)
Tangible fixed assets per person (logarithm)	0.0082 ***	0.0082 ***	0.0082 ***	0.0081 ***	0.0082 ***	0.0062 ***	0.0063 ***	0.0064 ***	0.0064 ***	0.0064 ***	0.0081 ***	0.0081 ***	0.0082 ***	0.0082 ***	0.0081 ***	0.0097 ***	0.0098 ***	0.0098 ***	0.0095 ***	0.0096 ***
	(12.45)	(12.72)	(12.75)	(12.71)	(12.74)	(5.80)	(6.07)	(6.16)	(6.18)	(6.17)	(5.75)	(5.85)	(5.88)	(5.89)	(5.82)	(6.75)	(6.97)	(6.94)	(6.80)	(6.86)
Population density (person/km2, logarithm)	-0.0057	-0.0037	-0.0022	-0.0012	-0.0019	-0.0200 ***	-0.0178 **	-0.0171 **	-0.0165 **	-0.0172 **	0.0016	0.0025	0.0035	0.0057	0.0062	-0.0037	-0.0023	-0.0011	0.0004	-0.0024
	(-1.23)	(-0.80)	(-0.47)	(-0.25)	(-0.41)	(-2.73)	(-2.41)	(-2.30)	(-2.21)	(-2.30)	(0.16)	(0.26)	(0.36)	(0.58)	(0.62)	(-0.37)	(-0.23)	(-0.11)	(0.04)	(-0.23)
Year dummy			Significant negative in 1995, 2000 and positive in 2005					Significant negative in 1995, 2000					Significant negative in 1995, 2000 and positive in 2005					Significant negative in 1995, 2000 and positive in 2005		
Prefecture dummy			Significant negative in Miyazaki Prefecture					Significant negative in Miyazaki Prefecture					No significant prefecture					No significant prefecture		
Constant term	-5.0958 ***	-5.2747 ***	-5.1001 ***	-5.4827 ***	-4.7420 ***	-5.1569 ***	-5.2763 ***	-5.3847 ***	-5.6280 ***	-5.7978 ***	-4.9483 ***	-4.7326 ***	-4.5134 ***	-3.6809 ***	-3.4935 ***	-4.9127 ***	-4.5797 ***	-4.4191 ***	-5.6116 ***	-3.9919 ***
	(-54.25)	(-35.63)	(-25.26)	(-18.86)	(-12.87)	(-38.51)	(-25.57)	(-18.81)	(-14.46)	(-11.75)	(-26.53)	(-14.59)	(-10.41)	(-5.54)	(-3.94)	(-23.81)	(-12.38)	(-8.57)	(-7.16)	(-3.83)
Sample size			124,417					50,632					35,571					38,214		
Number of firms			37,421					18,838					16,072					18,177		
within	0.2442	0.2444	0.2444	0.2444	0.2443	0.2692	0.2693	0.2692	0.2692	0.2691	0.1842	0.1845	0.1845	0.1845	0.1847	0.2073	0.2074	0.2074	0.2074	0.2071
R square value: between	0.4302	0.3362	0.4316	0.3491	0.4148	0.2429	0.3552	0.2368	0.2421	0.2407	0.3704	0.3560	0.3861	0.2171	0.2122	0.4645	0.4144	0.3937	0.4740	0.3421
overall	0.3778	0.2826	0.3790	0.2965	0.3654	0.2218	0.3377	0.2162	0.2207	0.2201	0.3325	0.3183	0.3577	0.1987	0.1923	0.4022	0.3606	0.3438	0.4129	0.2992
F Test Prob > F	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Housman test Prob > Chi2	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Adopted model	Fixed effect	Fixed effect	Fixed effect	Fixed effect	Fixed effect	Fixed effect	Fixed effect	Fixed effect	Fixed effect	Fixed effect	Fixed effect	Fixed effect	Fixed effect	Fixed effect	Fixed effect	Fixed effect	Fixed effect	Fixed effect	Fixed effect	Fixed effect

Note: It shows statistical significant levels that *** is 1%, ** is 5%, * is 10%.
Parentheses shows z value.

