Quantitative Impact Analysis of the Centralization of Firms in the Tokyo Metropolitan Area Considering Firm-to-Firm Trade Networks

Kono, Tatsuhito and Nakajima, Kentaro and Ozane, Kanta

Tohoku University, Hitotsubashi University, Tohoku University

June 2023

Quantitative Impact Analysis of the Centralization of Firms in the Tokyo Metropolitan Area Considering Firm-to-Firm Trade Networks

Tatsuhito Kono[1*], Kentaro Nakajima[2], Kanta Ozane[1]

[1]*Tohoku University, Aoba 09, Aoba-ku, Sendai 980-8579, Japan*

[2]*Hitotsubashi University, Naka 2-1, Kunitachi, Tokyo, Japan*

Abstract. When a firm makes a location decision, it considers only its own transportation costs and ignores the transportation costs of its trading partners, resulting in inefficient sparce locations of firms. Since Beckmann (1976), it has been known that such inefficient sparse locations occur in the canonical land use models with interactions between agents, and this externality is referred to as locational externality by Kanamoto (1990). We quantitatively analyze the scale of locational externalities using micro data of the listed firms located in the Tokyo metropolitan area and firm-to-firm trade network data. We show (1) which trade patterns involve locational externalities, (2) the ratio of trade generating locational externalities as a percentage of total trade is about 24%, (3) the transfer of a randomly-chosen 5% of firms to two business centers, Marunouchi and Shibuya, generates median external benefits of 1.9% and 1.3% in the total industry in terms of value-added, respectively, (4) benefits vary according to industry and location (e.g., about 10% in the case of firms located far from the centers, and about 5% in the case of firms in the information and communications industry).

JEL Classification: L14; R30

Keywords: locational externalities, productivity, trade network

Acknowledgments. We gratefully acknowledge grants from JSPS. Despite assistance from many sources, any errors in the paper remain the sole responsibility of the authors. In addition, we would like to thank Naoki Kitamura and Kosuke Shoda, who initiated this line of this research with us and we owe a lot to them.

* Corresponding author. *E-mail address:* kono@tohoku.ac.jp (T. Kono). The authors are listed in alphabetical order.

1. Introduction

Productivities of firms increase when firms concentrate geographically, which is called agglomeration economies. One of the various factors of agglomeration economies which were originally identified by Marshall (1890) is savings in trading costs. Indeed, when making a location decision, a firm considers its own transportation costs, and chooses the best place for the firm. However, the firm may have trading partners who pay their own transportation costs. The transportation costs paid by those trading partners are dependent on the firm's location decision, but are excluded from the firm's location decision.

The exclusion of these costs from the firm's location decision causes an externality and results in inefficiently sparse location of firms. The spatial distribution of agents which emerges with this externality has been analyzed from the theoretical viewpoints since Beckman (1976). The current paper is the first empirical study to quantify the actual scale of the externalities, using micro data of the listed firms and the actual firm-to-firm trade network.

Beckman (1976) shows that in a situation where a resident has one unit of face-to-face communicate with all residents in a city, the spatial distribution of residents becomes bell-shaped. A similar trade network can be applied to firms, and the spatial distribution of firms has been studied for over fifty years by Borukhov and Hochman (1977), O'Hara (1977), Ogawa and Fujita (1980), Fujita and Ogawa (1982), and Lucas and Rossi-Hansberg (2002)[1]. Besides the spatial distributions, one important property is that such location choices with interactions between agents inevitably generate an inefficiently sparse distribution from the social viewpoint. This inefficiency arises from firms' ignoring their trading partners' transportation costs when firms decide their locations. This externality has been theoretically

[1] Note that a decay function of the production efficiency in Fujita and Ogawa (1982) can be interpreted as transport costs between firms in the case of a specific elasticity of demand, as shown in Fujita and Thisse (2002).

analyzed by the above theoretical studies.

In these models, the relocation of a firm affects the trade costs of other firms with which it is interacting. This externality is referred to as "locational externality" in Kanemoto (1990). Locational externalities, which arise from the existence of traffic and communication costs, are technological externalities generated by firms through their location selection. Kanemoto (1990) shows locational externalities existing in the case of bilateral trading between firms, as shown in Fig. 1, which has firm A and firm B. In this situation, when firm A determines its location, it compares advantages (e.g., a reduction in transportation costs) and disadvantages (e.g., an increase in rents) of the location. For example, a move of firm A toward firm B will give benefits to not only firm A but also firm B through a reduction in transportation costs. This is a technological externality. In other words, the selection of a location by firm A is not socially optimal due to the existence of locational externalities. From the social viewpoint, the combined advantages for both firm A and firm B should be compared with the disadvantages for firm A alone, when the location of firm A is determined.

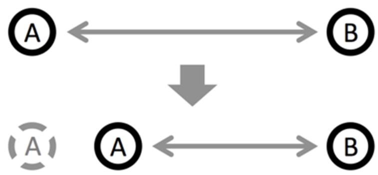


Figure 1. The mechanism generating locational externalities

To manage such locational externalities, Kanemoto (1990) proposes the Pigouvian subsidy as the first best policy. However, this Pigouvian subsidy is politically difficult to implement and has never been practiced. Fujita and Thisse (2002) show that doubling transport costs can yield the first-best outcome when demands of trades are inelastic. Instead of such first best policies, some theoretical studies explore land use regulations to mitigate these locational externalities as practical second-best policies (e.g., Rossi-Hansberg (2004), Zhang and Kockleman (2016) and Kono and Joshi (2018)).

One feature of the previous papers on locational externalities is that their analyses have been only theoretical, and there are no empirical analyses. To introduce the policy to mitigate the welfare loss by the externalities, we need to understand the scale of the cost and benefit. In addition, these theoretical papers all assume trade between firms is bilateral, not unilateral. In the real economy, not all trade is bilateral; on the contrary, most trade is unilateral. To empirically evaluate the size of locational externalities, the existing theoretical model, which analyzes only the case of bilateral trade, has a significant limitation.

In contrast to the previous theoretical papers, our purpose is to empirically estimate the actual size of the locational externalities generated by firm-to-firm trades and show which firms in which industries could generate greater value-added by clustering in the Tokyo metropolitan area[2]. In the empirical approach, we use panel data of firms and firm-to-firm trade for all the listed firms in the Greater Tokyo Metropolitan area to estimate the firm-to-firm trade costs. Then, using the estimates, we quantify the locational externalities by counterfactual simulation.

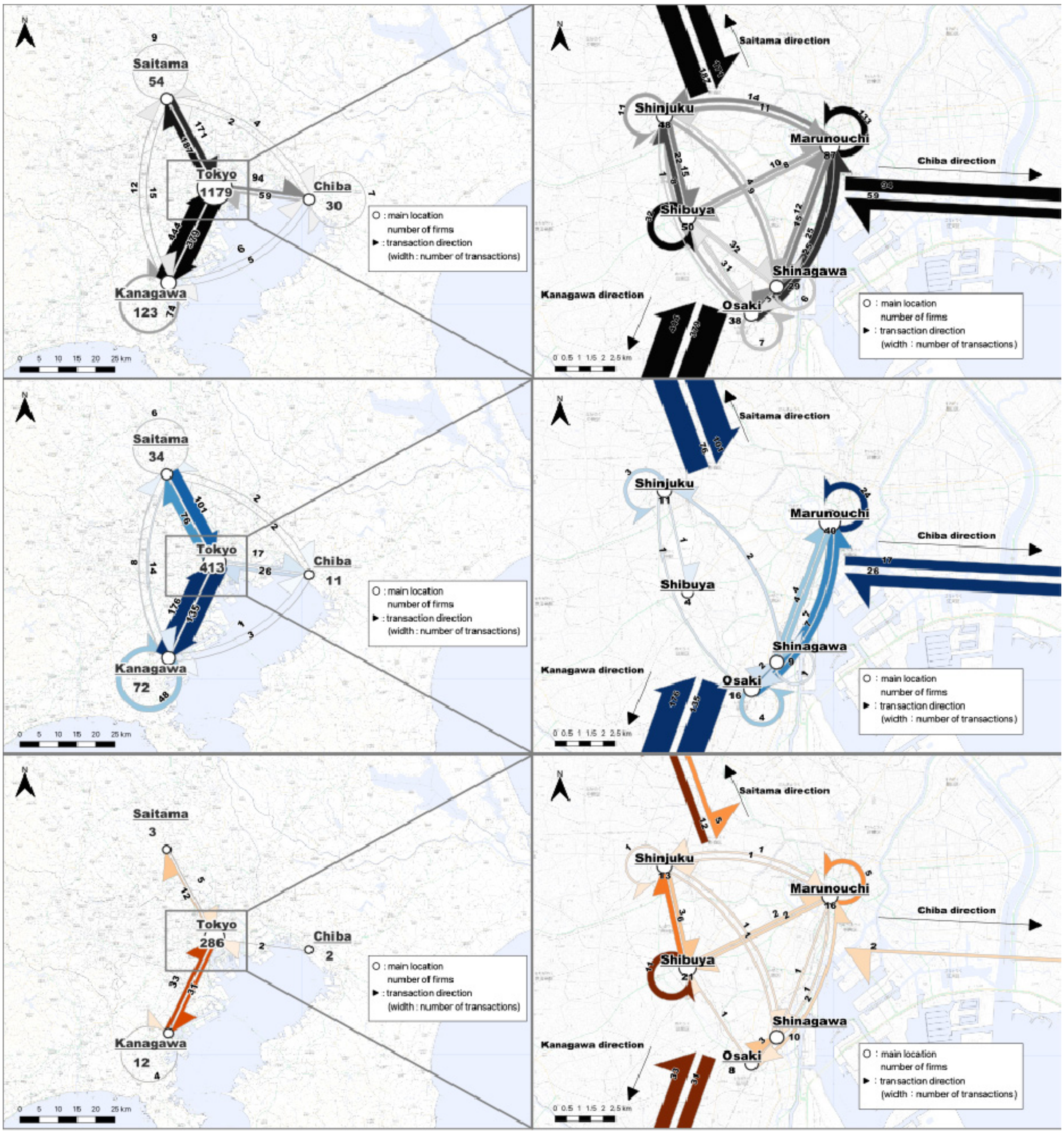
Our methodology is divided into three parts. First, we theoretically identify trading patterns which generate locational externalities among all the possible patterns, including unilateral and bilateral trades. Second, we calculate the share of actual trade patterns which

[2] The current paper contributes to the literature on firm-to-firm transaction relationships as an agglomeration force on economic activities as well as the literature on locational externalities (e.g., Kanemoto, 1990; Fujita and Ogawa 1982; Lucas and Rossi-Hansberg, 2001). Ellison et al. (2010) show that input-output dependencies are the most important factor for coagglomeration of firms because of transportation costs, by exploring factors affecting agglomeration indices (including labor market pooling and knowledge spillovers). Nakajima et al. (2012) and Furusawa et al. (2017) show that the firm-to-firm transaction relationships are geographically concentrated. Bernard et al. (2019) show that a decrease in travel cost decreases matching frictions between firm-to-firm trades, and increases the productivity of firms through improving matching efficiency. Miyauchi (2018) shows that increasing returns to scale on firm-to-firm matching act as a source of agglomerations. Many empirical studies try to measure Marshallian externalities. One recent related paper is Jofre-Monseny et al. (2014). Our paper also focuses on firm-to-firm trade generating agglomeration economies. The externality we focus on is locational externalities, which is also a Marshallian externality.

generate locational externalities in the Tokyo metropolitan area by using Japanese firm-to-firm trade data. Next, we estimate the elasticity of transportation cost on firm profitability by industry. Finally, we simulate several counterfactual cases: five percent of firms move to two centers in Tokyo, and estimate how much the profit of the firms changes through the relocations. These simulations clarify which firms should be centralized.

