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Role of Inter-firm Transactions on Industrial Agglomeration: Evidence from Japanese firm-level data[1]

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Abstract

This paper investigates the role of inter-firm transaction structure on industrial agglomeration by using Japanese firm-level transaction relationship data. First, we measure the industrial agglomeration for each industry. Next, we measure the intensity of transactions and inequalities of transaction partners as the measures of the micro structure of transaction networks in each industry. Then, we regress the index of agglomeration by the indexes of transaction structure. We find that the intensity of intra-industry transactions statistically enforces the agglomeration. Further, the inequality of transaction partners has a negative effect on the agglomeration. This suggests that the industries that attract a few hub-firms have a large number of intra-industry transaction partners that are not agglomerated.

Keywords: Network; Micro-geographic data; Economic geography

JEL classification: R11, L14

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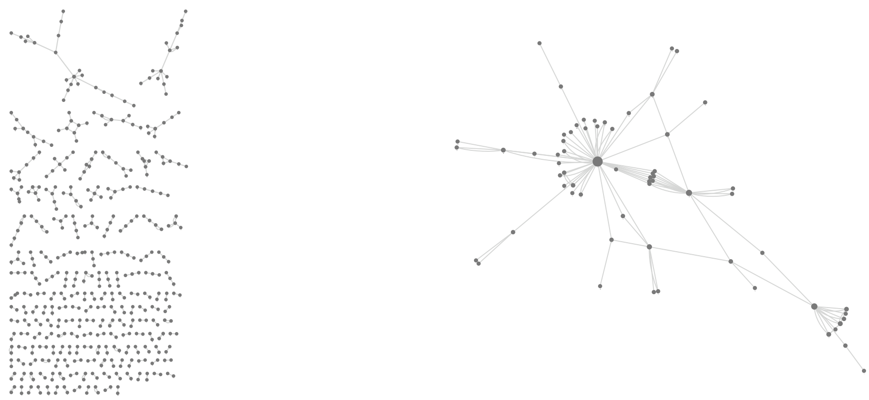
1 Introduction

Economic activities and industries are not uniformly distributed but tend to cluster in certain areas. It is well recognized automobile industry concentrates in Detroit in the United States and Toyota City in Japan. By using actual data, many empirical studies have measured the degree of industrial agglomeration.[1]

Since the Marshall (1890) pioneering works to clarify the mechanism of the industry agglomeration, uncountable theoretical models have been developed, and it is well recognized that the reducing transaction cost by the location proximity between firms is one of the important determinants of agglomerations. From this point of view, Borukhov and Hochman (1977) O'Hara (1977), and Fujita and Ogawa (1982) theoretically describe the agglomeration of economic activities to the urban metropolitan areas. They introduce the communication externality to the production function to express the inter-firm transactions and analyze the location pattern of the firms within a city.

Further, preceding research has examined this theoretical consequences by using Input-Output (I-O) table as a proxy for the intensity of interfirm transactions (Rosenthal and Strange, 2001; Ellison, Glaeser, and Kerr, 2010). They found the causal relationship from the intensity of transactions to the degree of agglomerations and coagglomerations. The intensity of transaction that is captured by the I-O table, however, could not capture the other feature of intra-industry transaction structure. Figures 1(a) 1(b) show examples of the actual transaction relationships within industries in Japan. Figure 1(a) is the transaction relationship in Metal Coating, Engraving and Heat Treating (JSIC 256). Each circle represents firm in the industry, and edge between firms represents the existence transaction between them. In the figure, each firm has similar number of transaction partners. On the other hand, in Aircraft and Parts (JSIC 304) industry (Figure 1(b)), a few firms attracts most of the transactions within the industry. This industry has large inequality on the number of transaction partners. Those difference on the microstructure of transaction network might affect the industry location distribution. For example, large hub-firms requires to gather transaction and their transaction partners locate close to them. Or, the large hub-firms may have large purchasing power, and can buy their inputs from remote firms. In this case, those industry might disperse each other. We examine the

[1] Ellison and Glaeser (1997), Maurel and Sedillót (1999), Devereux, Griffith, and Simpson (2004), Mori, Nishikimi, and Smith (2005), Tokunaga and Akune (2005), Duranton and Overman (2005), Duranton and Overman (2008), Nakajima, Saito, and Uesugi (2012) are examples.



(a) Metal Coating, Engraving and Heat Treating (JSIC 256)

(b) Aircraft and Parts (JSIC 304)

Figure 1: Network structure of Lower Gini and Higher Gini industries

role of microstructure of transaction network especially focusing on the inequality of number of transaction partners on location distribution of the industry, by using actual data on micro transaction relationship between firms.

