Technological Externalities and Economic Distance: A Case of the Japanese Automobile Suppliers*

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Abstract

This paper in the spirit of Marshall(1920) raise a question of how economic distance affects the firms' productivities, focusing upon roles of idea in sharing technological knowledge or information between firms. In order to quantify the degree of knowledge spillover or information sharing, we take production function approach. Assuming core-periphery structure around automobile assemblies surrounded with auto-parts suppliers, we estimate plant-level production functions of the Japanese auto-parts suppliers, where productivity function depends upon economic distance measuring information sharing with both geographic plant location and membership of technological cooperation associations. We take econometric issues of cross-sectional dependence of productivities and a simultaneity problem between inputs, applying methods to the standard OLS and GMM estimators. Positive technological externalities(i.e. agglomeration effects) are seen in general or for independent plants, the fact which is robust to specifications of the production functions. Agglomeration effects are rarely observed for relation-specific or cooperative plants. Some of them cost the auto-parts plants substantial negative externalities. Once a simultaneity problem is econometrically considered, instead of increasing returns, decreasing returns to scale emerge in cases of total materials. Agglomeration, if any, could be brought about not by increasing returns to scale, but by productivities spillover among proximate suppliers around automobile assemblies.

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1 Introduction

Spatial and growth economics look to the productivities of firms as a primary driving force of economic development. Consequently, productivity analysis investigates how to quantify the unobservable stuff and capture the effects upon economic development. However, while the measurements of productivities are well understood, relatively little is known about how *economic distance* affects the productivities and firms' growth, although the old issue raised by Marshall(1920) is modernity.

For instance, Toyota Motor Corporation is famous for its 'just-in-time' production system, where the make-to-order system aims to reduce goods-in-process inventories of automobile parts provided by the Japanese circumvoluting suppliers. The domestic production system supported mainly by the suppliers sited in Mikawa Area at the center of Aichi Prefecture, however, has changed in a form of step-up overseas production. From 1999 to 2008, the total automobile production rose more than 1.7 times in a decade, while there were then gradual decreases from 65.9% to 48.9% in domestic production ratio of the manufactured automobiles. Will the decentralization of the Toyota's producer regions make the Japanese giant producer more globally competitive as well as in domestic markets? Will the domestic R&D jointly involving the vicinity suppliers be replaced with arm's-length patent license granted across the borders? The answers to these questions could hinge upon distributions of the productivities shared by auto suppliers on the periphery of automobile assembly plants. If the productivity distributions agglomerate into a mass or group, then the organizational decentralization would deteriorate the competitiveness. Otherwise if the distributions reveal congestion in the neighbourhood of the core assemblies, then the replacement of R&D with granted patent license would enhance the productivities.

In this paper, we estimate production functions of the Japanese automobile-parts plants, specifying relation between the productivities and some measured economic distance. The estimations take into account some econometric issues. Our main results are as follows:

1. In 2003, the number of membership companies with associations for technology cooperation is so limited. Most of the auto-parts corporations are independent of the memberships.

2. Locations of the general or independent plants is distributed in positively skewed way. On the other hand, the relation-specific or cooperative plants show differences in locations between the automobile assembly groups or the association memberships for technology cooperation.

3. The general or independent plants could benefit from positive technological externalities. Agglomeration effects of relation-specific or cooperative plants are rarely noticed for the Japanese automobile corporations and

their technology cooperation associations. A few of them cost the auto-parts plants or the member companies substantial negative externalities in productivity.

4. Qualitative results concerning agglomeration or congestion vary between the standard OLS or GMM and an estimator with cross-sectional dependence(Conley, 1999). However, general, a relationship group or independent plants still achieve agglomeration effect upon the auto-parts plants. The agglomeration effect of general and independent locations is also robust to specifications of production function in material variables and in cross-sectional dependence of productivities.

5. Once a simultaneity problem associated with unobservable productivities is econometrically considered, decreasing returns to scale emerge instead of increasing returns. Material variables also lose significance in estimating production functions. The rejection of constant returns to scale leads to agglomeration, if any, brought about not by increasing returns to scale, but by productivities spillover among proximate suppliers around automobile assemblies.

The paper is organized in the following Sections. Section 2 presents a brief overview upon roles of economic distance in economic theory and management science. Based upon the definitions of economic distance detailed in Appendix, we then construct some distance variables from data on plants' location and memberships with associations for technology cooperation. In Section 3, the production functions augmented with the productivity function are estimated with OLS and GMM estimators. The specification of the productivity function nests some types of agglomeration and congestion effects. Section 4 takes a few econometric issues associated with either cross-sectional dependence of productivities or a simultaneity problem between inputs. Finally, we conclude in Section 5.

2 Economic Distance in Theory and Practice

2.1 Related Literatures

In order to explain why we raise a question "agglomeration or congestion?" in terms of productivity, in economic theory and management science among related literatures, we briefly view roles of *economic distance*. Economic distance can be so broadly interpreted in several meanings of geographical, industrial, social/sociological, organizational, or legal context. Literatures covered from a view point of economic distance, however, are confined to economic growth theory, spatial economics, industrial organization, productivity analysis, and management science.

Marshall(1920) emphasized advantages of proximity for production in entrepreneurship, with provident yet immature view upon industrial agglomeration through three channels of goods, people and ideas.