Table 6 Agglomeration effect results (firms of more than 29 people, the dependent valuable is relative TFP)

	All data					Life related industry					Basic material industry					Processing and assembly industry				
	1km	5km	10km	20km	40km	1km	5km	10km	20km	40km	1km	5km	10km	20km	40km	1km	5km	10km	20km	40km
Number of firms in 1km (3km square) (logarithm)	0.0603 ***					0.0739 **					0.0354					0.0704 *				
	(3.36)					(2.27)					(0.99)					(1.81)				
Number of firms in 5kn (11km square) (logarithm)		0.0395 **					0.0123					0.0733 *					0.0501			
		(2.00)					(0.29)					(1.92)					(1.30)			
Number of firms in 10km (21km square) (logarithm)			0.0307					-0.0220					0.0760 *					0.0579		
			(1.29)					(-0.41)					(1.80)					(1.24)		
Number of firms in 20km (41km square) (logarithm)				0.0503 *					0.0135					0.0550					0.1755 ***	
				(1.64)					(0.18)					(1.15)					(2.89)	
Number of firms in 40km (81km square) (logarithm)					0.0169					0.0804					0.0135					0.0267
					(0.47)					(0.72)					(0.23)					(0.42)
Year trend	0.0071	0.0028	0.0052	0.0090	0.0101	0.0073	0.0005	0.0037	0.0096	0.0132	-0.0048	-0.0068	-0.0030	-0.0014	-0.0045	0.0171	0.0162	0.0186	0.0229 *	0.0273 *
	(1.17)	(0.55)	(0.96)	(1.51)	(1.48)	(0.63)	(0.06)	(0.38)	(0.88)	(0.94)	(-0.46)	(-0.78)	(-0.31)	(-0.13)	(-0.35)	(1.28)	(1.45)	(1.53)	(1.70)	(1.93)
Cross term	-0.0075 ***					-0.0069 **					-0.0035					-0.0112 ***				
Number of firms in 1km surrounding and year trend	(-4.31)					(-2.09)					(-1.20)					(-2.88)				
Cross term		-0.0039 ***					-0.0042 **					-0.0010					-0.0068 ***			
Number of firms in 5km surrounding and year trend		(-3.83)					(-2.15)					(-0.55)					(-3.03)			
Cross term			-0.0038 ***					-0.0048 ***					-0.0014					-0.0059 ***		
Number of firms in 10km surrounding and year trend			(-4.01)					(-2.64)					(-0.77)					(-2.87)		
Cross term				-0.0036 ***					-0.0045 ***					-0.0017					-0.0042 **	
Number of firms in 20km surrounding and year trend				(-3.95)					(-2.61)					(-0.99)					(-2.10)	
Cross term					-0.0037 ***					-0.0037 **					-0.0016					-0.0060 ***
Number of firms in 40km surrounding and year trend					(-3.04)					(-2.30)					(-0.91)					(-3.12)
Number of persons par firm (logarithm)	0.0174 ***	0.0167 ***	0.0168 ***	0.0166 ***	0.0170 ***	0.0336 ***	0.0342 ***	0.0344 ***	0.0342 ***	0.0339 ***	0.0046	0.0038	0.0035	0.0036	0.0040	0.0188 **	0.0182 **	0.0179 **	0.0161 **	0.0181 **
	(4.14)	(3.98)	(4.00)	(3.94)	(4.03)	(3.66)	(3.73)	(3.75)	(3.73)	(3.69)	(0.58)	(0.49)	(0.44)	(0.46)	(0.50)	(2.47)	(2.39)	(2.35)	(2.01)	(2.37)
Salary of year per person (logarithm)	0.2237 ***	0.2256 ***	0.2263 ***	0.2267 ***	0.2283 ***	0.2754 ***	0.2781 ***	0.2785 ***	0.2787 ***	0.2795 ***	0.2014 ***	0.2000 ***	0.1989 ***	0.2015 ***	0.2046 ***	0.2035 ***	0.2043 ***	0.2046 ***	0.2050 ***	0.2064 ***