This paper's empirical strategy follows to the preceding research on identifying the determinants of agglomeration (Rosenthal and Strange, 2001; Ellison, Glaeser, and Kerr, 2010). First, we calculate the degree of agglomeration in each industry by EG index (Ellison and Glaeser, 1997). Then, we define two measures of the structure of transaction network. The first one is the intensity of within industry transactions that is similar to the previous measure of intensity of transactions calculated by I-O table used by Rosenthal and Strange (2001) and Ellison, Glaeser, and Kerr (2010). The second one is a measure of inequality of number of transaction partners defined by the gini coefficient of the distribution of number of transaction partners. Then, we regress EG index by the two measures of transaction network structure.

We obtained the following results. First, the intensity of intra-industry transaction positively affects the agglomeration that is consistent to the preceding research (Rosenthal and Strange, 2001; Ellison, Glaeser, and Kerr, 2010). Second, the inequality of the number of transaction partners has a significant negative effect on the industry agglomeration. Further, the inequality in the number of buyer partners has robust and larger negative effect on industry agglomeration than that of seller partners. This result implies that the industry that has a few of large assemblers does not tend to be agglomerated in certain areas.

The rest of this paper is organized as follows. The next section shows the empirical strategy and data. We give detailed definition of the measures of the structure of transaction network. Then we show the results and the robustness in Section 3. Finally, Section 4 concludes this paper.

2 Empirical strategy

2.1 Data

We employ a unique and massive dataset of Japanese firms compiled by Tokyo Shoko Research (TSR). The TSR dataset covers 826,169 firms, which is equivalent to over half of all incorporated firms in Japan, and provides information on firms' location, two-, three- and four-digit JSIC (Japan Standard Industry Code) industry classification and number of employees. We geocode the firm location data using the CSV Address Matching Service provided by the Center for Spatial Information Science, University of Tokyo.[2] Following previous studies on industry concentration, we focus on the manufacturing sector, which reduces the sample used for our analysis to 143,628 firms. Another uniqueness of this database is about the inter-firm transaction information. Each firm reports main transaction partners identified by firms' id. Here, the transaction partners mean suppliers, customers and shareholders. In this paper, we do not pay attention to shareholding relations, but stick to the product transactions relations, such as suppliers and customers. We focus on the three-degree industry code in JSIC.

2.2 Index of agglomeration

As the indexes of agglomeration, we apply EG index (Ellison and Glaeser, 1997). Industry i's EG-index γ_i can be defined as follows,

$$\gamma_i = \frac{\sum_{m=1}^{M}(s_{mi} - x_m)^2}{1 - \sum_{m=1}^{M} x_m^2}, \tag{1}$$

where $m \in \{1, ..., M\}$ is a geometrical unit such as the administrative area, s_{mi} is share of region m for industry i and x_m is size of region m. We suppose size of region x_m is defined by a share of number of all manufacturing firms in region m. We apply three-digit industry classification code of the Japanese Standard Industry Classification (JSIC) as industry i and municipal unit as geometrical unit m.

[2] http://newspat.csis.u-tokyo.ac.jp/geocode/

The first row in Table 1 shows descriptive statistics of EG index. Table 2 shows the industries with highest EG index. Leather-related industries have higher value of EG index. These results resemble to previous researches, Tokunaga and Akune (2005) and Mori, Nishikimi, and Smith (2005).

Table 1: Descriptive statistics for agglomeration analysis

	Mean	Stand. Dev	Min	Max
EG	0.02	0.04	0.00	0.37
Ratio	0.36	0.15	0.00	0.72
Gini	0.40	0.10	0.00	0.59

Table 2: Highest agglomerations

Rank	ID	Industry	EG
1	215	Leather gloves and mittens	0.37
2	316	Ophthalmic goods, including frames	0.28
3	213	Cut stock and findings for boots and shoes	0.12
4	218	Fur skins	0.11
5	219	Miscellaneous leather products	0.10
6	321	Precious metal products, including jewel	0.10
7	211	Leather tanning and finishing	0.09
8	328	Manufacture of ordnance and accessories	0.07
9	201	Tires and inner tubes	0.06
10	214	Leather footwear	0.06
11	322	Musical instruments	0.05
12	151	Pulp	0.05
13	124	Japanese style apparel and tabi-sock	0.05
14	224	Pottery and related products	0.04
15	326	Lacquer ware	0.04

2.3 Indexes of inter-firm transaction

In this subsection, we introduce two indexes of inter-firm transaction within the same industry. One index is ratio of transactions and the other is a gini index of number of each firm's partners.