We focus on manufacturing and the information and communications industry. Manufacturing has long been widely recognized as an industry where agglomeration economies play a positive role, as in Kawashima (1975) and Sveikauskas (1975). The information and communications industry has been flourishing in recent years, and its rapid technological progress makes the exchange of information vital, leading to its agglomeration.

Fig. 2 shows the transaction maps of listed firms in the Tokyo metropolitan area in 2019. This figure has six maps. The top two maps, the middle maps, and the bottom maps show trading partnerships in all industries, manufacturing, and the information and communications industry, respectively. The three maps on the left show the relationship among Tokyo, Saitama, Chiba, and Kanagawa prefectures in the greater Tokyo metropolitan area. The three maps on the right show the Tokyo metropolitan area in more geographical detail, focusing on the relationship between Marunouchi, Shinagawa, Osaki, Shibuya, and Shinjuku. These five centers are selected on the basis of the town block (i.e., *chome* in Japanese) with the largest number of firms contained within a 0.5 km radius of the center town block. These maps also show the business relationships between Tokyo and Saitama, Chiba, and Kanagawa with the numbers of firms and trading partnerships. The number of firms is indicated by the size of the circle on the number, and the number of trading partners between towns is indicated by the thickness of the arrow on the number.



•In the figures on the left, the number of transactions between Tokyo districts is omitted for readability purposes.
•Ibaraki Prefecture is also included in the data, but is omitted due to the small number of both companies and transactions.

Figure 2. Trading partnership maps of listed firms in the Tokyo metropolitan area in 2019

First, focusing on the left side of the figure, we see that Kanagawa Prefecture has more trading partnerships with Tokyo in all industries, in manufacturing, and in the information and communications industry. Among them, the information and communications industry has the highest percentage in Kanagawa. In addition, manufacturing accounts for a large share of all industries, indicating that the manufacturing firms do business with many manufacturing firms outside of Tokyo. Next, focusing on the right side of the figure, we can see clear differences in business relationships across industries. The numbers of firms and trading partnerships in the manufacturing industry show that they are concentrated in the coastal areas such as Marunouchi, Shinagawa, and Osaki. Of these three areas, Marunouchi has the largest concentration, while firms and trading partnerships in the information and communications industry are more concentrated in Shibuya, followed by Shinjuku, than in the coastal areas.

Based on this actual firm-to-firm trade network, we show that about 21-24% of the trade in the Tokyo metropolitan area generates locational externalities. Furthermore, when a randomly-chosen 5% of the targeted firms move to two specific areas, the centers of Marunouchi and Shibuya generate median external benefits of 1.92% and 1.29%, respectively, in the total industry in terms of value-added. Furthermore, firms located far from the two centers, such as those in Chiba, Kanagawa, and Saitama prefectures and firms in the manufacturing and information and telecommunications industries have higher external benefits: about 10% and about 5%, respectively. Locational externality deserves to be considered for future industrial policies.

Section 2 explores the location patterns that cause locational externalities. In Section 3, we extract the trading structures that involve locational externalities. In Section 4, we ascertain the size of an increase in the value-added according to concentration of firms in the specific concentration areas. Finally, Section 5 presents conclusions.

2. Locational externalities in unilateral trading structures

This section describes the patterns of firm-to-firm trading which generates locational externalities. In general, firms trade with a variety of partners, which in turn trade with a variety of other trading partners. So, in order to identify the trading patterns that generate externalities, it is necessary to divide and classify the structures of these complex trading relationships into patterns. Before classification of such trading patterns, this section shows that there are unilateral trading patterns which involve locational externalities. Next, we enumerate all the possible trading patterns.

As discussed in the Introduction, previous research considers locational externalities only for the case of bilateral trading between firms. However, this section shows that locational externalities can occur if three or more firms are linked, even if not by bilateral trading.

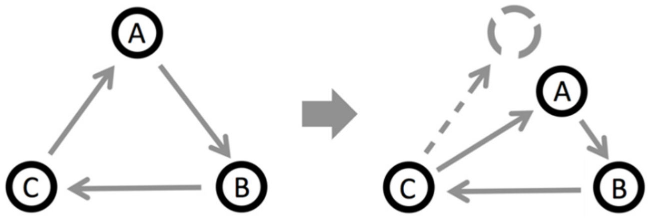


Figure 3. Trading patterns that generate locational externalities in unilateral trading

Let us assume there are three firms A, B, and C, as in Fig. 3. Firm A purchases goods from firm B, firm B from firm C, and firm C from firm A. The arrow expresses the flow of money of the trade. Here, assuming that the purchasing firm pays the trading costs[3], the firms at the arrow tails pay the transportation costs. In business areas, travel time costs incurred by businesspeople are important as well as out-of-pocket money costs. In this scenario, when firm A investigates whether to move closer to firm B in order to reduce its own trading costs, it makes this decision based on advantages and disadvantages to itself. However, we find that the relocation of firm A also affects the trading costs of firm C, which purchases goods from firm A. This mechanism generates locational externalities in unilateral trading.

However, there are some network patterns that do not generate locational externalities even when three firms are linked. For example, as shown in Fig. 4, when firm A purchases goods from both firm B and firm C (on the left side in Fig. 4), or when firm B and firm C

[3] It is also possible to perform this analysis while assuming that the selling side pays the trading costs. In this case, the findings of this research fundamentally do not change.

purchase goods from firm A (on the right side in Fig. 4), any moves of firms to reduce their own transportation costs do not affect the transportation costs of the other firms. In other words, the move does not generate locational externalities. That is, in a situation of unilateral trading among three firms, both trading patterns that generate locational externalities and those that do not generate them exist.

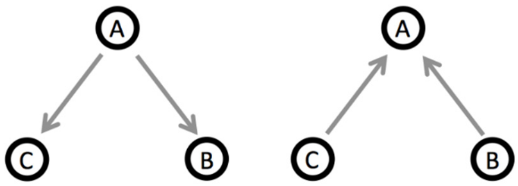


Figure 4. Trading patterns that do not generate locational externalities

Next, we clarify what network patterns of firms can generate locational externalities by investigating whether or not locational externalities arise for each of the network patterns. First, we break down the whole transaction network into possible subgraphs consisting of three nodes. This is known as motif analysis in the field of network analysis.[4] There are thirteen patterns of subgraphs consisting of three nodes (see Fig. 5 or 6 for graphical exposition). In addition, each node is classified as one of thirty types of trading according to its position in the network, the presence or absence of trading, and its direction. That is, the "type" is defined by the node's number in Figs. 5 and 6. In this case, each firm is generally connected to multiple other firms and a single firm engages in multiple types of trading.

First, Figs. 5 and 6 show the network patterns and trading types which are affected by locational externalities and those which generate locational externalities, respectively. In Fig. 4, the trading types that are affected by locational externalities are indicated by red dashed circles. To explain this, we can use pattern 3 as a specific example. It shows that trading type 5 (i.e., node 5) in red, is affected by locational externalities when a firm in trading type 6 (i.e.,

[4]Ohnishi et al. (2009, 2010a, 200b) analyzes the characteristics of firm-to-firm trading patterns in Japan using this motif analysis approach.

node 6) moves (it has an incentive to move closer to the firm conducting trading type 7 in order to reduce its trading costs). On the other hand, in Fig. 5, the blue dashed circles show the trading type that generates locational externalities. If we use pattern 3 again to give a specific example, it shows that a firm in trading type 6, in blue, gives locational externalities to trading type 5 when it moves. In real markets, whether transportation costs are paid by the purchasing firm or by the selling firm depends on the commercial custom in the industry. But we assume that the purchasing firm pays transport costs and the arrows indicate the direction of the payment of trading costs. The reverse case can be explored similarly.

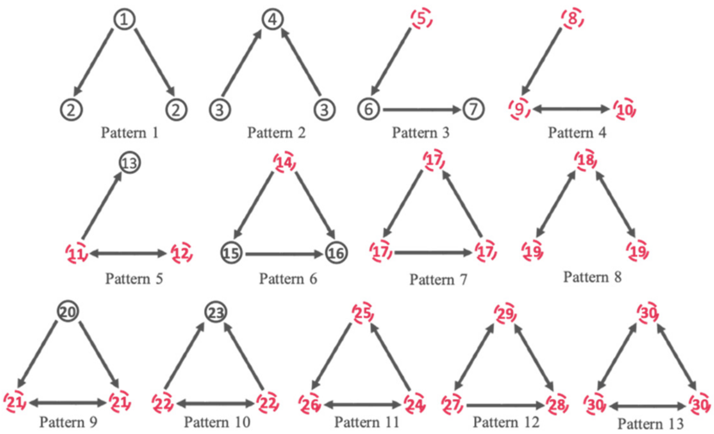


Figure 5. Network patterns and trading types affected by locational externalities (red)

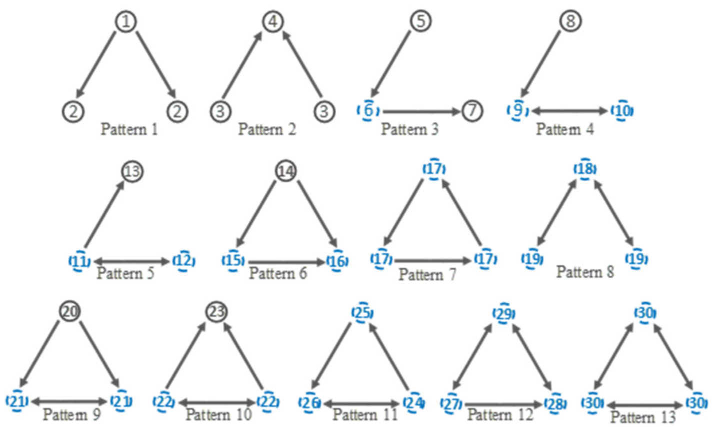


Figure 6. Network patterns and trading types generating locational externalities (blue)

3. Data：Targeted regions and industries

For quantitative analyses, we use listed firms in the Tokyo metropolitan area.[5] Our analysis is restricted to listed firms because we need to obtain data on capital and labor for each firm from their annual securities report to estimate their production function.

The main dataset of the analysis is TSR Business Information (fiscal 2010, 2015 and 2019 editions) published by Tokyo Shoko Research, Ltd. This database includes the information of a firm's input firms and output firms. The trading partner data is created based on the responses provided by the firms to a questionnaire on their twelve main input firms and output firms. Furthermore, the database includes locations of headquarters; category of industries; capital stock; the number of employees, plants, and branch offices; directions (purchases and sales) of main trading for each firm; sales; and so on.

3.1 Classifying trading structures of firms into patterns

Based on the classification of trading structures in Section 2, this section calculates the frequency of each type of trading structure in the Tokyo metropolitan area for 2019.[6] Table 1 shows the number of trading partnerships per trading type within the Tokyo metropolitan area. The types in red (also, with an asterisk to their left) show the trading types that are affected by locational externalities; the types in blue (also, with an asterisk to their left) show the trading types that generate locational externalities. From this table, the ratio of trading relationships that are affected as a percentage of the total trading partnerships is 26.75%. On the other hand, the ratio of trades that generate locational externalities is 23.66%.

Regarding the number of trading partnerships of each type, the number of each trading type from 1 to 7 is very large. That implies that network patterns from 1 to 3 in Figs. 5 and 6

[5] The definition of Tokyo metropolitan area is Tokyo and four surrounding prefectures: Saitama, Chiba, Kanagawa, and Ibaraki.
[6] Similarly, we have also analyzed the data using 2010 and 2015 data. However, the results are very similar and have been omitted.

occupy a large share of total trade. Among the trading types that are affected by locational externalities, the number of type 5 is large. On the other hand, among the trading types that generate locational externalities, the number of type 6 is large. These trading patterns together account for approximately 11% of the total trade.