> When an industry has thus chosen a locality for itself, it is likely to stay there long: so great are the advantages which people following the same skilled trade get from near neighborhood to one another. The mysteries of the trade become no mysteries; but are as it were in the air, and children learn many of them unconsciously. Good work is rightly appreciated, inventions and improvements in machinery, in processes and the general organization of the business have their merits promptly discussed: if one man starts a new *idea*, it is taken up by others and combined with suggestions of their own; and thus it becomes the source of further new *ideas*. And presently subsidiary trades grow up in the neighborhood, supplying it with implements and materials, organizing its traffic, and in many ways conducing to the economy of its material.(IV, X, 7, Marshall, 1920)

Among "externalities" through the three channels, as Scitovsky(1954) pointed out, there is a distinction of technological externalities and pecuniary ones. The former externalities deal with non-market interactions directly affected by production function of a firm, while the latter ones refer to interactions through market mechanisms. For the sake of this paper, our interest is in 'technological externalities' in production function caused by proximity to 'source of further new ideas'.

The Marshallian externalities have been often addressed in the economic growth theory(for instance, Romer, 1986). Monopoly rights to 'lean' production technology associated with superior world knowledge, become barriers to international transferability of technology to proximate countries in technological closeness, delaying economic development(Parente and Prescott, 1994; Schmitz, 1989). In the cross-sectional empirical studies following Barro and Sala-i-Martin(1997), using some spatial econometric methods, spatial externalities of technological interdependence are analyzed in the convergence equation(Ertur and Koch, 2007) or the costs of transporting physical capital between countries are taken into account to reevaluate the Barro-regression's results(Conley and Ligon, 2002).

More directly in the regional and spatial economics, including economic agglomerations within congested 'cities'(Fujita and Thisse, 1996) or industrial agglomerations from increasing returns(Krugman, 1991), a variety of social interactions are analyzed. Among them, there is a model of social distance, where correlated with social distance between agents, such social decisions as educational attainment or childbearing may reproduce social 'class' stability(Akerlof, 1997). Some indexes for plants' geographic concentration and 'coagglomeration' are constructed based upon a model of location choice, in cases of the US manufacturing industries(Ellison and Glaeser, 1997) and the UK data(Duranton and Overman, 2005). Input-output relations also provide an economic distance measure that is used to characterize interactions between sectors(Conley and Dupor, 2003).

In the field of industrial organization, empirical studies on production(Ackerberg, Benkard, Berry and Pakes, 2006) address such market outcomes as industry dynamics of firms' entry and exit(Olley and Pakes, 1996), industry dynamics from product switching(Bernard, Redding and Schott, 2008), R&D spillover through patents(Griffith, Harrison and van Reenen, 2006; Bloom, van Reenen and Schankerman, 2007), or spillover effects of opening "million dollar plants" on incumbent plants(Greenstone, Hornbeck and Moretti, 2008). These analyses suggest that the degree of proximity in industries, products or inputs is a key factor to industry dynamics or technological spillover. In a series of papers by van Biesebroeck(2002, 2003) on productivity in the automobile assembly plants in the North America, technology choice or switch between heterogeneous mass or lean(flexible) production accounts for differences between the US and Japanese automobile producers in complementarities of productivity(Milgrom and Roberts, 1990; van Biesebroeck, 2007).

In the management science literature, complementarities in production are mathematically represented in supermodular function(Topkis, 1995). As evidence of the complementarities, firms locating near one another at Silicon Valley learn innovations(Saxenian, 1996). Another case study on Toyota Motor Corporation(Nishiguchi and Beaudet, 1998) elaborates a fire accident and rapid recovery from production stoppage, in 1997 at Kariya Plant of Aisin Seiki Co., Ltd., the Toyota's exceptionally major supplier of an auto-part 'p-valve'[1]. The disaster was followed by collegial efforts of reproducing the same parts as the Aisin's products by corporations affiliated with Toyota. The corporations included member companies belonging to Kyoho-kai, Toyota's association for technology cooperation described in Appendix. The episode reminds the management researchers of sociological "small worlds" framed by Watts(1999), where horizontal bypass between suppliers is usually effective in hierarchical cluster structures(Aoki, 1986; Rajan and Zingales, 2001).

In practice, the most prominent activity between proximate firms may be research collaboration. The collaboration network has typical forms of either 'joint ventures and research corporations' or 'joint R&D and technology exchange'(Hagedoorn, 2002). The former collaboration is set up in a distinct new firm which is based upon equity investment jointly contributed by concerned firms. For instance, Toyota Motor Co., Ltd. and Panasonic Corporation established a firm, Panasonic EV Energy Co., Ltd., on December 1996 at Kosai, Shizuoka Prefecture, Japan. It is within $18km$ from a Toyota's major assembly, Tahara Plant as the crow flies. The new firm develops, manufactures and sells Nickel metal hydride and Lithium ion rechargeable batteries for HEVs(hybrid electric vehicles) and PEVs(pure electric vehicles), the profits of which are dis-

[1] There was another accident visiting Riken Corporation, located at Niigata Prefecture in Japan that the Mid Niigata Prefecture Earthquake directly hit in 2007. Riken Co. then shared near a half the market of an automobile engine part, piston ring. Not only Toyota but also all the other Japanese motor corporations had to stop their productions, but the break period was up to one week.

tributed in proportion to the investments(Toyota 60% and Panasonic 40%). The latter form of research collaboration, R&D partnerships, however has relatively dominated over joint ventures of declining importance, especially in industries such as pharmaceuticals or information technology[2].