Ratio of transactions ($\mathbf{Ratio}_i$). This index is defined by the ratio of number of firms who participate in the intra-industry transaction to number of all firms of each industry.

For example, Figure 2 expresses transaction relations for industry i. Each circle represents firm belongs to the industry, and each arrow represents the transaction from seller to buyer. Here, number of firms of industry i is expressed by n_i. We see that seven firms in Figure 2, and $n_i = 7$. Next we define number of firms who have a transaction partners within the industry as n_i^t. Here we first ignore the direction of transactions,[3] and we see that firm 1 to 5 have transaction partners in the industry, and $n_i^t = 5$ in Figure 2. Then the index of ratio Ratio_i is defined by n_i^t/n_i. We find that the ratio for industry i is 5/7. The descriptive statistics of this ratio is shown in The second row in Table 1. In average, 36 % of firms have transaction partners

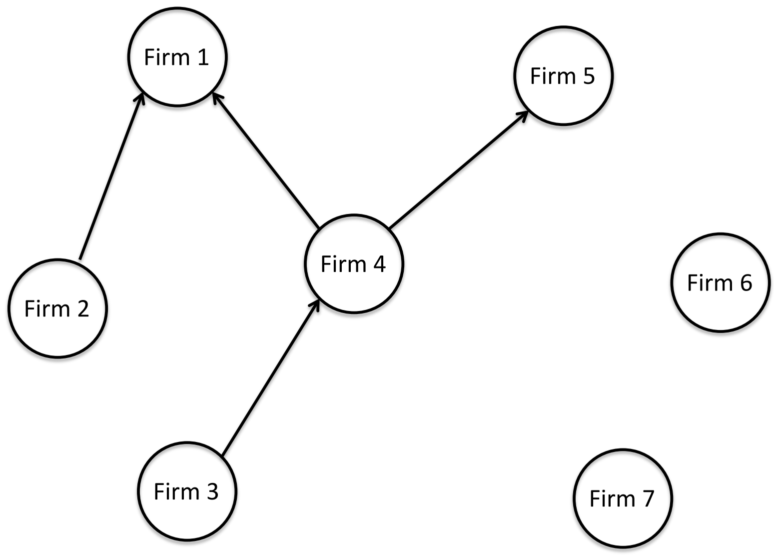


Figure 2: An example of buyer-seller network

within the industry. Table 3 shows the industries with highest Ratio_i. Musical instruments (JSIC 322) has the highest ratio of firms that have transaction partners within the industry. The Table do not necessarily includes industries that also have highest value of EG index, but Ophthalmic goods, including frames (JSIC 316) is also has a highest values EG-index.

Gini index of number of each firm's partners (Gini_i). This index expresses an inequality of number of partners. We consider about the firms who have partners of the same industry. In Figure 2, firm 1 to 5 have transaction partners within the industry, and the corresponding numbers of partners to these firms are 2, 1, 1, 3, and 1. The gini coefficient of this distribution

[3]Later, we will conduct analysis with focusing on the direction of transactions.

Table 3: Highest transaction ratios

Rank	ID	Industry	Ratio
1	322	Musical instruments	0.72
2	176	Drugs and medicines	0.67
3	273	Electric bulbs and lighting fixtures	0.66
4	315	Optical instruments and lenses	0.65
5	316	Ophthalmic goods, including frames	0.65
6	201	Tires and inner tubes	0.65
7	91	Livestock products	0.64
8	117	Rope and netting	0.64
9	244	Electric wire and cable	0.63
10	103	Tea and coffee	0.62
11	301	Motor vehicles, parts and accessories	0.60
12	317	Watches, clocks, clockwork-operated devices and parts	0.59
13	304	Aircraft and parts	0.59
14	155	Paper containers	0.56
15	95	Sugar processing	0.55

is 0.12. This is Gini_i of industry i. When a Gini_i is high, a few hub-firms atract a large number of partners in the industry. This index captures more detailed microstructure of the buyer-seller network in the industry that cannot be captured by the Input-Output table.