	(24.80)	(25.27)	(25.37)	(25.52)	(25.78)	(16.17)	(16.41)	(16.47)	(16.51)	(16.56)	(11.54)	(11.73)	(11.62)	(11.84)	(12.06)	(11.65)	(11.80)	(11.82)	(11.87)	(11.99)
Tangible fixed assets per person (logarithm)	-0.0111 ***	-0.0115 ***	-0.0117 ***	-0.0117 ***	-0.0121 ***	-0.0211 ***	-0.0217 ***	-0.0220 ***	-0.0218 ***	-0.0215 ***	-0.0245 ***	-0.0241 ***	-0.0241 ***	-0.0247 ***	-0.0253 ***	0.0011	0.0007	0.0007	0.0006	0.0002
	(-3.48)	(-3.62)	(-3.68)	(-3.69)	(-3.82)	(-3.43)	(-3.52)	(-3.58)	(-3.54)	(-3.49)	(-4.09)	(-4.06)	(-4.04)	(-4.16)	(-4.27)	(0.18)	(0.12)	(0.11)	(0.10)	(0.04)
Population density (person/km2, logarithm)	-0.0039	-0.0033	-0.0021	-0.0012	-0.0016	0.0013	-0.0007	-0.0003	0.0025	0.0021	-0.0065	-0.0064	-0.0046	-0.0045	-0.0053	-0.0057	0.0011	0.0023	0.0031	0.0026
	(-0.75)	(-0.63)	(-0.39)	(-0.23)	(-0.31)	(0.11)	(-0.06)	(0.03)	(0.21)	(0.18)	(-0.71)	(-0.69)	(-0.50)	(-0.48)	(-0.57)	(-0.06)	(0.12)	(0.24)	(0.33)	(0.28)
Year dummy			Significant positive in 1995, 2000, 2005					Significant positive in 1995, 2000, 2005					Significant positive in 1995, 2000, 2005					Significant positive in 1995, 2000, 2005		
Prefecture dummy			No significant prefecture					No significant prefecture					Only Osaka Prefecture is significantly positive.					No significant prefecture		
Constant term	-1.4972 ***	-1.5160 ***	-1.5145 ***	-1.6837 ***	-1.4945 ***	-1.8659 ***	-1.7027 ***	-1.5268 ***	-1.7573 ***	-2.2570 ***	-1.1376 ***	-1.3820 ***	-1.4831 ***	-1.4204 ***	-1.1507 ***	-1.4777 ***	-1.5200 ***	-1.6847 ***	-2.4752 ***	-1.4989 ***
	(-18.01)	(-13.48)	(-10.13)	(-7.94)	(-5.35)	(-11.01)	(-6.77)	(-4.47)	(-3.38)	(-2.71)	(-7.29)	(-6.42)	(-5.56)	(-4.14)	(-2.57)	(-9.02)	(-7.06)	(-5.82)	(-5.81)	(-2.98)
Sample size			26,423					7,842					9,508					9,073		
Number of firms			10,147					3,816					4,221					4,600		
within	0.1236	0.1245	0.1139	0.1237	0.1235	0.1517	0.1505	0.1496	0.1508	0.1494	0.1209	0.1224	0.1212	0.1212	0.1210	0.1124	0.1134	0.1125	0.1102	0.1126
R square value: between	0.1521	0.1533	0.1624	0.1466	0.1655	0.2755	0.2853	0.2214	0.2862	0.2352	0.0512	0.0448	0.0440	0.0462	0.0535	0.0883	0.0872	0.0818	0.0641	0.0813
overall	0.1206	0.1213	0.1343	0.1158	0.1344	0.2498	0.2570	0.2007	0.2581	0.2153	0.0467	0.0394	0.0379	0.0410	0.0490	0.0650	0.0636	0.0676	0.0484	0.0579
F Test Prob > F	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Housman test Prob > Chi2	0.0000	0.0000	0.0000	0.0000	0.0000	-	0.0000	0.0000	0.0000	0.0000	0.0000	0.0009	0.0001	0.0016	0.0015	-	-	0.0360	-	-
Adopted model	Fixed effect	Fixed effect	Fixed effect	Fixed effect	Fixed effect	Fixed effect	Fixed effect	Fixed effect	Fixed effect	Fixed effect	Fixed effect	Fixed effect	Fixed effect	Fixed effect	Fixed effect	Fixed effect	Fixed effect	Fixed effect	Fixed effect	Fixed effect