Table 1. Number of trading partnerships by trading type

	Time period = 2019			
	Trading partnerships receiving locational externalities		Trading partnerships generating locational externalities	
type 1	18317	5.61%	18317	5.61%
type 2	36634	11.23%	36634	11.23%
type 3	75878	23.26%	75878	23.26%
type 4	37939	11.63%	37939	11.63%
type 5	*35775	10.97%	35775	10.97%
type 6	35775	10.97%	*35775	10.97%
type 7	35775	10.97%	35775	10.97%
type 8	*9059	2.78%	9059	2.78%
type 9	*9059	2.78%	*9059	2.78%
type 10	*9059	2.78%	*9060	2.78%
type 11	*5134	1.57%	*5134	1.57%
type 12	*5135	1.57%	5134	1.57%
type 13	5134	1.57%	5134	1.57%
type 14	*1199	0.37%	1199	0.37%
type 15	1199	0.37%	*1199	0.37%
type 16	1199	0.37%	*1200	0.37%
type 17	*273	0.08%	*273	0.08%
type 18	*702	0.22%	*702	0.22%
type 19	*1404	0.43%	*1404	0.43%
type 20	*161	0.05%	161	0.05%
type 21	*322	0.10%	*322	0.10%
type 22	*284	0.09%	*284	0.09%
type 23	142	0.04%	142	0.04%
type 24	*116	0.04%	*116	0.04%
type 25	*116	0.04%	*116	0.04%
type 26	*116	0.04%	*116	0.04%
type 27	*97	0.03%	*97	0.03%
type 28	*97	0.03%	*97	0.03%
type 29	*97	0.03%	*97	0.03%
type 30	*48	0.01%	*48	0.01%
Total	*78252	23.99%	*69032	21.16%

In total, there exist significant shares of trading relationships which are affected by locational externalities (24%) and generate locational externalities (21%). This suggests that the welfare loss by locational externalities may not be ignorable. Next, we discuss the actual welfare loss by locational externalities in more detail.

3.2 Data for quantitative analysis of locational externalities

For quantitatively analyzing locational externalities, in addition to the TSR Business Information, we use the annual securities reports from the Nikkei Economic Electronic Databank System (NEEDS) to estimate production functions. Table 2 shows the source of our data. We use the data of labor costs, operating profit, and ‘property, plant, and equipment’ obtained from NEEDS by averaging the values for the fiscal year and one previous fiscal year to obtain data showing the firm’s average production activity as of the fiscal year. The reason for not averaging over three years of data is that it would include the FY2020 period, which was significantly affected by COVID 19.

Table 2. Data sources

Data	Targeted firms	Used items	Sample size
TSR Business Information (Tokyo Shoko Research, Ltd)	Listed company (headquaters)	Locations of headquarters, Categories of business, Capital stock, Main input firms, Main output firms, Number of employees	1,322 firms (2019) 1,158 firms (2015) 906 firms (2010)
Nikkei Economic Electronic Databank System	Listed company	Labor costs, Operating profit, and Property, plant, and equipment	1,322 firms (2019) 1,158 firms (2015) 906 firms (2010)
NITAS (*National Integrated Transport Analysis System*)	Analysis objects	Generalized costs between any pairs of points by train, taxi, or on foot	9,449 pairs (2019) 7194 pairs (2015) 13,238 pairs (2010)

For analysis, we merge the data from TSR Business Information and NEEDS. We only take account of firms which have data for 2010, 2015 and 2019. We also exclude firms with negative average operating income for the two fiscal years because these firms probably had their own specific problems, and firms with no data in NEEDS. In addition, we do not consider holding firms, because they do not conduct business on their own, or firms in the Primary and Construction industries because the number of the firms is very small.

We construct panel data shown in Table 2. To do so, we target firms which have data for three time points. Excluding the firms which have no data, negative profits, and inconsistent industry categories across time points, we have 740 firms. Table 3 shows, we divide the 740 target firms into three industry sectors: the manufacturing industry, the information and communications industry, and the tertiary sector except for the information and communications industry, according to Japan Standard Industrial Classifications (JSIC). The reason we set these three divisions, as mentioned in the Introduction, is to focus on locational externalities between the manufacturing industry and the information and communications industry.

Table 3. Industrial classifications for targeted firms

Industry	No. of firms	Classification
Manufacturing industry	348	Manufacture of food; Manufacture of beverages, tobacco, and feed; Manufacture of textile products; Manufacture of lumber and wood products, except furniture; Manufacture of furniture and fixtures; Manufacture of pulp, paper and paper products; Printing and allied industries; Manufacture of chemical and allied products; Manufacture of petroleum and coal products; Manufacture of plastic products, except otherwise classified; Manufacture of rubber products; Manufacture of leather tanning, leather products, and fur skins; Manufacture of ceramic stone and clay products; Manufacture of iron and steel; Manufacture of non-ferrous metal, and products; Manufacture of fabricated metal products; Manufacture of general-purpose machinery; Manufacture of production machinery; Manufacture of business oriented machinery, electronic parts, and devices and electroic circuit; Manufacture of electrical machinery, equipment and supplies; Manufacture of information and communication electronics equipment; Manufacture of transportation equipment; Miscellaneous manufacturing industries (JSIC 9-32)
Information-communications industry	112	Communications; Broadcasting; Information Services; Services incidental to internet; Video picture information, sound information, character production and distribution (JSIC 37-41)
Other tertiary sector industries	280	Railway transport; Road passenger transport; Road freight transport; Water transport; Air transport; Warehousing; Services incidental to transport; Postal Services, including mail delivery; Wholesale trade; General merchandise, Wholesale trade (textile and apparel); Wholesale trade (food and beverages); Wholesale trade (building material and metals, etc); Wholesale trade (machinery and equipment); Miscellaneous wholesale trade; Retail Trade; General merchandise; Retail trade (woven fabrics, apparel, apparel, accessories and notions); Retail trade (food and beverage); Retail trade (machinery and equipment); Miscellaneous retail trade; Nonstore retailers; Banking; Financial insititutions for cooperative organizations; Non-deposit money corporations, including lending and credit card business; Financial products transaction dealers and futures commodity transaction dealers; Financial auxilaiaries; Insurance insititutions, including insurance agents; Brokers and services; Real estate agencies; Real estate lessors and managers; Goods renatl and leasing; Scientific and development research institutes; Professional services N.E.C.; Advertising; Technical services N.E.C.; Accomodations, Eating and drinking places; Food take out and delivery services; Laundry; Beauty and bath services; Miscellaneous living-related and personal services; Services for amusement and recreation; School education; Miscellaneous education, learning support; Medical and other health services; Public health and hygiene; Social insurance; Social welfare and care services; Postal services; Cooperative association, N.E.C.; Waste disposal business; Automobile maintenance services; Machine, etc. repair services, except otherwise classified; Employment and worker dispatching services; Miscellaneous business services; Political, business and cultural organizations; Religion; Miscellaneous services; Foreign governments and international agencies in Japan; National government services; Local government services; Industries unable to classify (JSIC 42-99)

Table 4 shows descriptive statistics of the total data on the number of employees, labor costs, property, plant, and equipment, and operating profit in 2010, 2015, and 2019, respectively. Checking the medians and averages, we can see that labor, labor costs, and ‘property, plant, and equipment’ have increased slightly as time goes. In contrast, we can see that operating costs are highest in 2010.

Table 5 shows how many trading relationships there are in each industry. The rows *j* show the industry of input firms. The columns *i* show the industry of output firms. So, trade direction is from industry j to industry i. The number within the parentheses is the average number of input-output firms per firm. The number of trading relationships between firms in the same industry are larger than the number of trading relationships across industries.

Table 4. Descriptive statistics of production factors in 2010, 2015, and 2019

(Unit: JPY million)

Year	2019				2015			
	Number of employees	Labor costs	Property, plant, and equipment	Operating profit	Number of employees	Labor costs	Property, plant, and equipment	Operating profit
Minimum value	4	46	13	6	5	110	5	24
1st quartile	278	1,272	3,547	1,092	258	1,103	2,903	911
Median value	586	3,430	12,900	3,139	544	3,038	11,126	2,562
Mean value	1,438	14,296	103,697	17,001	1,337	12,412	90,226	14,417
3rd quartile	1,376	10,727	47,579	11,190	1,252	9,162	39,877	8,869
Maximum value	46,019	546,312	6,692,223	533,670	50,194	395,281	6,089,000	543,963

Year	2010			
	Number of employees	Labor costs	Property, plant, and equipment	Operating profit
Minimum value	5	114	10	8
1st quartile	242	1,037	2,580	2,632
Median value	532	2,651	9,435	9,410
Mean value	1,282	10,290	73,722	73,304
3rd quartile	1,201	7,836	31,698	31,790
Maximum value	52,578	360,912	5,890,776	5,903,285

Table 5. Descriptive statistics of the number of input-output firms by industry

i / *j*	Manufacturing [348]	Information-communications [112]	Other tertiary sector industries [280]	Sum [740]
Manufacturing [348]	403	8	178	589
(Average number per firm)	(1.16)	(0.07)	(0.64)	(0.80)
Information-communications [112]	46	52	17	115
(Average number per firm)	(0.13)	(0.46)	(0.06)	(0.16)
Other tertiary sector industries [280]	264	16	134	414
(Average number per firm)	(0.76)	(0.14)	(0.48)	(0.56)
Sum [740]	713	76	329	1,118
(Average number per firm)	(2.05)	(0.68)	(1.18)	(1.51)

4. Quantitative analysis of locational externalities

Section 3 enumerates the trading types involving locational externalities and counts their frequency for the listed firms in the Tokyo metropolitan area. The objective of this section is to quantitatively estimate the scale of the locational externalities. A quantitative analysis of locational externalities is performed as described below. First, we set the profit functions of firms that specify the trading costs among headquarters of the firms, and measure the effects of transportation costs on the profits by estimating the parameters using actual data. Based on this, we quantitatively analyze the impact of location change of firms on profits through locational externalities.

4.1 The Model

The production technology is specified as follows. First, firm h uses intermediate inputs x_{hj} from input firms in industry j to produce output X_h in the form of the Leontief technology. We assume that there are enough number of input firms in j so that the market is perfectly competitive. The production function is shown in eq. (1).

$$X_h = \min\left\{\frac{G_h(N_h, K_h)}{a_{h0}}, \frac{x_{h1}}{a_{h1}}, \cdots, \frac{x_{hj}}{a_{hj}}, \cdots, \frac{x_{hJ}}{a_{hJ}}\right\}, \quad (1).$$

where G_h is the value-added production function of the number of employees N_h and capital stock K_h. Eq. (1) implies eq. (2) below.

$$G_h(N_h, K_h) = a_{h0}X_h,\ x_{hj} = a_{hj}X_h, \quad (2).$$

where a_{hj} is the input coefficient satisfying the following relation.

$$a_{h0} + \sum_{j=1}^{J} a_{hj} = 1. \quad (3).$$

The intermediate input x_{hj} is composed of the supply of multiple intermediate firms s_{hm_j} in industry j. The supply s_{hm_j} requires communication volume φ_{hm_j} between the supply headquarters and the demand headquarters. These are shown as eqs. (4) and (5).

$$a_{hm_j}x_{hj} = s_{hm_j}, \quad (4).$$

$$\varphi_{hm_j} = \beta_{hm_j} s_{hm_j}, \quad (5).$$

where a_{hm_j} is the input coefficient and β_{hmj} is a positive coefficient. a_{hm_j} satisfies the following relation.

$$\sum_{m_j}^{M_j} a_{hm_j} = a_{hj}. \quad (6).$$

Next, labor and capital are used in the form of the Cobb-Douglas technology, because such primary factors of production are substitutable unlike intermediate inputs, and the expenditure composition for them is stable[7]. The value-added production function G_h is specified as shown in eq. (7).

$$G_h(N_h, K_h) = v_h \cdot N_h^{\alpha_h} \cdot K_h^{1-\alpha_h}, \quad (7).$$

where v_h is the productivity inherent for firm h, including benefits from firm location such as agglomeration economies and location fundamentals[8], and the profit function is expressed as shown in eq. (8). Here, the firm's cost function per unit value-added is shown in eq. (9).

$$\max_{N_h, K_h} \pi_h = P_h X_h - \sum_{j=1}^{J} (p_{hj} x_{hj} + \sum_{m_j}^{M_j} d_{hm_j} \varphi_{hm_j}) - (wN_h + rK_h), \quad (8).$$

$$C_h(w, r) = \min_{N_h, K_h} (wN_h + rK_h), \quad (9).$$

where π_h is profit, P_h is the price of the output and p_{hj} is the price of the intermediate good from industry j, d_{hm_j} is trading cost between firms h and m, and C_h is the firm's cost function. Here, we assume $P_h = 1$ and $p_{hj} = 1$, so the production X_h and x_{hj} are represented in terms of unit value. Using eqs. (2) to (8) with this assumption yields

---

7 Indeed, this combination, which is that of the Cobb-Douglas for labor and capital and the Leontief technology for intermediate good, is typical in the traditional computable general equilibrium (CGE) approach (see Shoven and Whalley, 1992; Bröcker, 1998; Dixon and Jorgenson, 2013).