The descriptive statistics of Gini_i is shown in the third row in Table 1. And Table 4 lists the top industries that have highest Gini_i. Industries that have hub-firms that have large number of

Table 4: Highest Gini

Rank	ID	Industry	Gini
1	301	Motor vehicles, parts and accessories	0.59
2	273	Electric bulbs and lighting fixtures	0.54
3	102	Alcoholic beverages	0.54
4	91	Livestock products	0.53
5	315	Optical instruments and lenses	0.53
6	244	Electric wire and cable	0.53
7	173	Industrial organic chemicals	0.52
8	304	Aircraft and parts	0.52
9	172	Industrial inorganic chemicals	0.52
10	176	Drugs and medicines	0.52
11	222	Cement and its products	0.52
12	254	Fabricated constructional and architectural metal products, including fabricated plawasm	0.52
13	175	Oil and fat products, soaps, synthetic detergents, surface active agents and paints	0.51
14	272	Household electric appliances	0.51
15	223	Structural clay products, except those of pottery	0.51

transaction partners like Motor vehicles, parts and accessories (JSIC 301) and Aircraft and parts (JSIC 304), are included in the Table 4. The transaction network structure can be confirmed in Figures 1(a), 1(b).

Figure 1(a) shows the transaction network in Metal coating, engraving and heat treating (JSIC 256) that has lower value of Gini. In this industry, every firm has 1–4 transaction partners within the industry, and there is no hub-firm in the industry. On the other hand, in Figure 1(b) that represents the transaction network in Aircraft and parts (JSIC 304) that has a highest values of Gini, transactions are concentrated in a few hub firms. Especially, the largest firm transact with over half of the firms in the industry. These figures suggest that the index of Gini represents the presence of hub firms in the transaction network within the industry.

By using those measures of agglomeration and structure of transaction network, next, we investigate the relationship between them.

2.4 Empirical model

Following the preceding research that identifies the determinants of agglomeration, we estimate the following equation,

$$\gamma_i = \alpha + \beta_1 \ln(\text{Ratio}_i) + \beta_2 \ln(\text{Gini}_i) + \beta_2 \ln(\text{szgini}_i) + \text{digit2}_i + \varepsilon_i \qquad (2)$$

where γ_i is EG-index, Ratio_i is ratio of transactions and Gini_i is the gini index of the number of transaction partners that are defined in the previous section. In order to control the industrial characteristics, we introduce fixed effect of two-digit industry classification code digit2_i.

One may concern that the firm size distribution might correlate to the distribution of number of firm's transaction partners and the degree of agglomeration. In order to control this concern, we introduce gini coefficient of firms' employment size for industry i (szgini_i) in the estimation equation.

3 Results

3.1 Baseline results

Estimating results are shown in Table 5. Columun (1) of this table shows the baseline result. We found that coefficient of $\log(\text{Ratio}_i)$ is significantly positive which implies that the industry that has higher ratio of firms who participate in the intra-industry transaction is the more agglomerate. This result is consistent to the preceding research that reduction of transaction cost is one of the forces to industrial agglomeration(Rosenthal and Strange, 2001; Ellison, Glaeser, and Kerr, 2010). More interestingly, the coefficient for $\ln(\text{Gini}_i)$ is negatively significant. This implies that industries tend to more agglomerate when transaction structure is decentralized and each firm has almost the same number of partners, compared with the industry where a few hub-firms have a large number of partners.

These results are robust after we control firm size distribution (Column 2), and industry characteristics by the two-digit industry fixed effects (Column 3).

Table 5: Estimation results of agglomeration

Dependent: EG index	(1)	(2)	(3)
ln(Ratio)	0.0300*	0.0308*	0.0393**
	(0.0164)	(0.0159)	(0.0190)
ln(Gini)	-0.0947**	-0.0819**	-0.0853**
	(0.0447)	(0.0360)	(0.0426)
ln(sz_gini)		-0.0553*	-0.0322
		(0.0329)	(0.0284)
Constant	-0.0386	-0.0458	-0.0314
	(0.0269)	(0.0293)	(0.0253)
2 digit FE	no	no	yes
Observations	143	143	143
Adjusted R^2	0.140	0.163	0.260

Standard errors in parentheses
* $p < 0.10$, ** $p < 0.05$

3.2 Controlling other determinants of agglomeration

As many preceding research pointed, other than the interfirm transactions, there are many determinants of agglomeration like knowledge spillovers, or labor pooling (Marshall, 1890; Duranton and Puga, 2004; Rosenthal and Strange, 2001; Ellison, Glaeser, and Kerr, 2010). If those factors also correlate to the interfirm transaction network structure, our baseline OLS results are not consistent. For example, it would be well observed that the interfirm products transaction would induce the R&D collaboration for developing or improving products. To respond this concern, we introduce other determinants in the estimation equation following Rosenthal and Strange (2001). First, as a proxy for knowledge spillovers, we introduce share of R&D investment in the total sales. Second, for a measure of labor pooling, we introduce labor productivity. Third, following to the new economic geography theory, transportation cost is also an important determinants of agglomeration, we introduce the share of firms in transportation sector in total firms that are the seller of the firms in the industry. This measure represents the presence of the transportation sector in the seller-side of the industry. Finally, to measure the importance of the first nature, we introduce the share of firms in water and energy sector, and mining sector in total firms that are the seller of the firms in the industry.