Among the comprehensive literatures, the closest approach to this paper is ones estimating some forms of productivity functions. Griffith, Harrison and van Reenen(2006) assume that productivities depend upon the number of patent citations. van Biesebroeck(2002, 2003) emphasizes differences in productivities between 'lean' and 'mass' production systems. Henderson(2003) also identifies local information spillover in plant-level production functions for the US machinery and high-tech industries.

2.2 Data Construction

We construct some measures of *economic distance* d_i applied to each plant i. We assume core-periphery structure around automobile constructors surrounded with auto-parts suppliers. In the structure, technological information can be shared through both locating plants with geographic closeness and joining technological cooperation associations organized by auto-assemblies.

Our data source of geographic distance is *Current Survey of Production*, conducted by Ministry of Economy, Trade and Industry, Government of Japan. We use cross section in the fiscal year 2003, when the Japanese macro economy had recovered from a severe deflationary episode. We pick up two broad items for auto-parts: automotive body and concomitant of an industrial subclassification 3012; and automotive component and accessory of 3013. We choose as the automobile constructors the following 10 companies, listed in an alphabetic order: Daihatsu, Hino, Honda, Isuzu, Matsuda, Mitsubishi, Nissan, Subaru, Suzuki, and Toyota. As described in Appendix, our data excludes automobile assemblies, a 4-digit industrial subclassification 3011, but the real constructor or group names are stipulated to be confidential in utilizing the plant-level data. Note that a subscript j denoting automobile production companies does not correspond to the order above.

The other data source of us is *The Japanese Auto Parts Industries*, published by Japan Auto Parts Industries Association. It contains membership of each auto-parts company belonging to 8 technological cooperation associations organized by 8 constructors(Daihatsu; Hino; Isuzu; Matsuda; Nissan; Subaru; Suzuki; Toyota) and company names of business partners with Honda and Mitsubishi.

We integrate both data sources to construct four measures of economic distance with the following definitions:

Definition 1 *General: Minimum distance of a plant i measured from any au-*

[2]The evidence is from Hagedoorn(2002), which presents some international evidence using the MERIT-CATI database, an extensive survey on inter-firm allianaces starting in 1960.

tomobile construction plants affiliated with major 10 production companies.

$$d_i^g \text{ for a plant } i \tag{1}$$

Definition 2 *Relationship: Minimum distance of a plant i from any plants of either automobile production company above* $j = 1, 2, 3, 4, 5, 6, 7, 8, 9, or\ 10$

$$d_{i,j}^r \text{ for a plant } i \text{ and a company } j \tag{2}$$

where consequently, $d_i^g = \min_j d_{i,j}^r$.

Definition 3 *Cooperation: Measured with the following product term:*

$$d_{i,j}^c \equiv d_{i,j}^r \times (1 - dum_j) \text{ for a plant } i \text{ and a company } j \tag{3}$$

where dum_j *is a dummy variable consisting of a value* 1 *in case of each company joining a technology cooperation association organized by an automobile production company above* $j = 1, 2, 3, 4, 5, 6, 7, 8, 9, or\ 10$*, or a value* 0 *otherwise.*

If two suppliers join the same association organized by a constructor, then they can share the technological information, so that the minimum distance of the plants from the constructor's establishment should be zero.

Definition 4 *Independence: A measure for non-affiliating companies or plants with any specific automobile production companies.*

$$d_i^i \equiv d_i^g \times dum_{-j} \tag{4}$$

where a dummy variable dum_{-j} *denotes technologically independent plants without cooperative relationships with any production companies* $j = 1, 2, 3, 4, 5, 6, 7, 8, 9, or$ 10*.*

Concerning the economic distance measures summarized in Table 12, there are a few characteristics to mention. First, we plot plants locations of our sample on the virtual globe software Google Earth, longitude and latitude of which are coded with the geographical information software ArcGIS. Figure 1 indicates location information on plants joining any technology cooperation associations organized by either automobile assembly corporation, that is plants with zero value of $d_{i,j}^c$. Compared with Figure 2 of independent companies' locations, we find that the number of member companies of the associations is so limited.

Second, some histograms indicate that distribution of the general or independence distance measure is positively skewed(Figure 3 and Figure 4). The relationship or cooperation distance measures show differences between the automobile assembly corporations(as typical cases, Figure 5 and Figure 7), or between the groups for technology cooperation(similarly, Figure 6 and Figure 8).

3 Production Functions Estimated

This paper estimates the Cobb-Douglas type of production function measuring gross revenue y_i with an i.i.d. component η_i,

$$\ln y_i = \beta_0 + \beta_k \ln k_i + \beta_l \ln l_i + \beta_m \ln m_i + \omega_i + \eta_i \tag{5}$$

where capital stocks k_i, labour inputs l_i, and intermediate materials m_i are the production factors. Productivity of a plant i is then measured with the estimates $\widehat{\beta}_0 + \widehat{\omega}_i$. Note that the Cobb-Douglas type of production function satisfies the supermodularity formulated by Topkis(1995).