8 Since our dataset includes few relocation firms, we cannot identify the firm fixed effect and location fixed effect separately. In the simulation in Section 4, productivity v_h is fixed although the location fixed effect can change when relocating firms. But this can be justified in the following way. We calculate the external benefits only, which are the benefits in the un-moved firms, which do not change the location fixed effects.

$$\max_{N_h, K_h} \pi_h = \left\{1 - \sum_{j=1}^{J} (a_{hj} + a_{hj} \sum_{m_j=1}^{M_j} d_{hm_j} \beta_{hm_j} a_{hm_j}) \right\} \frac{G_h}{a_{h0}} - (wN_h + rK_h). \quad (10).$$

Under the condition of zero profit because of competition between firms, using eq. (7), eq. (10) is rewritten as

$$\pi_h = \left\{1 - \sum_{j=1}^{J} a_{hj} (1 + \sum_{m=1}^{M_h} d_{hm_j} \beta_{hm_j} a_{hm_j}) \right\} \frac{G_h}{a_{h0}} - (wN_h + rK_h) = 0,$$

$$wN_h + rK_h = \left\{1 - \sum_{j=1}^{J} a_{hj} - \sum_{j=1}^{J} a_{hj} \sum_{m=1}^{M_h} d_{hm_j} \beta_{hm_j} a_{hm_j} \right\} \frac{v_h \cdot N_h^{\alpha_h} \cdot K_h^{1-\alpha_h}}{a_{h0}} \quad (11).$$

$$\Leftrightarrow \frac{wN_h + rK_h}{N_h^{\alpha_h} \cdot K_h^{1-\alpha_h}} = \frac{v_h}{a_{h0}} \left(1 - \sum_{j=1}^{J} a_{hj} \right) - \frac{v_h}{a_{h0}} \sum_{j=1}^{J} a_{hj} \sum_{m=1}^{M_h} d_{hm_j} \beta_{hm_j} a_{hm_j},$$

$$\Leftrightarrow \frac{wN_h + rK_h}{N_h^{\alpha_h} \cdot K_h^{1-\alpha_h}} = v_h - \frac{v_h}{a_{h0}} \sum_{j=1}^{J} a_{hj} \sum_{m=1}^{M_h} d_{hm_j} \beta_{hm_j} a_{hm_j}, \quad (12).$$

In eq. (12), the numerator of the left side of the equation is the firm's total value-added and the denominator is the combination of inputs. Therefore, the left side of eq. (12) is total factor productivity (*TFP*), which is defined as TFP_h hereafter. This *TFP* can be calculated as a residual error using the production function as follows. We use 'property, plant, and equipment' for capital K_h, and the number of employees for N_h. Parameter α_h can be obtained as the labor cost share of the total value-added from the data. Combining these, we can calculate the denominator. Regarding the numerator, wN_h+rK_h, we use the sum of labor costs and operating profit from the data. Although we cannot obtain a_{hj}, β_{hm_j}, a_{hm_j}, and φ_{hm} from each firm's data, we can estimate the value of these parameters of a group of firms in eq. (12), applying regression analyses to the group of firms.

The explanatory variables for the left-hand side of eq. (12), TFP_h, include the generalized cost of transport d_{hm_j}. This is calculated based on actual transportation networks and location patterns of firms in the Tokyo metropolitan area. These variables depend on the year. So, adding year index y, we hereafter represent TFP_h and d_{hm_j} as $TFP_{h,y}$ and $d_{hm_j,y}$, respectively.

Since this research uses data for a 10-year period from 2010 to 2019, it is clear that there have been some technological changes in the industry during that time that are expected to affect productivity v_h. For example, there has been progress in the automation of manufacturing lines in the manufacturing industry. Therefore, in order to control for changes in the industry over time, we include the interaction term between year fixed effects and industry fixed effects. We hereafter call them "industry time-fixed effects". As a result, we use eq. (13) for regression analyses.

$$TFP_{h,y} = \sum_{j=1}^{J} \theta_{ij} \cdot \frac{\sum_{m=1}^{M_{h,y}} d_{hm_j,y}}{M_{h,y}} + u_h + v_{i,y} + \varepsilon_{h,y}, \quad (13).$$

where θ_{ij} is the parameter for transport costs between the headquarters of the output industry i $(h \in i)$ and those of input industry j $(m \in j)$, $M_{h,y}$ is the number of firms in industry h in year y, u_h is unobserved time-invariant heterogeneities, which can control for firm fixed effects, $v_{i,y}$ is unobserved changes in the industry over time, which can control for industry time-fixed effects, and $\varepsilon_{h,y}$ is the error term that shows iid in year y, which is used for parameter analysis in sub-section 4.2. Furthermore, because the first term on the right-hand side of eq. (13), the sign of θ_{ij} is expected to be negative, since an increase in trading costs associated with a greater generalized cost of transport reduces TFP.

The parameters of eq. (13) can be estimated for a combination of the sectors which contain industries i (output industry) and j (input industry), using fixed effects regression. The reason we use fixed effects regression is that endogeneity biases possibly exist. The unobserved firm fixed effects and industry time-fixed effect u_h and $v_{i,y}$ such as the ability of the management team or changes in the industry over time can be correlated with both an explained variable

TFP_h, and explanatory variable $d_{hm_j,y}$. For example, if a firm's business ability is high, productivity will be high, and the management team will locate its firm near the center of Tokyo considering the firm's transaction costs. In this sense, firm fixed effects u_h and $v_{i,y}$ can be correlated with the generalized cost of transport $d_{hm,y}$, too, and the estimation of coefficient θ_{ij} for *TFP* can be biased. We therefore conduct fixed effects regression as follows. We estimate θ_{ij} by using the entity and time averaging method.

For parameter estimation, both i (output industry) and j (input industry) are classified into three sectors: manufacturing, the information and communications, and other tertiary sector industries.

The trading cost between firms h and m, $d_{hm_j,y}$ can be represented by the function of generalized transport cost, $b_{hm_j,y}$, $d_{hm_j,y} = f\left(b_{hm_j,y}\right)$. The generalized transport cost comprises the travel time cost and the fare. The functional form of $f\left(b_{hm_j,y}\right)$ is not necessarily linear. We consider linear and quadratic functions and their intermediate one (i.e., $d_{hm_j,y} = b^t_{hm_j,y}$ with t = 1, 1.5, and 2). t is called the transportation parameter, hereafter. To calculate the generalized transport costs $b_{hm_j,y}$ between firms, we use the "NITAS (*National Integrated Transport Analysis System*)" provided by the Ministry of Land, Infrastructure and Transport[9]. NITAS calculates generalized costs between any pairs of points by train or automobile or on foot, and gives the cheapest mode of transport and cost. The parameters for calculating generalized transport cost are as follows. We set value of time at 1,200 yen/hour for both train and vehicle modes. To calculate the generalized transport cost by vehicle mode, we assume that the vehicle is a taxi, and the taxi fare is set to follow the fare rate table for the year. This is because trading partnerships between headquarters in the Tokyo metropolitan area are considered to be highly important, and people frequently use taxis, which can be expensive. To be specific, before 2017, the starting fare was 730 yen with an additional

[9] Refer to the Appendix for NITAS.

80 yen for every 280 meters after 2 km. From 2017 on, the system is based on a starting fare of 410 yen and an additional 80 yen for every 237 meters after 1.052 km. To calculate the generalized transport cost on foot and by train, we consider the travel time and fare, and set walking speed at 4 km/hour.

4.2 Parameter estimates

4.2.1 Regression analysis

Some real data are not consistent with the assumptions of our model. So, we exclude several firms from the data set. First, we use only firms with non-zero inputs. This is because firms with zero inputs have no trading costs, and the model could not be applied to these firms. Secondly, we only use firms that have not changed their trading pattern in the relevant industry between the three years. This is because the structure of the industry must be maintained in the production of goods, as we assume Leontief technology in our production technology. Thirdly, we remove the top 5% of firms of *TFP* and the bottom 5% of firms in terms of *TFP* to exclude outliers. For example, our model does not take into account the impact of a particular firm's dramatic innovation in any given year, or the failure of a business and the deterioration of its management. Therefore, these are considered outliers. We tried some other removal rates, but the estimation results did not change much. As a result, the number of firms used for parameter estimation is 155 in the manufacturing industry, 29 in the information and communications industry, and 105 in the other tertiary sector industries. The simulation analyses following the parameter estimation also use these firms.

Table 6 shows regression results. The three industry sectors in row i are output industries; the three industry sectors in column j are input industries. Parameters are estimated with transportation parameter t set to 1.0, 1.5, and 2.0. The table shows the values of parameter θ and one-way standard (firm) errors in parentheses below the values.

Table 6. Estimated parameter θ of each sector

i / j	Manufacturing industry			Information and communications industry			Other tertiary sector industries		
	t = 1.0	t = 1.5	t = 2.0	t = 1.0	t = 1.5	t = 2.0	t = 1.0	t = 1.5	t = 2.0
Manufacturing industry	-1.72×10^{-4}*	-1.39×10^{-6}	-8.21×10^{-9}	-5.08×10^{-3}***	-8.70×10^{-5}***	-1.65×10^{-6}***	-6.39×10^{-4}	-9.06×10^{-6}	-1.15×10^{-7}*
	(1.01×10^{-4})	(1.21×10^{-6})	(1.27×10^{-8})	(1.21×10^{-3})	(2.06×10^{-5})	(3.69×10^{-7})	(4.32×10^{-4})	(5.81×10^{-6})	(6.41×10^{-8})
Information and communications industry	-1.43×10^{-4}	-5.56×10^{-6}	-2.06×10^{-7}	-3.32×10^{-3}**	-6.97×10^{-5}***	-1.63×10^{-6}***	4.84×10^{-4}	7.89×10^{-6}**	1.09×10^{-7}***
	(7.53×10^{-4})	(1.72×10^{-5})	(4.21×10^{-7})	(9.11×10^{-4})	(1.52×10^{-5})	(2.83×10^{-7})	(3.28×10^{-4})	(2.59×10^{-6})	(3.11×10^{-8})
Other tertiary sector industries	3.79×10^{-4}*	5.21×10^{-6}*	-5.80×10^{-8}	-2.07×10^{-3}	-4.78×10^{-5}*	-1.09×10^{-6}	-3.42×10^{-4}	-5.27×10^{-6}	-8.72×10^{-8}
	(2.15×10^{-4})	(2.97×10^{-6})	(4.28×10^{-8})	(5.67×10^{-3})	(1.23×10^{-4})	(2.81×10^{-6})	(4.22×10^{-4})	(6.34×10^{-6})	(9.04×10^{-8})
Fixed-Effects:									
Firms	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Industry × Time	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
S.E.: Clustered	by: Firms	by: Firms	by: Firms	by: Firms	by: Firms	by: Firms	by: Firms	by: Firms	by: Firms
Number of observations		465			87			315	
R^2	0.818	0.880	0.879	0.928	0.955	0.954	0.949	0.949	0.949
Within R^2	0.015	0.010	0.006	0.203	0.186	0.176	0.013	0.014	0.013

One-way standard errors in parentheses

*Signif. symbols: *** :0.01, ** : 0.05, * : 0.1*

The values of parameter θ are significantly negative when transportation parameter t is set to 1.0 for the following three industry combinations of i (output industry) and j (input industry): 1) the manufacturing industry and the manufacturing industry, 2) the manufacturing industry and the information and communications industry, and 3) the information and communications industry and the information and communications industry. This negative θ means that the TFPs of output firms increase when the transportation costs from input firms to output firms decrease in these three industry combinations. The absolute value of the parameters in the information and communications industry is more than 10 times greater than that of the manufacturing industry. This shows that the value per unit of transportation cost is very high in the information and communications industry. The value per unit of transportation cost is composed of trade volume and per-transaction value. Similar results are observed when transportation parameter t is set to 1.5 or 2.0.