The results are shown in Table 6. Column (1) is baseline result that have already shown in

Table 6: Estimation results of agglomeration

Dependent: EG index	(1)	(2)	(3)	(4)	(5)
ln(Ratio)	0.0393**	0.0206**	0.0384**	0.0406**	0.0173**
	(0.0190)	(0.00758)	(0.0192)	(0.0196)	(0.00558)
ln(Gini)	-0.0853**	-0.0510**	-0.0823*	-0.0892**	-0.0454**
	(0.0426)	(0.0106)	(0.0437)	(0.0448)	(0.00779)
ln(szgini)	-0.0322	0.0105	-0.0431	-0.0420	-0.00421
	(0.0284)	(0.0129)	(0.0306)	(0.0319)	(0.0202)
R&D intensity		-0.000145			-0.000110
		(0.000351)			(0.000478)
Transportation use			0.124*		0.238**
			(0.0743)		(0.0963)
Energy use			-0.0230		-1.128*
			(0.0874)		(0.620)
Mining products use			-0.293		-0.181
			(0.239)		(0.165)
Labor productivity				8.02e-08	-2.16e-08
				(6.09e-08)	(2.07e-08)
Constant	-0.0314	-0.00981	-0.0369	-0.0411	-0.0201*
	(0.0253)	(0.00618)	(0.0254)	(0.0317)	(0.0101)
2 digit FE	yes	yes	yes	yes	yes
Observations	143	49	143	143	49
Adjusted R^2	0.260	0.654	0.245	0.262	0.719

Standard errors in parentheses

* $p < 0.10$, ** $p < 0.05$

Column (3) in Table 5 as a benchmark. Column (2) shows results introducing R&D investment. Because of the data availability, sample size are limited, but the results are mostly unchanged. The coefficient of ln(Ratio) is still significantly positive and the coefficient of ln(Gini) is significantly negative. On the other hand, the coefficient for R&D investment itself is not statistically significant. Column (3) shows results introducing transportation, water and energy, and mining input use. The results in ln(Ratio) and ln(Gini) are unchanged. Further, the coefficient for transportation use is positively significant which suggests that the increase of the dependence on transportation sector increases the degree of agglomeration to reduce the cost for transportation. This is consistent to the intuition. Column (4) shows results introducing labor productivity. The results in ln(Ratio) and ln(Gini) are also unchanged, but the coefficient for labor productivity is not significant. Finally, Column (5) introduces all the determinants of agglomeration. The results in ln(Ratio) and ln(Gini) are still mostly unchanged: the coefficient of ln(Ratio) is still significantly positive and the coefficient of ln(Gini) is significantly negative. On the other determinants of agglomeration, the coefficient of transportation use is positively significant, and that of energy use is negatively significant. Negative coefficient for energy use implies that the increase of energy use disperse the firm location.

These results suggest the robustness of our results. The coefficient of ln(Ratio) is still significantly positive and the coefficient of ln(Gini) is significantly negative even controlling the other determinants of agglomeration. Microstructure of transaction network robustly correlated to the location agglomeration.

3.3 Buyer-seller decomposition

By the previous analysis, we found that the microstructure of transaction network significantly affects to the location agglomeration. But, we ignore the direction of transaction. Put differently, we do not distinguish buyers and sellers. To consider the difference role between buyer and seller, this section consider the direction of the transaction and revisit the analysis.

Gini index of number of each firm's partners with considering the differnce in buyer and seller (InGini$_i$, OutGini$_i$). We redifine the gini index with considering the direction of transaction. To consider the inequalities of number of buyers of each firm, we define InGini$_i$ as the gini coefficient of the distribution of number of buyers of each firm. Specifically, in Figure 2, firm 1, 4, and 5 have buyers within the industry, and the distribution of transaction partners is $\langle 2, 1, 1 \rangle$. The gini coefficient of this distribution is 0.17, and is the value of InGini$_i$ in the industry. This InGini$_i$ represents the presence of large buyers in the industry. For example, like autobobile industry, if there exist large assemblers that have large number of buyers, InGini$_i$ takes larger value. In the similar manner, we define OutGini$_i$ as the gini coefficient of the distribution of number of sellers of each firm.