We decompose the serially correlated component of productivity ω_i into two parts,

$$\omega_i = \omega_i^d + \omega_i^{\tilde{d}} \tag{6}$$

where ω_i^d denotes distance-dependent productivity, and $\omega_i^{\tilde{d}}$ means the residual productivity independent of economic distance. We assume that the distance-dependent productivity ω_i^d is exogenous, in that location choice of each plant or corporation is predetermined ahead of production decisions including input choices. We recognize that plant location is another choice variable for corporations, as market entry and exit are endogenous decisions. However, as in the above citation from Marshall(1920), "When an industry has thus chosen a locality for itself, it is likely to stay there long: so great are the advantages which people following the same skilled trade get from near neighborhood to one another," the location choice is probably associated with sunk costs. The assumption is also appropriate for us, since this paper analyzes cross-sectional data.

3.1 Specification of Productivity Function

We approximate ω_i^d with a third-order polynomial in distance d_i.

$$\omega_i^d = \alpha_1 d_i + \alpha_2 (d_i)^2 + \alpha_3 (d_i)^3 \tag{7}$$

where a distance measure d_i is one among the 4 types of economic distance above. Our simplified specification of the productivity function draws upon the Silicon Valley hypothesis of Saxenian(1996) that nearby firms learn innovations.

Note that in the polynomial function, the distance measures and either input variables should be independent of each other. The constant predetermined locations cannot be state variables determining endogenous production inputs. The distance measures are also in cases results of location choices by parents companies, which is out of scope for each plant.

Applying the specification of productivity function, we define agglomeration effect and congestion one. Agglomeration(congestion) has the same meaning as positive(negative) technological externalities defined by Scitovsky(1954). We evaluate the externalities in a neighbourhood of core automobile assemblies, that is when $d_i \to +0$. In our interpretation, congestion effect for instance indicates 'lock-in-effect' preventing suppliers from getting access to more advanced technology provided by more remotely located constructors.

Definition 5 *The agglomeration effect on productivity in the sphere of any core assemblies, is measured with signs of the estimates in the following cases:*

A.1 Linear agglomeration:

$$\frac{d\omega_i^d}{d(d_i)}|_{\to +0} = \frac{d\omega_i^d}{d(d_i)}|_{\to +0}\left[\widehat{\alpha_1} + 2\widehat{\alpha_2}(d_i) + 3\widehat{\alpha_3}(d_i)^2\right] = \widehat{\alpha_1} < 0$$

A.2 Quadratic agglomeration:

$$\frac{d\omega_i^d}{d(d_i)}|_{\to +0} = \frac{d\omega_i^d}{d(d_i)}|_{\to +0}\left[\widehat{\alpha_1} + 2\widehat{\alpha_2}(d_i) + 3\widehat{\alpha_3}(d_i)^2\right] = \widehat{\alpha_1} = 0 \wedge$$

$$\frac{d\omega_i^d}{d(d_i)}|_{\to +0} = \frac{d\omega_i^d}{d(d_i)}|_{\to +0}\left[2\widehat{\alpha_2} + 6\widehat{\alpha_3}(d_i)\right] = 2\widehat{\alpha_2} < 0$$

A.3 Cubic agglomeration:

$$\frac{d\omega_i^d}{d(d_i)}|_{\to +0} = \frac{d\omega_i^d}{d(d_i)}|_{\to +0}\left[\widehat{\alpha_1} + 2\widehat{\alpha_2}(d_i) + 3\widehat{\alpha_3}(d_i)^2\right] = \widehat{\alpha_1} = 0 \wedge$$

$$\frac{d\omega_i^d}{d(d_i)}|_{\to +0} = \frac{d\omega_i^d}{d(d_i)}|_{\to +0}\left[2\widehat{\alpha_2} + 6\widehat{\alpha_3}(d_i)\right] = 2\widehat{\alpha_2} = 0 \wedge$$

$$\frac{d\omega_i^d}{d(d_i)}|_{\to +0} = 6\widehat{\alpha_3} < 0.$$

Definition 6 *The congestion effect is also measured in the following cases:*

C.1 Linear congestion:

$$\frac{d\omega_i^d}{d(d_i)}|_{\to +0} = \frac{d\omega_i^d}{d(d_i)}|_{\to +0}\left[\widehat{\alpha_1} + 2\widehat{\alpha_2}(d_i) + 3\widehat{\alpha_3}(d_i)^2\right] = \widehat{\alpha_1} > 0$$

C.2 Quadratic congestion:

$$\frac{d\omega_i^d}{d(d_i)}|_{\to +0} = \frac{d\omega_i^d}{d(d_i)}|_{\to +0}\left[\widehat{\alpha_1} + 2\widehat{\alpha_2}(d_i) + 3\widehat{\alpha_3}(d_i)^2\right] = \widehat{\alpha_1} = 0 \wedge$$

$$\frac{d\omega_i^d}{d(d_i)}|_{\to +0} = \frac{d\omega_i^d}{d(d_i)}|_{\to +0}\left[2\widehat{\alpha_2} + 6\widehat{\alpha_3}(d_i)\right] = 2\widehat{\alpha_2} > 0$$

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$$\frac{d\omega_i^d}{d(d_i)}|_{\to +0} = \frac{d\omega_i^d}{d(d_i)}|_{\to +0}\left[2\widehat{\alpha_2} + 6\widehat{\alpha_3}(d_i)\right] = 2\widehat{\alpha_2} = 0 \wedge$$

$$\frac{d\omega_i^d}{d(d_i)}|_{\to +0} = 6\widehat{\alpha_3} > 0.$$

3.2 OLS and GMM Estimates

We estimate the production functions augmented by the economic distance measures with OLS and GMM. The GMM estimator instruments the first lagged variables of endogenous production inputs, labour, capital stocks and materials. The instrument data is supplemented by the year 2002 sample. We alternate either variable of total materials including raw materials, fuel, electricity and outsourcing costs, or raw materials. Heteroskedasticity robust standard errors are ones proposed by Davidson and MacKinnon(2004).