4.3 Quantifying locational externalities

4.3.1 Simulation

Using the estimated parameters in subsection 4.2, we estimate the sizes of locational externalities through a counterfactual simulation. The counterfactual scenario is that given the current trading partners, we increase the geographic concentration of firms by relocating several firms to two central locations of Tokyo. This scenario changes the trading distances of non-relocating firms as well as the relocating firms. These changes in trading costs of the non-relocating firms, which are ignored by the relocating firms for their relocation decisions, are the source of the locational externalities. By calculating the changes in trading costs by the non-relocating firms, we can evaluate the scale of locational externalities. This is interpreted as the benefits of relocating the firms. If we additionally consider the cost of buildings which the relocating firms use, we can calculate the social net benefit[10] of relocating the firms.

This subsection conducts analyses for all industries. Here, we randomly choose 5% of firms (13 firms), and relocate them to two specific areas one by one. The first one is the center of Marunouchi (the address is Marunouchi 1-chome). Marunouchi is close to the Tokyo Station and one of the most popular business areas in Japan for a long time. The other is the center of Shibuya (the address is Sakuragaoka-cho). In Shibuya, the IT industry and other industries have become increasingly concentrated in recent years. As the main objective is to analyze the changes in value-added arising from locational externalities (i.e. the social benefit), we do not consider the construction costs of new buildings that the moved firms use. The steps for the simulation case are shown below.

STEP 1) Choose a random 5% of firms from sample firms and relocate them to the specific area.

STEP 2) Recalculate the trading costs among firms for all the firms.

STEP 3) Recalculate *TFP* based on eq. (13) with the new trading costs.

STEP 4) Calculate the value-added by the renewed *TFP*, and calculate only the externality part (the change of *TFP* of a firm by the relocation of trading partners not the firms' own relocations), by subtracting the increase in their firms' own profits from the increase in the total value-added.

STEP 5) Repeat STEP 1) to STEP 4) 5000 times and draw a distribution of the change of

[10] Note that the increases in land rents or floor rents are not the social costs.

TFP.

Note that when the transportation costs between firms are changed by moving 5% of firms, the productivities of the moved firms as well as those of trading partners change. But the increases in their own productivities are not externalities. So, we exclude this increase from the change in value-added in STEP 4 to calculate locational externalities.

4.3.2 Results

Table 7 shows the results of the simulations for Marunouchi and Shibuya with transportation parameter t set to 1.0 and 2.0.[11] In each of these four cases, the value-added change for the moved firms and the value-added change for the non-moved firms are shown in terms of the amount and as a percentage of total value-added before relocation.

First, we focus on the results when the destination is Marunouchi and the transportation parameter is 1.0. The median value of locational externalities, which is change in value-added of non-moved firms, is 92.2 billion JPY, which is 1.92% of the total value-added of our sample firms. Furthermore, the value of locational externalities (92.2 billion JPY) is much larger than the benefit of moved firms (16.95 billion JPY).

In this simulation, moved firms do not incur increases in floor rents and building costs associated with the increase in floor areas. In the real world, they must pay higher rents if they move to the center. In other words, because such costs outweigh the increase in the benefit accruing to the moved firms, the moved firms in the simulations do not move in the real world. But, in the real world also, if they move, the increases in value-added of non-moved firms arise. The simulation implies that these increases amount to 1.92% of the total value-added in the Tokyo metropolitan area. This percentage is not negligible because the average growth rate

[11] The result for the case where transportation parameter t is set to 1.5 is omitted for readability purposes. The result is not significantly different from the case of t = 1.0 or 2.0

of real GDP during the period 1996-2015 in Japan is 0.8%.

Next, we focus on the results when the destination is the center of Shibuya and the transportation parameter t is 1.0. The median value of locational externalities is 61.7 billion JPY, which is 1.29% of the total value-added of our sample firms. This external benefit is also not negligible, since it is a larger percentage than the above-mentioned GDP growth rate although the median value is less than when the destination is set to the center of Marunouchi.

Figure 7 shows the distribution of the estimated locational externalities for Marunouchi and Shibuya at t = 1.0. Almost all the results are located in the positive region. Thus, the relocation of firms generates significant positive locational externalities for non-moved firms. We can observe that the distribution in the Shibuya case is slightly larger than that in the Marunouchi case. In fact, the area where the rate of increase in total value-added for non-moved firms exceeds 7.5% is greater in the Shibuya case (751 times) than in the Marunouchi case (614 times). This implies that Shibuya is a district that can generate more value-added than Marunouchi if we choose appropriate firms to move.

Next, when transportation parameter t is 2.0, the median value-added change for non-moved firms is lower than when transportation parameter t is 1.0. This feature can be shown by comparing Figure 8 and Figure 7. Figure 8 shows the distribution of the estimated locational externalities for Marunouchi and Shibuya at t = 2.0. Note that the maximum value of x axis and y axis differs between Figures 7 and 8. Even when t is 2.0, almost all the results are located in the positive region, but they are distributed mostly in the 0.0% to 0.1% range.

Table 7. Summary of locational externalities (the all-industry case)

(Unit: JPY Billion)

Destination		Marunouchi		Shibuya	
Transportation parameter		t = 1.0	t = 2.0	t = 1.0	t = 2.0
Value-added before relocation		5.08			
Changes in value-added of non-moved firms	Average	151.44	104.02	148.32	118.05
	%	3.16	2.13	3.09	2.42
	Median (a)	92.20	14.42	61.70	17.92
	%	1.92	0.30	1.29	0.37
	98th percentile	569.13	688.68	601.53	839.69
	%	11.86	14.10	12.53	17.19
	2nd percentile	-26.42	-72.33	-13.32	-1.42
	%	-0.55	-1.48	-0.28	-0.03
Changes in value-added of moved firms	Average	32.04	15.92	16.66	10.78
	%	11.41	8.18	5.93	5.54
	Median (b)	16.95	3.41	6.46	1.59
	%	6.03	1.75	2.30	0.82
Externalities for non-moved firms/ Total benefits to firms	Ratio (a/a+b)	0.84	0.81	0.91	0.92

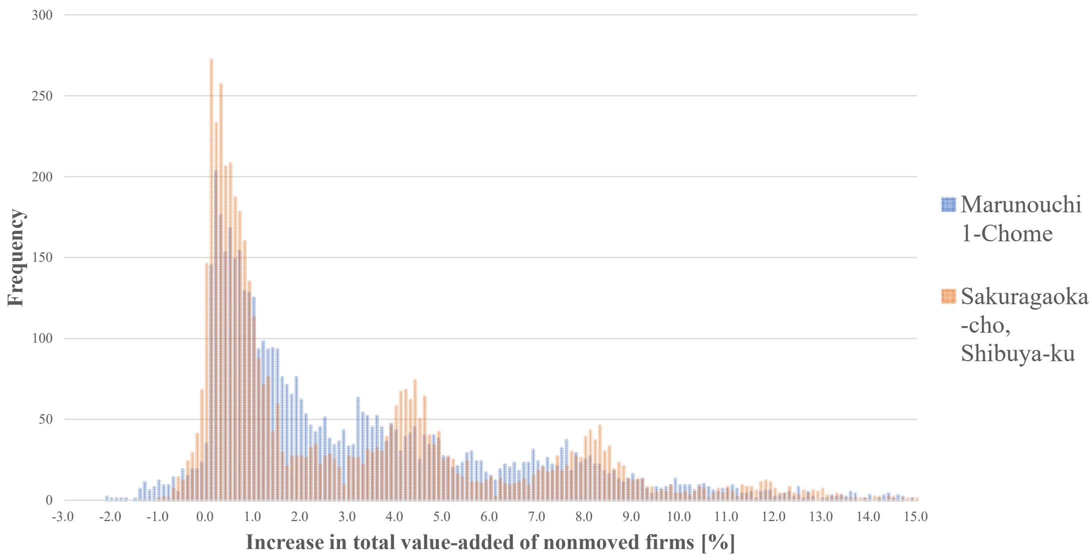


Figure 7. The frequency of increase in total value-added (t = 1.0)

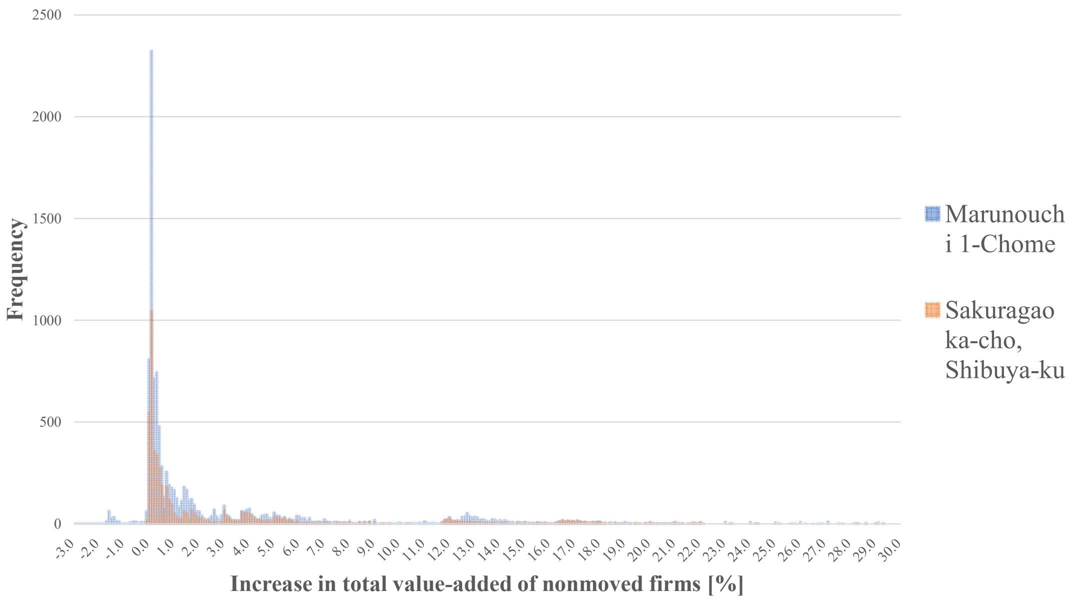


Figure 8. The frequency of increase in total value-added of non-moved firms (t = 2.0)

4.3.3 Additional simulations (Selected firms)

We find that firms in the manufacturing and the information and communications industries located in Saitama, Chiba, and Kanagawa are more frequently among the moved firms when external benefits are higher in the previous simulation by analyzing what kind of firms generate high external benefits.[12] To directly investigate whether such firms really generate high external benefits, we conduct additional simulations. Here we consider three cases. The first is the case where the targeted moving firms are limited to the manufacturing industry; the second is the case where the targeted moving firms are limited to the information and communications industry; and the third is the case where the targeted moving firms are limited to firms located in Saitama, Chiba, and Kanagawa. For each of the three cases, we randomly choose 13 firms (which is the same number as in subsection 4.3.1) and relocate them to two specific areas, the centers of Marunouchi and Shibuya one by one. The other steps for each simulation case are the same as in subsection 4.3.1.