Note: It shows statistical significant levels that *** is 1%, ** is 5%, * is 10%.

Parentheses shows z value.

When Housman test fails, fixed effect model has been used to compare the value with others.

per firm and productivity is clear because the coefficients (12th row from the top) are all positive and the significance level is high in Table 5. In Table 6, although there is a low level of significance in the basic material industry category, the sign of the coefficients is positive. Thus, the firm scale has a positive relationship with productivity enhancement. All coefficients of yearly salaries per person are significantly positive in Table 5 and Table 6. Thus, it seems that good workers deliver high productivity. In Table 6, the coefficients of tangible fixed assets per person are significantly negative in some cases. This phenomenon relates to industry characteristics, which are beyond the scope of this study. The signs of the coefficients of population density are generally negative and the significance is generally low, however the disadvantages caused by overcrowding are recognized in many industries. These results, except for the cross-term of the year trend and the number of firms in the surrounding area, are the same as those of previous studies.

5.3 Reasons for the decreasing effect of agglomeration

It is clear from Figure 4, Table 5, and Table 6 that the effect on productivity of surrounding firms is decreasing year by year. Hypothesis 1 and hypothesis 2 relate to the productivity of the core firm, and so allow direct analysis. But hypothesis 3 and hypothesis 4 relate to the reasons for the productivity decreasing, and so we should consider indirect analysis. The reasons for this decrease in the agglomeration effect are considered in relation to the advantages of industrial agglomeration listed in the introduction. Therefore, the next two key reasons are considered based on the model of the previous works, and in terms of the data used for the analyses undertaken in this study.

(1) The effect of agglomeration has decreased because the economic distance has shortened and the influence of firms has expanded as a result of improvements in communications and transport infrastructure within Japan.

(2) The intermediate goods market has expanded globally, and thus the effect of agglomeration on domestic firms has decreased as a result of international trade and the global value chain, aided by developments in transportation, the Internet, and telecommunications technology.

If the economic distance is shortened and the range of the agglomeration effect is extended, either the effect of agglomeration may increase more over a larger range in an increasing case or may decrease less over a larger range in a decreasing case. This tendency is thought to be strong in relation to TFP when the technology spillover effect is considered. Considering the coefficients of the cross-term with the year trend and the number of surrounding firms shown in Table 5 and Table 6 (rows 7 to 11), similar values are shown for all distances in the 'All data' column. Moreover, the decrease in the agglomeration effect is no less in the larger surrounding areas. Thus, the development of industrial infrastructure cannot be seen as the reason for the decrease in the effect of agglomeration from 1990 to 2010. So, the differences associated with distance are not clear. Therefore, Hypothesis 3, the effect of industrial agglomeration on productivity improvement in manufacturing firms is decreasing less across larger areas than smaller areas, is not supported during the period studied here. It seems that Japanese industrial infrastructure changed little during this period.