Since some of the Japanese auto-parts suppliers at least probably maintain pricing power in their auto-parts markets, productivity term in estimated production function might contain changes in market demand for auto-parts. In order to control the market demand, we include in production function the products dummy variables, which are equal to 1 if each auto-parts supplier list each product; or 0 otherwise. We cover total 28 items subordinate to the 2 broad items of auto-parts.

We first show estimation results when excluding any distance variable in the explanatory variables. Evidently in Table 1, the fit is well with R^2 at least 0.88. All the estimated coefficients on production inputs are significant, though the relative magnitude is different between two cases with total or raw materials as an explanatory variable. The null hypothesis of constant return to scale(CRTS) $\beta_k + \beta_l + \beta_m = 1$ is strongly rejected in all the cases, which implies increasing returns to scale in the Japanese automobile-part plants.

We proceed to estimating each equation augmented by productivity function of each economic distance variable one by one. The magnitude and significance of the coefficients on inputs remain almost the same as in the production function without distance. The increasing returns to scale is also accepted. Results on the coefficients in the productivity function are in Table 2 for OLS estimates and Table 3 for GMM. Qualitative results of OLS are very similar to those of GMM. We make some remarks about the GMM results.

In a case of total materials, few of the economic distance measures are significant except for general distance, and independence distance. In the estimated productivity functions of the two distance variables, we find the agglomeration effect of a type $A.1$ defined above. On the other hand, the other case of raw materials generates more coefficients in the productivity polynomial which are significant with a significance level of 10%. There are not only seven equations of the $A.1$ agglomeration including general, relationship $j = 1$ and independence distance, and one equation of the $A.2$ agglomeration effect, but also six of the $C.1$ congestion effect for the automobile assembly corporation $j = 3$. The remaining estimated equations also suggest neither agglomeration nor congestion effect.

The results imply that general and independence distances do matter with positive technological externalities of plant location. Agglomeration effects of relationship and cooperation distances on productivity are only noticeable for some of the Japanese automobile corporations and their technology cooperation associations. A few of them cost the auto-parts plants or the member companies substantial negative externalities in productivity.

4 Econometric Issues

Estimates of productivity have been resulted in by numerous analyses on estimation of production functions, especially influenced by Griliches and Mairesse(1998) which pointed out econometric problems associated with estimation of production functions with micro data. There are broadly two problems, cross-sectional dependence(Conley, 1999; Conley and Ligon, 1995) and simultaneity problem(Olley and Pakes, 1996; Levinsohn and Petrin, 2003; Bond and Sőderbom, 2005)[3]. We take the two econometric issues in the estimation.

4.1 Cross-Sectional Dependence

We are concerned about possibilities of interdependence among unobservable productivities in the plants and its possible econometric influences upon the OLS estimates above. We draw upon a non-parametric covariance matrix estimators proposed by Conley(1999). Conley(1999) applies the time series method of Newey and West(1987) or White and Domowitz(1984) to cross-sectional data with possible spatial dependence characterized by economic distance. The covariance matrix estimators based upon GMM estimator are shown to be consistent even when economic distances are measured with errors. The key component reflecting the cross-sectional dependence lies in a weight matrix associated with spatial autocovariances, where the weights are used to calculate weighted averages of the spatial autocovariance terms. Considering roles of economic distance in ideas or knowledge, we suppose the weights as being zero for plants located farther apart than some cutoff levels L_x and L_y at longitude and latitude, respectively. More concretely, instead of truncated estimator of White and Domowitz(1984), we take the following weight function $W_{xy}(j,k)$ of a Bartlett window(Newey and West, 1987), where a square regular lattice spaces each plant in square at longitude j and latitude k for $|j| < L_x$, $|k| < L_y$,

$$W_{xy}(j,k) = \{ \begin{array}{cl} (1 - \frac{|j|}{L_x})(1 - \frac{|k|}{L_y}) & \text{for a plant in square at longitude } j \text{ and latitude } k \\ 0 & \text{otherwise.} \end{array} \tag{8}$$

In setting the cutoff levels L_x and L_y in the weight function, we take into account geographical information on territory of Japan. Prefecture Hokkaido is located at the northernmost extreme, with eastern end at longitude $148\,°53'42''$ and northern one at latitude $45\,°33'28''$. At the southernmost extreme of the

[3]The reflection problem is also related to the estimation of production functions(Manski, 1993), in case that endogenous social or peer effects are considered in production process. There are the cases of endogenous social effects of technology or location choice. Another possible problem is group effects on individual response variables in cluster sample(Moulton, 1990; Wooldridge, 2003). The Marshallian externalities in aggregate physical capitals are an example of the cluster effects.

continental Japan(excluding small-island shaped Okinawa Prefecture), Prefecture Kagoshima has western end at longitude $128^{\circ}23'43''$ and southern one at latitude $27^{\circ}01'07''$. Considering the differences of the rectangular national land in longitude and latitude as well as the histograms displayed in Figure 3 to Figure 8, cutoff levels for either longitude or latitude are set in the Conley(1999) method, at sample means of each distance measure multiplied with $\cos(\arctan(\frac{45-27}{148-128})) \doteqdot 0.743294$ or $\sin(\arctan(\frac{45-27}{148-128})) \doteqdot 0.668965$, respectively.