[12] Refer to the Supplement 8.3 for this analysis.

4.3.4 Results of simulations in the case of the transfer of selected firms

Table 8 shows the results of the simulations for all industries, the manufacturing industry, and the information and communications industry. The result for all industries is the same as in subsection 4.3.2, but we include it in the table for reference. Here we only calculate the t = 1.0 case.[13] The structure of this table follows Table 7. First, a comparison with the median changes in value-added of non-moved firms shows that it is about two to four times larger than the case for all industries.

Looking at the 98th percentile value of changes in value-added of non-moved firms, the case when firms in the manufacturing industry are moved to the center of Shibuya is the highest of the six cases, at 792.3 billion yen, which is 17.6% of the total value-added of our sample firms. This means that the manufacturing firms would generate more external benefits by moving to Shibuya than to Marunouchi, although the numbers of firms and trading partnerships in Marunouchi are much higher than those in Shibuya as shown in Figure 2. This implies that Shibuya has a high value for location of firms in the manufacturing industry.

On the other hand, when firms in the information and communications industry are moved, the 98th percentile value of changes in value-added of non-moved firms is not as high as that in the manufacturing case, but rather lower than that in the all-industry case. However, the median value and the 2nd percentile value of changes in value-added of non-moved firms are higher than in the other cases, for the cases of both Marunouchi and Shibuya. The value of changes in value-added of non-moved firms does not change significantly whether the destination is the center of Marunouchi or Shibuya, but changes in value-added of moved firms are different. When the destination is the center of Shibuya, the median value of changes in value-added of moved firms is negative. This suggests that these firms strongly prefer to be located outside of Shibuya.

[13] The results for the cases where transportation parameter t is set to 1.5 and 2.0 are omitted for ease of viewing. The result is not significantly different from the case of t=1.0.

Table 8. Summary of locational externalities (the transfer of firms in manufacturing and the information and communications industry)

(Unit: JPY Billion)

Industry of moved firms		All		Manufacturing		Information and Communications	
Destination		Marunouchi	Shibuya	Marunouchi	Shibuya	Marunouchi	Shibuya
Transportation parameter		t = 1.0					
Value-added before relocation		5.08					
Changes in value-added of non-moved firms	Average	151.44	148.32	232.27	233.96	283.67	251.28
	%	3.16	3.09	5.16	5.19	5.77	5.11
	Median (a)	92.20	61.70	187.39	203.82	288.02	268.64
	%	1.92	1.29	4.16	4.52	5.86	5.47
	98th percentile	569.13	601.53	730.02	792.30	529.48	470.16
	%	11.86	12.53	16.21	17.59	10.77	9.57
	2nd percentile	-26.42	-13.32	-16.60	-7.73	26.14	29.58
	%	-0.55	-0.28	-0.37	-0.17	0.53	0.60
Changes in value-added of moved firms	Average	32.04	16.66	46.40	33.98	80.73	-9.02
	%	11.41	5.93	8.06	5.90	48.80	-5.46
	Median (b)	16.95	6.46	32.57	20.50	80.53	-8.09
	%	6.03	2.30	5.66	3.56	48.72	-4.89
Externalities for non-moved firms/ Total benefits to firms	Ratio (a/a+b)	0.84	0.91	0.85	0.91	0.78	1.03

Table 9 shows the results of the simulations for all firms and firms located in Saitama, Chiba, and Kanagawa. The result for all areas is the same as in subsection 4.3.2, but we include it in the table for reference. The structure of this table follows Tables 7 and 8. The median value of locational externalities, which is change in value-added of non-moved firms with the center of Shibuya as the destination, are 535.9 billion JPY, which is a remarkable 10.7% of the total value-added of our sample firms. This median value is the highest among the moving patterns in the simulations addressed in this research. Furthermore, even the 2nd percentile value of changes in value-added of non-moved firms is high, at 34.5 billion JPY, which is 0.69% of the total value-added of our sample firms. This implies that these firms have many input firms around Shibuya. However, these firms are located far from input firms since they only consider their production costs, i.e., low rents and their own trading costs, and ignore trading costs paid by trading partner firms. Therefore, it is desirable that these firms are preferentially targeted as a location policy and agglomerated around Shibuya because of the large scale of their locational externalities.

Table 9. Summary of locational externalities (the transfer from Saitama, Chiba, and Kanagawa)

(Unit: JPY Billion)

Areas of moved firms		All		Saitama, Chiba, and Kanagawa	
Destination		Marunouchi	Shibuya	Marunouchi	Shibuya
Transportation parameter		t = 1.0			
Value-added before relocation		5.08			
Changes in value-added of non-moved firms	Average	151.44	148.32	505.63	555.13
	%	3.16	3.09	10.05	11.04
	Median (a)	92.20	61.70	487.42	535.91
	%	1.92	1.29	9.69	10.66
	98th percentile	569.13	601.53	1151.59	1246.10
	%	11.86	12.53	22.90	24.78
	2nd percentile	-26.42	-13.32	22.83	34.52
	%	-0.55	-0.28	0.45	0.69
Changes in value-added of moved firms	Average	32.04	16.66	74.62	73.14
	%	11.41	5.93	144.61	141.73
	Median (b)	16.95	6.46	48.92	48.61
	%	6.03	2.30	94.79	94.21
Externalities for non-moved firms / Total benefits to firms	Ratio (a/a+b)	0.84	0.91	0.91	0.92

5. Conclusion

The current paper empirically estimates the size of the locational externalities generated by firm-to-firm trades. We theoretically identify trading patterns which generate locational externalities from general trading patterns including unilateral trades as well as bilateral trades. Then, we calculate the share of actual trade patterns which generate locational externalities in the Tokyo metropolitan area by using Japanese firm-to-firm trade data. As a result, the ratios of trade affected by and generating locational externalities as a percentage of total trade were 24% and 21%, respectively.

Next, we quantitatively analyze the scale of locational externalities in the Tokyo metropolitan area. We estimate the parameter of the quantitative model including firm-to-firm trade relationship in the production function considering firm fixed effects. Then, we estimate the scale of locational externalities by counterfactual simulation analyses using the estimated parameters.

The simulations find that, under the scenario that a randomly-chosen 5% of the firms move to the center of Marunouchi, which is one of the important business areas in Tokyo, positive locational externalities of approximately 92.2 JPY billion (14.4 JPY billion) is generated in terms of value-added when transportation parameter, $t = 1.0$ ($t = 2.0$), which are 1.92% (0.30%) of the total value-added of our sample firms. Next, we find that firms located far from Tokyo, such as in Chiba, Kanagawa, and Saitama prefectures and firms in the manufacturing and information and communications industries have higher external benefits. For example, the median value of locational externalities in the case of the move of firms located in Chiba, Kanagawa, and Saitama prefectures, to the center of Shibuya, is 535.9 billion JPY, which is a remarkable 10.7% of the total value-added of our sample firms.

Our results show that appropriate relocations of firms can generate large positive agglomeration economies through locational externalities. In policies other than such firm relocation policies, policy makers should consider this locational externality. For example, when constructing a new transportation facility, it is possible to perform a more accurate cost-benefit analysis by considering the effect of locational externalities. By identifying industries that would potentially benefit from locational externalities, we can internalize this effect by location subsidies or land use regulations.

Appendix. NITAS (National Integrated Transport Analysis System)

We calculate the generalized costs of transport using the following parameters: hour unit price is 1,200 JPY/hour, fuel efficiency is 10 km/liter, gasoline cost is 100 JPY/liter, and walking speed is 4 km/hour.

References

Beckmann, M. J. (1976), Spatial equilibrium in the dispersed city, *Environment, Regional Science and Interregional Modeling*, pp.132-141

Bernard, A. B., Moxnes, A., & Saito, Y. U. (2019). Production networks, geography, and firm performance. Journal of Political Economy, 127(2), 639-688.

Bröcker, J. (1998). Operational spatial computable general equilibrium modeling, the annals of regional science, Vol.32, pp.367-387, 1998.

Hanck, C., Arnold, M., Gerber, A., & Schmelzer, M. (2019). Introduction to Econometrics with R. University of Duisburg-Essen, 1-9.

Ciccone, A. (2002). Agglomeration effects in Europe. European Economic Review, 46 (2), 213-227.

Ciccone, A., & Hall, R. E. (1996). Productivity and the density of economic activity (No. w4313). National Bureau of Economic Research.

Dixon, P.B. and D.W. Jorgenson (2013, editors). Handbook of Computable General Equilibrium Modeling, Vol.1 and 2, Elsevier, Amsterdam,

Ellison, G., Glaeser, E. L., & Kerr, W. R. (2010). What causes industry agglomeration? Evidence from coagglomeration patterns. American Economic Review, 100(3), 1195-1213.

Fujita, M., & Ogawa, H. (1982). Multiple equilibria and structural transition of non-monocentric urban configurations. Regional science and urban economics, 12 (2), 161-196.

Fujita, M., & Thisse, J. F. (2002). Economics of agglomeration: Cities, industrial locations, and regional growth. Cambridge: Cambridge University Press.

Furusawa, T., Inui, T., Ito, K., and Tang, H. (2017). Global Sourcing and Domestic Production Networks, CESifo Working Paper, No. 6658

Graham, D. J. (2005). Wider economic benefits of transport improvements: link between agglomeration and productivity- stage 1 report.

Graham, D. J. (2006). Wider economic benefits of transport improvements-link between agglomeration and productivity-stage 2 report.

Henderson, J. V. (2003). Marshall's scale economies. Journal of urban economics, 53(1), 1-28.

Jofre-Monseny, J., Marín-López, R., & Viladecans-Marsal, E. (2014). The determinants of localization and urbanization economies: Evidence from the location of new firms in Spain. Journal of Regional Science.

Kanemoto, Y., Ohkawara, T., & Suzuki, T. (1996). Agglomeration economies and a test for optimal city sizes in Japan. Journal of the Japanese and International Economies, 10, 379-398.

Kanemoto, Y. (1990). Optimal cities with indivisibility in production and interactions between firms. Journal of Urban Economics, 27, 46-59.

Karato, H. (2006). Benefits and costs of the reforms to the plot ratio regulations. Japan Center for Economic Research, 53, 42-71. (in Japanese)

Kawashima, T. (1975). Urban agglomeration economies in manufacturing industries. Papers in Regional Science, 34 (1), 157-172.

Kono, T. and Joshi, K., K., (2018). Spatial externalities and land use regulation: an integrated set of multiple density regulations, Journal of Economic Geography 18, 571–598.

Kono, T., Nakajima, K., & Shoda, K. (2019). External Benefits of Geographical Concentration of Firms with Trade Networks. SSRN Electronic Journal, 1–29.

Lucas, R. E., & Rossi–Hansberg, E. (2002). On the internal structure of cities. Econometrica, 70(4), 1445-1476.

Marshall, A., Principles of economics (8th edition) Macmillan, New York (1890).

Miyauchi, Y. (2023) Matching and Agglomeration: Theory and Evidence from Japanese Firm-to-Firm Trade. mimeograph.

Moretti, E. (2004). Workers education, spillovers, and productivity: Evidence from plant-level production functions. The American Economic Review, 94 (3), 656-690.

Nakajima, K., Saito, Y., and Uesugi, I. (2012) Localization of Interfirm Transaction Relationships and Industry Agglomeration, RIETI Discussion Paper Series, 12-E-23.

Ogawa, H., & Fujita, M. (1980). Equilibrium land use patterns in a monocentric city. Journal of regional science, 20 (4), 455-475.