Next, the influence of global supply chains, such as the overseas expansion of related firms, was analyzed using inter-industry relationship data from the Ministry of Internal Affairs and Communications.[23] We analyze the relation between the year trend of the effect of the surrounding firms and that of export and import by industries. Figure 5 shows the export production rate, represented by the volume of exports divided by regional output. Figure 6 shows the import production rate, represented by the volume of imports divided by regional output. The industry classification is the same as that used for the mesh data. Table 7 shows the inclinations of the data presented in Figure 5 and Figure 6 calculated using the least squares method.

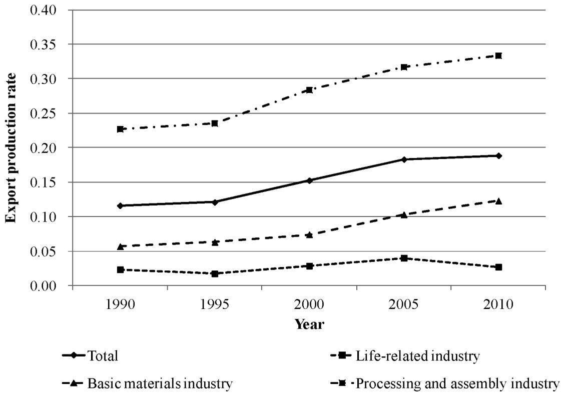

Fig. 5　Change in export production rate

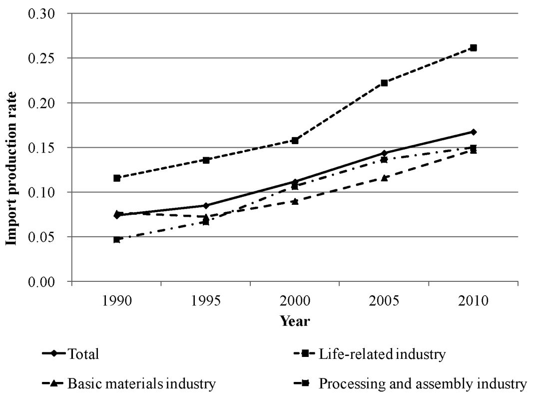

Fig. 6　Change in import production rate

Table 7　Changes in import production rate and export production rate (inclination)

	Export production rate	Import production rate
Total	0.004138 *** (6.95)	0.004922 *** (12.08)
Life-related industry	0.000606 (1.22)	0.007560 *** (7.77)
Basic materials industry	0.003443 *** (6.84)	0.003698 ** (4.65)
Processing and assembly industry	0.005892 *** (8.44)	0.005503 *** (11.37)

Note: It shows statistical significant levels that *** is 1%, ** is 5%, * is 10%. Parentheses shows t value.

Comparison of the relationships among industries shown in Table 5 and Table 6 with those shown in Table 7 reveals a similarity between the export production rate and the results shown in Table 5 (coefficient of the cross-term in rows 7 to 11). That is, in the relationship between the number of surrounding firms and labor productivity in Table 5, the inclination (absolute value of the cross-term coefficient) is greater in the basic materials industry and the processing and assembly industry. This is the same as the export production rate in Table 7 and Figure 5, although the change is smaller in the life-related industry. Moreover, there is a similarity between the results shown in Table 6 and the import production rate in Table 7. That is, in the relationship between the number of surrounding firms and TFP in Table 6, the inclination is greater in the life-related industry and the processing and assembly industry. This is the same as the import production rate in Table 7 and Figure 6, although the inclination is smaller in the basic materials industry. These results can be explained by the fact that labor productivity is mainly influenced by added value, while TFP is mainly influenced by the production factors in equations (1), (2), (3), and (4), and the volume of exports is related to added value, while the volume of imports is related to production factors. The results presented in Table 5, Table 6, and Table 7 (relationships among industries) suggest that there is a relationship between the decreasing effect of surrounding firms on productivity in these years and the expansion of importing and exporting. The effect of industry agglomeration on productivity improvement decreases because of international trade, i.e., the expansion of the global value chain. Thus, Hypothesis 4, international trade decreases the effect of industrial agglomeration on productivity improvement in manufacturing firms, is supported. This result supports the results of Krugman's model and of Tomiura (2003).