The results are shown in Table 4 for total materials and Table 5 for raw materials for OLS estimations of an equation without the productivity function. The OLS estimates are the same values whether with or without cross-sectional dependence. The spatial standard errors are of almost the same order as the heteroskedasticity robust standard errors for most of the variables, remaining the significance of the coefficients unchanged in both cases of material variables.

Incorporating the productivity function in the equation, we examine changes in significance of the coefficients in the productivity function to check out whether there is agglomeration or congestion. Results are presented in Table 6 for total materials case and Table 7 for raw materials. Qualitative results concerning agglomeration or congestion are so different from the OLS estimates disregarding cross-sectional dependence. At a significance level of 10% in each case of total or raw materials, there are six or ten functions of productivity with $C.1$ type of congestion, while general, relationship $j = 1$ and independence distances still achieve agglomeration effect upon the auto-parts plants. The agglomeration effect of general and independent locations is thus robust to specifications of production function in material variables or in cross-sectional dependence of productivities.

4.2 Simultaneity

The GMM estimates above took into account endogeneity of the explanatory input variables in the production function. However, there are no concerns about simultaneity problem between the input variables. Since Marschak and Andrews(1944) among the literature on productivity estimates, there has been known that a simultaneity problem is serious for estimating production function. The simultaneity problem occurs when there is contemporaneous correlation between unobservable productivity and production inputs. The simultaneity makes it difficult for econometricians to gain unbiased and consistent estimates. If capital stocks and labour input are positively correlated and correlation with productivity shocks is higher for labour than for capital stocks, then an OLS estimate of a coefficient on labour input would be overestimated and one of a coefficient on capital stocks be underestimated.

In order to address the simultaneity problem, we follow a partially-linear semi-parametric model of Levinsohn and Petrin(2003) with firm's intermediate inputs a proxy variable for unobservable productivity[4]. Since we assume

[4] A seminal paper in the literature, Olley and Pakes(1996) present an identification method

that plants' location choices are predetermined, an economic distance term of productivities' determinant can be separable from an unobservable technology component $\tilde{\omega_i^d}$. In the estimating equation $\ln y_{it} = \beta_0 + \beta_k \ln k_{it-1} + \beta_l \ln l_{it} + \beta_m \ln m_{it} + \sum_{s=1}^{3} \alpha_s (d_{it})^s + \tilde{\omega_{it}^d} + \eta_{it}$ at a period t augmented by a third-order polynomial in an exogenous distance-variable, we assume a demand function m_{it} of a firm i for intermediate inputs $\ln m_{it}$,

$$\ln m_{it} = m_{it}(\tilde{\omega_{it}^d}, \ln k_{it-1}) \tag{9}$$

which proxies for productivity $\tilde{\omega_{it}^d}$ at the current period and depends upon a state variable of capital stocks $\ln k_{it-1}$ at the end of the previous period t[5]. It is also assumed that the demand function m_{it} is monotonic in the productivity $\tilde{\omega_{it}^d}$ for all the capital stocks $\ln k_{it-1}$. The monotonicity of the intermediate inputs demand makes it possible to gain an inverse function $\tilde{\omega_{it}^d} = \tilde{\omega_{it}^d}(\ln m_{it}, \ln k_{it-1})$, which replaces the productivity term in the estimating equation:

$$\ln y_{it} = \beta_l \ln l_{it} + \sum_{s=1}^{3} \alpha_s (d_{it})^s + \phi_{it}(\ln m_{it}, \ln k_{it-1}) + \eta_{it} \tag{10}$$

where $\phi_{it}(\ln m_{it}, \ln k_{it-1}) \equiv \beta_0 + \beta_k \ln k_{it-1} + \beta_m \ln m_{it} + \tilde{\omega_{it}^d}(\ln m_{it}, \ln k_{it-1})$. The monotonicity assumption leads to dropping from our data some samples with zero value of either material variable. The number of zero zero-value is 9 in a case of total materials or 48 in the raw material case, in either year of 2002 or 2003.

The computational procedure is as follows. The first step of the Levinsohn and Petrin(2003) procedure with an application of a third-order polynomial $\sum_{p=0}^{3} \sum_{q=0}^{3-p} \delta_{pq} (\ln k_{it-1})^p (\ln m_{it})^q$ to the function $\phi_{it}(\ln m_{it}, \ln k_{it-1})$, is to consistently estimate a coefficient β_l on labour input $\ln l_{it}$ and coefficients $\alpha_s, s = 1, 2$ and 3 on distance variables d_{it} in Equation (10). Using the consistent estimates $(\widehat{\beta_l}, \widehat{\alpha_s})$, $s = 1, 2$ and 3, the second step is to identify another coefficients (β_k, β_m) on capital stocks and intermediate inputs in Equation (10). Using the estimates $\widehat{\phi_{it}}$ gained in the first step, we define $\widehat{\tilde{\omega_{it}^d}} \equiv \widehat{\phi_{it}} - \beta_k \ln k_{it-1} - \beta_m \ln m_{it}$ for any value of (β_k, β_m). Assuming a first-order Markov process of productivity $\tilde{\omega_{it}^d}$, we also define $E(\widehat{\tilde{\omega_{it}^d} | \tilde{\omega_{it-1}^d}})$ as predicted values from a regression

of production function estimated, which is an application of a partially linear semi-parametric model of Robinson(1988). Olley and Pakes(1996) use investment variables as a proxy for correlation between production inputs and unobservable productivity. Levinsohn and Petrin(2003) point out practical uselessness of the method, however, since the Olley and Pakes(1996)'s identification relies upon the monotonic inverse relation between investment and productivity. In practice, there are so many observations of investment variable with a zero value in whatever plant-level data. The zero-values break the monotonic condition, upon which the identification of Olley and Pakes(1996) crutially depends.