Ohnishi, T., Takayasu, H., & Takayasu, M. (2009). Hubs and authorities on Japanese inter-firm network: characterization of nodes in very large directed networks. Progress of Theoretical Physics Supplement, 179, 157-166.

Ohnishi, T., Takayasu, H., & Takayasu, M. (2010a). Network motifs in an inter-firm network. Journal of Economic Interaction and Coordination, 5 (2), 171-180.

Ohnishi, T., Takayasu, H., & Takayasu, M. (2010b). Mathematical structure of an inter-firm network. Bulletin for the Japan Society for Industrial and Applied Mathematics, 20, 223-235

Ravinder, K., & Kono, T. (2007). Location externality and its impact on transportation cost. Journal of the Eastern Asia Society for Transportation Studies, 7, 441-453.

Rosenthal, S. S., Strange, W. C. (2003). Geography, industrial organization, and agglomeration. Review of Economics and Statistics, 85, 377-393.

Rossi-Hansberg, E. (2004). Optimal urban land use and zoning. Review of Economic Dynamics, 7(1), 69-106.

Shoven, J.B. and Whalley, J. (1992). Applying General Equilibrium, Cambridge University Press, 1992.

Sveikauskas, L. (1975). The productivity of cities. The Quarterly Journal of Economics, 89, 393-413.

Tabuchi, T., & Yoshida, A. (2000). Separating urban agglomeration economies in consumption and production. Journal of Urban Economics, 48, 70-84.

Zhang, W., Kockelman, K. M. (2016). Congestion pricing effects on firm and household location choices in monocentric and polycentric cities. Regional Science and Urban Economics, 58, 1-1

Supplement

8.1 Classifying trading structures of firms into patterns in 2010 and 2015

Table S1 shows frequency of each type of trading structure in the Tokyo metropolitan area for 2010 and 2015. The results are similar to Table 1. There exist significant shares of trades which are affected by locational externalities (28%) and generate locational externalities (25%) in 2010. There exist significant shares of trades which are affected by locational externalities (27%) and generate locational externalities (24%) in 2015.

Table S1. Number of trade partnerships by trading types in 2010 and 2015

	Time period = 2010				Time period = 2015			
	Trading partnerships receiving locational externalities		Trading partnerships generating locational externalities		Trading partnerships receiving locational externalities		Trading partnerships generating locational externalities	
type 1	27841	5.80%	27841	5.80%	32641	6.02%	32641	6.02%
type 2	55682	11.59%	55682	11.59%	65282	12.03%	65282	12.03%
type 3	93582	19.48%	93582	19.48%	105372	19.43%	105372	19.43%
type 4	46791	9.74%	46791	9.74%	52686	9.71%	52686	9.71%
type 5	*51035	10.63%	51035	10.63%	*59882	11.04%	59882	11.04%
type 6	51035	10.63%	*51035	10.63%	59882	11.04%	*59882	11.04%
type 7	51035	10.63%	51035	10.63%	59882	11.04%	59882	11.04%
type 8	*14829	3.09%	14829	3.09%	*16232	2.99%	16232	2.99%
type 9	*14829	3.09%	*14829	3.09%	*16232	2.99%	*16232	2.99%
type 10	*14829	3.09%	*14829	3.09%	*16232	2.99%	*16232	2.99%
type 11	*14025	2.92%	*14025	2.92%	*13766	2.54%	*13766	2.54%
type 12	*14025	2.92%	*14025	2.92%	*13766	2.54%	*13766	2.54%
type 13	14025	2.92%	14025	2.92%	13766	2.54%	13766	2.54%
type 14	*1654	0.34%	1654	0.34%	*1977	0.36%	1977	0.36%
type 15	1654	0.34%	*1654	0.34%	1977	0.36%	*1977	0.36%
type 16	1654	0.34%	1654	0.34%	1977	0.36%	*1977	0.36%
type 17	*411	0.09%	*411	0.09%	*501	0.09%	*501	0.09%
type 18	*2911	0.61%	*2911	0.61%	*2478	0.46%	*2478	0.46%
type 19	*5822	1.21%	*5822	1.21%	*4956	0.91%	*4956	0.91%
type 20	*294	0.06%	294	0.06%	309	0.06%	309	0.06%
type 21	*588	0.12%	*588	0.12%	*618	0.11%	*618	0.11%
type 22	*444	0.09%	*444	0.09%	*506	0.09%	*506	0.09%
type 23	222	0.05%	222	0.05%	253	0.05%	253	0.05%
type 24	*192	0.04%	*192	0.04%	*234	0.04%	*234	0.04%
type 25	*192	0.04%	*192	0.04%	*234	0.04%	*234	0.04%
type 26	*192	0.04%	*192	0.04%	*234	0.04%	*234	0.04%
type 27	*143	0.03%	*143	0.03%	*156	0.03%	*156	0.03%
type 28	*143	0.03%	*143	0.03%	*156	0.03%	*156	0.03%
type 29	*143	0.03%	*143	0.03%	*156	0.03%	*156	0.03%
type 30	*66	0.01%	*66	0.01%	*93	0.02%	*93	0.02%
Total	*136767	28.48%	*121644	25.33%	*148718	27.42%	*132177	24.37%

8.2 Estimated parameters for different industry categories

We estimate parameters not only by the industry classification shown in subsection 4.2.1, but also by two other industry classifications. The first is the industry classification divided into three sectors: all industries, secondary industries, and tertiary industries. The second is the industry classification divided into ten sectors. The industry classification follows the Japan Standard Industrial Classification.

Table S2 shows the regression results based on the first industry classification. The three industry sectors in the rows are output industries; the three industry sectors in the columns are input industries. Parameters are estimated with transportation parameter t set to 1. The table shows the values of parameter θ and one-way standard (firm) errors in parentheses below the values. The values of parameter θ are significantly negative for the following three industry combinations of i (output industry) and j (input industry): 1) All industries and All industries, 2) Secondary industries and Secondary industries, and 3) Secondary industries and Tertiary industries.

Table S3 shows the regression results of the second industry classification. The ten industry sectors in the rows are output industries; the ten industry sectors in the columns are input industries. The parameters are estimated with transportation parameter t set to 1. The values of parameter θ are significantly negative for the following three industry combinations of i (output industry) and j (input industry): 1) manufacturing and manufacturing, 2) manufacturing and the information and communications industry, 3) the information and communications industry and the information and communications industry, 4) the wholesale and retail trade and the transport and postal services industry, 5) the real estate and goods rental and leasing industry and the wholesale and retail trade industry, 6) the wholesale and retail trade and the accommodations, eating, and drinking services industry, and 7) the wholesale and retail trade and the living related and personal services and amusement services industry.

These results are similar to the results shown in subsection 4.2.1 in terms of the features shown in the main text.

Table 10. Estimated parameters of the industry classification divided into 3 sectors

j \ i	All industries	Secondary industries	Tertiary industries
All industries	-2.10×10^4**	-	-
	(9.00×10^4)	-	-
Secondary industries	-	-1.59×10^4**	-4.72×10^4*
	-	(7.44×10^5)	(2.52×10^4)
Tertiary industries	-	1.33×10^4	-3.04×10^4
	-	(1.52×10^4)	(3.36×10^4)
Fixed-Effects:			
Firms	Yes	Yes	Yes
Industry × Time	Yes	Yes	Yes
S.E.: Clustered	by: Firms	by: Firms	by: Firms
Number of observations	1,845	729	681
R^2	0.957	0.917	0.957
Within R^2	0.003	0.006	0.008

One-way standard errors in parentheses

*Signif. symbols: *** :0.01, ** : 0.05, * : 0.1*

Table S3. Estimated parameters of each sector

j \ i	Manufacturing	Information and Communications	Transport and Postal Services
Manufacturing	-0.0002. (9.99e-5)	-0.004*** (0.0006)	1.33e-5 (8e-5)
Information and Communications	-2.81e-7 (0.0007)	-0.003** (0.0008)	
Transport and Postal Services	-0.0007 (0.0007)		-0.0004 (0.0004)
Wholesale and Retail Trade	0.0004. (0.0002)	0.003 (0.004)	-0.0009** (0.0003)
Finance and Insurance			
Real Estate and Goods Rental and Leasing		-0.038* (0.014)	
Scientific Research, Professional and Technical Services	-0.005 (0.005)	0.003. (0.002)	
Accommodations, Eating and Drinking Services			
Living Related and Personal Services and Amusement Services			
Services, N E C	0.0005** (0.0001)		
Fixed-Effects:	------------------	------------------	------------------
firm	Yes	Yes	Yes
industry × time	Yes	Yes	Yes
S E : Clustered		by: firm	
Observations	465	87	60
R2	0.88	0.96	0.98
Within R2	0.02	0.31	0.05

j \ i	Wholesale and Retail Trade	Real Estate and Goods Rental and Leasing	Scientific Research, Professional and Technical Services
Manufacturing	-0.001 (0.0007)	-0.015 (0.060)	
Information and Communications	0.0006** (0.0002)	-0.042 (0.055)	0.038* (0.012)
Transport and Postal Services	-0.0005 (0.0008)		
Wholesale and Retail Trade	-2.25e-5 (0.0005)	0.001 (0.002)	
Finance and Insurance	0.001* (0.0005)		
Real Estate and Goods Rental and Leasing	-0.088** (0.033)	0.004 (0.008)	
Scientific Research, Professional and Technical Services	0.069** (0.025)		-1.73e-5 (0.002)
Accommodations, Eating and Drinking Services	0.002 (0.003)		
Living Related and Personal Services and Amusement Services			
Services, N E C	-0.489** (0.179)		
Fixed-Effects:	-----------------	--------------	----------------
firm	Yes	Yes	Yes
industry × time	Yes	Yes	Yes
S E : Clustered		by: firm	
Observations	180	15	12
R2	0.96	0.94	0.86
Within R2	0.11	0.09	0.09

j \ i	Accommodations, Eating, and Drinking Services	Living Related and Personal Services and Amusement Services	Edcuation, Learning Support
Manufacturing	-0.003 (0.004)		0.002 (NaN)
Information and Communications	0.019* (0.004)	-0.005 (0.006)	0.070 (NaN)
Transport and Postal Services		0.002* (0.0006)	
Wholesale and Retail Trade	-0.033** (0.003)	-0.005*** (0.0001)	
Finance and Insurance			
Real Estate and Goods Rental and Leasing			
Scientific Research, Professional and Technical Services		0.017*** (0.0002)	
Accommodations, Eating and Drinking Services			
Living Related and Personal Services and Amusement Services	-0.003* (0.0009)		
Services, N E C			
Fixed-Effects:	----------------	------------------	-----------
firm	Yes	Yes	Yes
industry × time	Yes	Yes	Yes
S E : Clustered		by: firm	
Observations	12	15	6
R2	0.99	1.00	1.00
Within R2	0.94	0.79	1.00

j \ i	Services, N E C
Manufacturing	0.0009 (0.0007)
Information and Communications	
Transport and Postal Services	
Wholesale and Retail Trade	0.005** (0.0006)
Finance and Insurance	
Real Estate and Goods Rental and Leasing	
Scientific Research, Professional and Technical Services	
Accommodations, Eating and Drinking Services	
Living Related and Personal Services and Amusement Services	
Services, N E C	-0.001 (0.001)
Fixed-Effects:	---------------
firm	Yes
industry × time	Yes
S E : Clustered	by: firm
Observations	12
R2	0.93
Within R2	0.64

8.3 Factor analysis of results

In the 5,000 simulations performed in subsection 4.3.2, we find that there is variation in the scale that generates locational externalities. In this section, we identify what characteristics of firms cause these variations. We analyze the firms by industry (the manufacturing, the information and communications, and other tertiary sector industries) and by prefecture (Tokyo, Saitama, Chiba, and Kanagawa).[14] The procedure is divided into three parts. First, the percentage change in value-added of non-moved firms in the simulation conducted earlier is divided into 2.5% categories. Next, we add up all the moved firms in each category. Finally, we calculate the percentage of firms in each category along the two characteristics.