Introducing both InGini$_i$, OutGini$_i$ into the estimation equation, we estimate the equation again. The results are shown in Table 7.

Column (1) shows the results without controlling other determinants of agglomeration. The

Table 7: Estimation results of agglomeration

Dependent: EG index	(1)	(2)	(3)	(4)	(5)
ln(Ratio)	0.0424*	0.00573*	0.0387*	0.0399**	0.00506
	(0.0232)	(0.00303)	(0.0204)	(0.0191)	(0.00315)
ln(InGini)	-0.0848**	-0.0255**	-0.0776*	-0.0887**	-0.0257**
	(0.0405)	(0.00503)	(0.0404)	(0.0405)	(0.00505)
ln(OutGini)	-0.0201	-0.0146**	-0.0160	-0.0229	-0.0177**
	(0.0291)	(0.00671)	(0.0323)	(0.0274)	(0.00750)
ln(szgini)	-0.160*	0.0165	-0.176*	-0.189**	0.00244
	(0.0928)	(0.0124)	(0.0974)	(0.0910)	(0.0184)
R&D		-0.000509			-0.000430
		(0.000379)			(0.000510)
Transportation inputs			0.0250		0.0624
			(0.207)		(0.0810)
Energy inputs			-0.636		-0.423
			(0.695)		(0.524)
Mining inputs			-0.747		-0.0816
			(0.533)		(0.156)
Labor productivity				0.000000330	3.21e-08
				(0.000000222)	(2.64e-08)
Constant	-0.0578*	-0.00345	-0.0583*	-0.0923**	-0.0152*
	(0.0333)	(0.00612)	(0.0332)	(0.0454)	(0.00837)
2 digit FE	yes	yes	yes	yes	yes
Observations	145	49	145	145	49
Adjusted R^2	0.287	0.703	0.285	0.361	0.705

Standard errors in parentheses

* $p < 0.10$, ** $p < 0.05$

coefficient of ln(Ratio) is positively significant. Further, the coefficient of ln(InGini) is negatively significant. This implies industries that have larger presence of large hub-buyers (e.g. assemblers) tend to be more agglomerated. On the other hand, the coefficient of ln(OutGini) is not significant. These imply that the inequalities of transaction partners in buyers rather than sellers are important determinants of agglomeration. Column (2) shows the results introducing R&D to the equation. In this specification, the coefficients both of ln(IngGini) and ln(outGini) are negatively significant. Column (3) introduces transportation, energy, and mining inputs in the equation, and Column (4) introduces labor productivity. In those specifications, only the coefficients of ln(InGini) are negatively significant, and the coefficients of ln(OutGini) are not significant. Finally, Column (5) includes all the determinants of agglomeration, and coefficients both of ln(InGini) and ln(OutGini) are negatively significant.

In sum, the coefficient of ln(InGini) is robustly significant in negative sign. This implies the inequalities of transaction partners in buyers are significant dispersion force of location. Put differently, industry that has a few large hub-buyers is not agglomerate. On the other hand, inequalities of transaction partners in sellers works as dispersion force in location, but the force is not robust and weaker than that in buyers.

4 Conclusion

This paper examines the role of an inter-firm transaction on an industrial agglomeration, using Japanese firm-level location data and inter-firm transaction data. The novelty of the paper is focusing on the detailed network structure of the transaction relationship given by the rich-micro transaction relationship dataset. In the analysis, first, we calculate the indexes of industrial agglomeration applying EG index (Ellison and Glaeser, 1997). Then, we calculate two indexes of transaction network structure, a ratio of transactions and a gini index of number of each firm's transaction partners. By regressing the EG index by the measures of transaction structures, we found that the following results. First, the ratio of firms who participate in the intra-industry transactions has a significant positive effect on agglomeration. This is consistent to the preceding research (Rosenthal and Strange, 2001; Ellison, Glaeser, and Kerr, 2010). Second, we found that a gini index has a significant negative effect on the industry agglomeration. Further, the effect is robust and larger in inequality of the number of buyers than in the sellers. This suggests the industry that has a few large assemblers does not tend to be agglomerated. On the other hand, the industry that is consisted by firms that have even numbers of transaction partners are agglomerated in certain areas.

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