[5] As described in Appendix, the timing of our capital variable is different from that in Levinsohn and Petrin(2003). Their timing assumption makes them use as instruments "present-period capital and the first lag of the proxy variable".

$\widehat{\tilde{\omega_{it}^d}} = \gamma_0 + \gamma_1 \tilde{\omega_{it-1}^d} + \gamma_2 (\tilde{\omega_{it-1}^d})^2 + \gamma_3 (\tilde{\omega_{it-1}^d})^3$. The residual for the estimation is

$$\widehat{\eta_{it} + \xi_{it}} = \ln y_{it} - \widehat{\beta_l} \ln l_{it} - \sum_{s=1}^{3} \widehat{\alpha_s} (d_{it})^s - \beta_k \ln k_{it-1} - \beta_m \ln m_{it} - E(\widehat{\tilde{\omega_{it}^d}} | \tilde{\omega_{it-1}^d}) \tag{11}$$

where an innovation to productivity $\xi_{it} \equiv \tilde{\omega_{it}^d} - E(\widehat{\tilde{\omega_{it}^d}} | \tilde{\omega_{it-1}^d})$. We use as instruments the first lagged capital stocks $\ln k_{it-2}$ and the first lag of the proxy variable $\ln m_{it-1}$. Two moment conditions $E(\eta_{it} + \xi_{it} | \ln k_{it-2})$ and $E(\eta_{it} + \xi_{it} | \ln m_{it-1})$ lead to just identified estimates $(\widehat{\beta_k}, \widehat{\beta_m})$. Following Levinsohn and Petrin(2003), we use the Newton's method as a default solution to a minimization problem of the GMM criterion function, or when we obtain difficulties in convergence, we instead apply the grid search. The covariance matrix of the parameters is also calculated with the Stata's bootstrap command.

To examine whether the simultaneity problem affects the estimates gained in Section 3.2, we compare the GMM estimates with those from Levinsohn and Petrin(2003) method. Estimation results without productivity function are shown in Table 8 for total materials and in Table 9 for raw materials. The result suggests that, without consideration of simultaneity between inputs, the OLS and GMM estimators generate overestimates of coefficients on labour inputs and underestimates of capital stocks coefficients in the production function. It implies the case where both production inputs are positively correlated and correlation with productivity shocks is higher for labour than for capital stocks.

Estimations also reject a null of constant returns to scale, but once the simultaneity problem is considered, decreasing returns to scale emerge instead of increasing returns. Magnitude of the estimated coefficients totally changes, yet still significant except for material variables. The rejection of constant returns to scale is also confirmed in a case with value-added outputs the dependent variable in the production functions without any material input variables. The result leads to agglomeration, if any, brought about not by increasing returns to scale, but by productivities spillover among proximate suppliers around automobile assemblies.

Finally, we estimate the production function with productivity function with the Levinsohn and Petrin method. Evidently in Table 10 for total materials and Table 11 for raw materials, the qualitative results are similar to ones with cross-sectional dependence. There are a lot of congestion effects of type $C.1$ or $C.2$, but we find robustly qualified agglomeration effects for some specific distances of general, relationship $j = 1$ and independence in cases of raw materials. For a reference to the estimations, we plot the estimates of productivity that is defined as a sum of the predicted productivity term $E(\widehat{\tilde{\omega_{it}^d}} | \tilde{\omega_{it-1}^d})$ and the economic distance terms $\sum_{s=1}^{3} \widehat{\alpha_s} (d_{it})^s$ in the typical cases of cooperation distance for $j = 3$ probably with congestion effect and independence distance with agglomeration effect, as is evident in Figure 9 and Figure 10 respectively.

5 Conclusion

This paper in the spirit of Marshall(1920) raised a question of how economic distance affects the firms' productivities, focusing upon distributions of the productivities shared by auto-parts companies on the periphery of automobile assembly plants. We estimated production functions of the Japanese automobile-parts plants, with special attention to productivity function of measured economic distance. We took econometric issues of cross-sectional dependence of productivities and a simultaneity problem between inputs, as well as the standard OLS and GMM estimators.

It turned out that the number of membership companies with associations for technology cooperation is so limited. The rest of the auto-parts corporations are independent of the memberships. The general or independent plants gain positive technological externalities, the fact which is robust to specifications of the production functions. Agglomeration effects are rarely observed for relation-specific or cooperative plants. Some of them cost the auto-parts plants or the member companies substantial negative externalities. Once the simultaneity problem is considered, decreasing returns to scale emerge instead of increasing returns. Material variables loses significance in the production functions. The rejection of constant returns to scale leads to agglomeration, if any, brought about not by increasing returns to scale, but by productivities spillover among proximate suppliers around automobile assemblies.