Figure S1 shows the share of industries by level of locational externalities. The horizontal axis shows the percentage of increase in total value-added of non-moved firms divided by 2.5%. S stands for Shibuya and refers to the simulation with the center of Shibuya as the destination. Similarly, M stands for Marunouchi and refers to the simulation with the center of Marunouchi as the destination. The vertical axis is the share of industries. Firms divided into the manufacturing and the information and communications industries are more frequently among the moved firms when external benefits are higher due to the location simulation. This implies that the move of more firms in the manufacturing and the information and communications industries that supply to firms in the vicinity of Shibuya or Marunouchi would generate greater value-added.

Figure S2 shows the share of prefectures in which firms are located. The horizontal and vertical axes are the same as in Figure 9. Firms located in Saitama, Chiba, or Kanagawa are more frequently among the moved firms when external benefits are higher due to the location simulation. This implies that the move of more firms located outside of Tokyo prefecture that supply to firms in the vicinity of Shibuya or Marunouchi would generate greater value-added.

[14] We also analyze which trading patterns generate high benefits, which is discussed in Section 3. See the Supplement for the results.

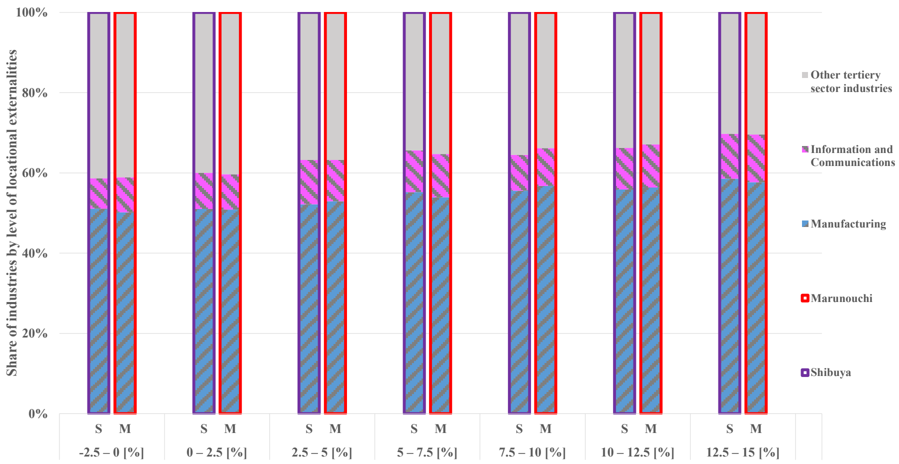


Figure S1. Share of industries by level of locational externalities

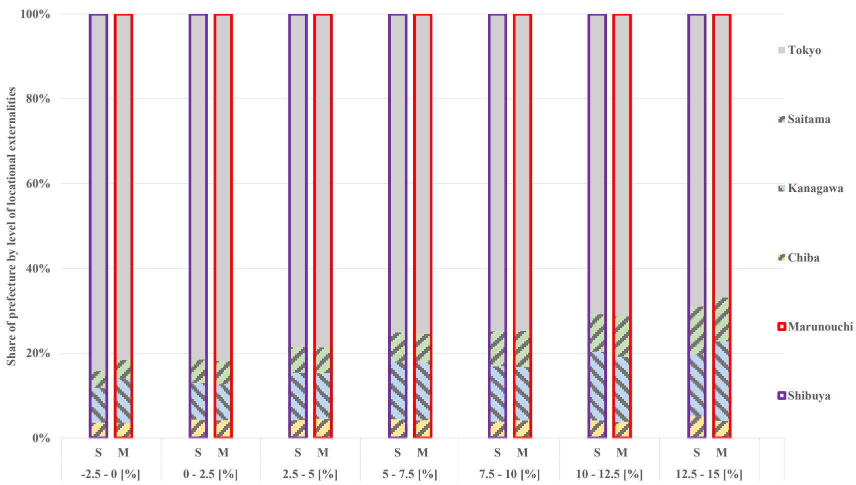


Figure S2. Percentage of applicable prefecture

To summarize this discussion, the move of firms in the manufacturing and the information and communications industries, as well as firms located outside of Tokyo, is more likely to generate high external benefits. This is probably because these firms consider only their own trading costs and ignore trading costs paid by its trading partners when making location decisions.

8.4 Other results of simulations

Table S4 shows the results of the simulations for Marunouchi and Shibuya with transportation parameter *t* set to 1.0, 1.5, and 2.0. The features are similar regardless of whether *t* = 1.0, 1.5, or 2.0. The median values of changes in value-added of non-moved firms at *t* = 1.5 are lower than when *t* = 1.0 or 2.0. The parameter of manufacturing firm is not significant at *t* = 1.5.

Table S4. Summary of locational externalities with *t* set to 1.0, 1.5, and 2.0

(Unit: JPY Billion)

Destination		Marunouchi			Shibuya		
		t=1.0	*t*=1.5	*t*=2.0	*t*=1.0	*t*=1.5	*t*=2.0
Value-added before relocation		5.08					
Changes in value-added of non-moved firms	Average	151.44	27.95	104.02	148.32	28.09	118.05
	%	3.16	0.56	2.13	3.09	0.57	2.42
	Median (a)	92.20	0.12	14.42	61.70	0.32	17.92
	%	1.92	0.00	0.30	1.29	0.01	0.37
	98th percentile	569.13	256.79	688.68	601.53	202.92	839.69
	%	11.86	5.17	14.10	12.53	4.08	17.19
	2nd percentile	-26.42	-2.42	-72.33	-13.32	-4.84	-1.42
	%	-0.55	-0.05	-1.48	-0.28	-0.10	-0.03
Changes in value-added of moved firms	Average	32.04	5.64	15.92	16.66	0.64	10.78
	%	11.41	5.05	8.18	5.93	0.57	5.54
	Median (b)	16.95	0.00	3.41	6.46	0.00	1.59
	%	6.03	0.00	1.75	2.30	0.00	0.82
Externalities for non-moved firms / Total benefits to firms	Ratio (a/a+b)	0.84	1.00	0.81	0.91	1.00	0.92

8.5 Factor analysis of results by trading pattern

We analyze another point to see what kind of firms generates more external benefits. That is by trading pattern introduced in Section 2. The procedure is the same as that in subsection 6.2.

Figure S3 shows the share of industries by level of locational externalities. The horizontal axis is the percentage increase in total value-added of non-moved firms by 2.5%. S stands for Shibuya and refers to the simulation with the center of Shibuya as the destination. M stands for Marunouchi and refers to the simulation with the center of Marunouchi as the destination. The vertical axis is the share of industries by level of locational externalities by trading types. Surprisingly, the percentage of firms with transactions that generate location externalities is almost constant regardless of the size of the external benefits of the relocation of firms.

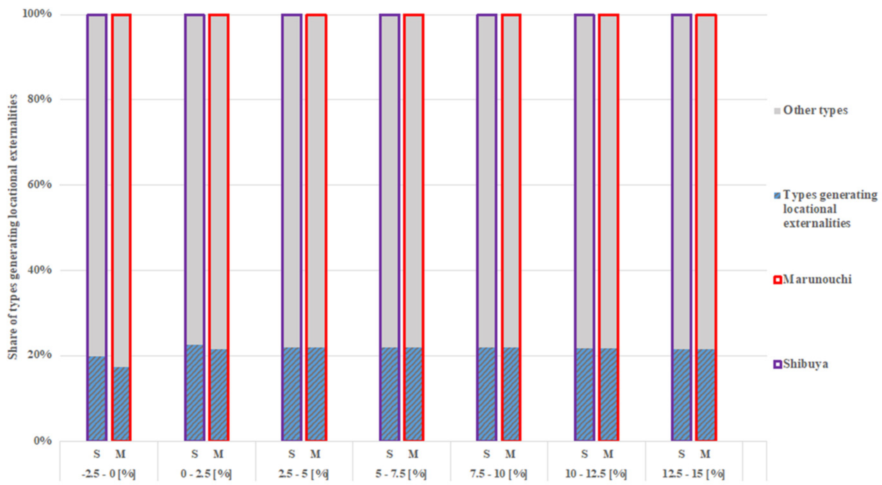


Figure S3. Share of industries by level of locational externalities

8.6 Other results of additional simulations

In this subsection, we show the results for additional simulations when transportation parameter *t* is 2.0. The results are similar to the results when *t* = 1.0.

Table S5 shows the results of the simulations for all industries, the manufacturing industry, and the information and communications industry. The result for all industries is the same as in subsection 4.3.2, but we include it in the table for reference. Here we only calculate the *t* = 2.0 case. The structure of this table follows Table 7. The median change in value-added of non-moved firms in the information and communications industry is much higher than that in other industries.

Table S6 shows the results of the simulations for all firms and firms located in Saitama, Chiba, and Kanagawa. The result for all areas is the same as in subsection 4.3.2, but we include it in the table for reference. The structure of this table follows Table 8. The 98th percentile value of locational externalities, which is change in value-added of non-moved firms with the destination as the center of Shibuya, are 1,450.3 billion JPY, which is 29.11 % of the total value-added of our sample firms. This implies that these firms have many input firms around

Shibuya.

Table S5. Summary of locational externalities in the manufacturing and the information and communications industry when t = 2.0

(Unit: JPY Billion)

Industry of moved firms		All		Manufacturing		Information and Communications	
Destination		Marunouchi	Shibuya	Marunouchi	Shibuya	Marunouchi	Shibuya
Transportation parameter		t = 2.0					
Value-added before relocation		5.08					
Changes in value-added of non-moved firms	Average	104.02	118.05	155.67	173.36	305.91	343.33
	%	2.13	2.42	3.28	3.66	6.36	7.14
	Median (a)	14.42	17.92	26.06	27.93	316.38	351.83
	%	0.30	0.37	0.55	0.59	6.58	7.32
	98th percentile	688.68	839.69	842.02	904.54	567.61	638.90
	%	14.10	17.19	17.76	19.07	11.81	13.29
	2nd percentile	-72.33	-1.42	-75.36	-0.99	20.09	43.54
	%	-1.48	-0.03	-1.59	-0.02	0.42	0.91
Changes in value-added of moved firms	Average	15.92	10.78	0.00	0.00	48.65	19.34
	%	8.18	5.54	0.00	0.00	17.80	7.06
	Median (b)	3.41	1.59	0.00	0.00	45.93	14.79
	%	1.75	0.82	0.00	0.00	16.78	5.40
Externalities for non-moved firms/ Total benefits to firms	Ratio (a/a+b)	0.81	0.92	1.00	1.00	0.87	0.96

Table S6. Summary of locational externalities in Saitama, Chiba, and Kanagawa

(Unit: JPY Billion)

Areas of moved firms		All		Saitama, Chiba, and Kanagawa	
Destination		Marunouchi	Shibuya	Marunouchi	Shibuya
Transportation parameter		t = 2.0			
Value-added before relocation		5.08			
Changes in value-added of non-moved firms	Average	104.02	118.05	432.42	446.58
	%	2.13	2.42	8.68	8.97
	Median (a)	14.42	17.92	312.93	265.76
	%	0.30	0.37	6.28	5.33
	98th percentile	688.68	839.69	1304.75	1450.30
	%	14.10	17.19	26.19	29.11
	2nd percentile	-72.33	-1.42	1.13	0.83
	%	-1.48	-0.03	0.02	0.02
Changes in value-added of moved firms	Average	15.92	10.78	25.11	21.74
	%	8.18	5.54	25.38	21.98
	Median (b)	3.41	1.59	6.08	5.56
	%	1.75	0.82	6.15	5.62
Externalities for non-moved firms / Total benefits to firms	Ratio (a/a+b)	0.81	0.92	0.98	0.98