6. Conclusions and future work

The relationship between productivity and the number of surrounding firms was analyzed using Japanese industrial mesh data to examine the effect of industrial agglomeration on productivity improvement in the manufacturing industry in Japan. The number of surrounding firms was used as the measure of agglomeration. Four hypotheses were proposed and the following results were obtained.

Hypothesis 1: Industrial agglomeration has a positive relationship with productivity improvement in manufacturing firms.

This hypothesis was not supported in every case. A positive relationship between industrial agglomeration and productivity improvement was not seen when endogeneity of self-selection is removed, especially in 2010, though positive relationships exist in many cases.

Hypothesis 2: The effect of industrial agglomeration on productivity improvement in manufacturing firms is decreasing year by year.

This hypothesis was supported for both dependent variables, labor productivity and TFP.

Hypothesis 3: The effect of industrial agglomeration on productivity improvement in manufacturing firms is decreasing less across larger areas than in smaller areas.

This hypothesis was not supported. This means the change in the industrial infrastructure has not affected the productivities of manufacturing firms in Japan during the period of this study.

Hypothesis 4: International trade decreases the effect of industrial agglomeration on productivity improvement in manufacturing firms.

This hypothesis was supported for both dependent variables, labor productivity and TFP. The results indicated that the effect of the number of surrounding firms on productivity improvement generally decreases with the extension of the global value chain.

These results suggest that the increase in international trade associated with the global value chain weakens the effect of industrial agglomeration in Japan and the expanding global value chain is rendering the simple accumulation of manufacturing firms in Japan ineffective. When a new industrial area, an industrial cluster or an R&D park is being planned, the relationship among the firms should be considered on the basis of optimization of the value chain to improve the productivities of the various firms.

This study did not include data relating to firms employing less than 4 people, and such analysis should be undertaken in the future to clarify the productivity of small firms in industrial clusters and understand how small firms affect other firms in the global value chain.

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1 This is a part of the Japanese Census of Manufactures (Kogyo Tokei, in Japanese).

2 Morikawa (2008) observed significant economies from agglomeration in the service industry.

3 Although an industrial specialization-type agglomeration analysis was also performed, no difference among industries was recognized in the data used in this study.

4 The empty meshes (unit area) are not included in this calculation.

5 All manufacturing industries are classified into these three categories.

6 The most recent data we were able to obtain were from 2010.

7 'Kou' means 'A' in Japanese.

8 The data for tangible fixed assets are necessary to calculate TFP, and the data for firms employing more than 29 people provide this information.

9 No industrial statistical mesh data are provided from 1983 to 1989.

10 These figures were calculated by Excel VBA.

11 The items of the industrial statistical mesh data are identified by double quotation marks.

12 Although relative labor productivity was also calculated using data for firms employing more than 29 people, the results are not presented because of the similarity to the results shown in Figure 2.

13 When the density of firms was used instead of the logarithm of the number of firms, a similar result was obtained.

14 To 'control' means to remove the effect.

15 This is same as the equipment/labor ratio.

16 The population density becomes the centrifugal force.

17 We cannot get the international trade data for each mesh. But the influence on coefficients e and h is not as large in this case as we considered in equation (5).

18 Only the number of surrounding firms is assumed to be endogenous.

19 The number of surrounding firms was calculated

only on the basis of all industries.

[20] The number of surrounding firms was calculated only by all industries.

[21] When data for firms employing more than 29 people are used, the significance is low in each year in many cases.

[22] When TFP was analyzed as a dependent variable, the results were similar, even when the numbers of surrounding firms employing more than 3 people were used.

[23] http://www.soumu.go.jp/toukei_toukatsu/data/io/ichiran.htm