In future work, we hope to incorporate into another econometric issue the group effects on individual response variables in cluster sample following Wooldridge(2003).

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Appendix: Variables used and their construction

- Observations: *Current Survey of Production*, conducted by Ministry of Economy, Trade and Industry, Government of Japan. The scope of this survey covers establishments or enterprises that produce manufactured goods and mineral products (including processed products) set forth by the ministerial ordinance. Survey items consist of minerals, steel and iron, non-ferrous metals, metal products, general machinery, electric machinery, transport machinery, precision machinery, ceramics, stone and clay products, manufactured chemical products, oil and coal products, plastics, pulp and paper, paper and paper processed goods, manufactured textile products, rubber products, leather products, and other manufactured products.

  We use cross-sectional data from the survey in a fiscal year 2003, accompanied with the year 2002 data as a supplemental sample in panel data. We confine sample into plants with more than 30 employees. This paper covers two items: automotive body and concomitant of a 4-digit industrial subclassification 3012; and automotive component and accessory of a classification number 3013. We exclude automobile(including two-wheeled vehicle) of a classification 3011, since the automobile sector contains plants of motor corporations, operating as core system of the whole automobile industry with probably different technologies than acquired by the constructors of automotive parts belonging to two classifications 3012 and 3013. The year 2002 and 2003 data is matched with a STATA program identifying 'firm ID' distributed among the sample plants, the work which resulted in the sample of 2346 observations. The location on maps browsed with the Google Earth, is displayed separately in Figure 1 for 'cooperation' plants defined with a dummy variable $dum_j = 1$ for either $j = 1, \cdots$,or 10, or in Figure 2 for 'independent' plants with a dummy $dum_{-j} = 1$. Construction of these dummy variables are described in a list of 'cooperation distance' below.

- Output: We construct nominal output as a sum of total shipment value, and changes in manufactured products and semifinished goods in inventory at the beginning and the end of the year in the *Current Survey of Production*. The real term is the nominal values divided by industry organization(IO) deflators in the *Japan Industrial Productivity Database 2006* (JIP 2006 database, available in http://www.rieti.go.jp/en/database/d05.html).

  The JIP database has been complied in a collaboration between the Research Institute of Economy, Trade and Industry(RIETI) as part of its "Study on Industry-Level and Firm-Level Productivity in Japan" research project and Hitotsubashi University as part of its Hi-Stat (21st-Century COE Program, "Research Unit for Statistical Analysis in the Social Sciences") project. The original version of the JIP Database (ESRI/Hi-Stat JIP Database 2003) was compiled through collaboration between the Economic and Social Research Institute (ESRI), Cabinet Office, Government of Japan as part of its research project on "Japan's Potential Growth" and the Hitotsubashi University Hi-Stat project. The JIP 2006 contains annual data on 108 sectors from 1970-2002 that can be used for total factor productivity (TFP) analyses. The database includes detailed information on sectoral capital service input indices and labor service input indices, including information on real capital stocks and the nominal cost of capital by type of capital and by industry, annual nominal, and real input-output tables, as well as some supplementary tables, such as statistics on trade, inward and outward FDI, and Japan's industrial structure. All real values are based on 1995 prices. The database is currently updated to 2008 and publicly on a website.

- Labour input: We construct labour input as a product of total number of full-time employees in the *Current Survey of Production* and industrial person-hours in the *JIP2006 database.*

- Capital stock: We calculate market values of tangible fixed assets by multiplying tangible fixed assets held at the beginning of the year in the *Current Survey of Production* and ratio of market to book values compiled in the *JIP2006 database.* The each plant i's market values k_{it} at the beginning of year $t+1$ are constructed following an equation

$$k_{it} = k_{it-1}(1-\delta) + i_{it} \tag{A.1.}$$

  where δ is an annual industrial depreciation rate in the JIP2006 and i_{it} is acquisition values of tangible fixed assets in the *Current Survey of Production.* Note that the timing of our capital variable is different from that in Levinsohn and Petrin(2003). They "assume investment occurring in this period enters capital in this period", instead of assuming that "investment reported last period enters the production function as capital in this period"(p. 324, Levinsohn and Petrin, 2003), as not only Olley and Pakes(1996) but also this paper does.

- Intermediate inputs or materials: We use total materials including raw materials, fuel, electricity and outsourcing costs, as well as raw materials used. The deflator is the IO deflators in the *JIP2006 database.*

- Products dummy: As variables controlling demand effects in production functions, we include products dummy variables which are equal to 1 if plants list each product or 0 otherwise. Products cover 28 items subordinate to the 2 broad classifications of auto-parts: Fabricated textile products, n.e.c., including knitted ones; Fabrication of plastic film, sheets, floor coverings and synthetic leathers (cutting, jointing, painting, evaporation and plating, buffing, etc.); Aluminum machinery parts, without machine finishing; Stamped and pressed machinery parts, without machine finishing; Piston rings; Charging generators; Starter generators; Miscellaneous auxiliary equipment for internal combustion engines; Parts, attachments and accessories of auxiliary equipment for internal combustion engines; Radio applied equipment; Passenger car bodies; Bus bodies; Truck bodies; Special-use car bodies; Trailers, including trailer chassis and bodies; Gasoline engines for motor vehicles; Diesel engines for motor vehicles; Internal combustion engines for motorcycles and motor scooters; Parts, attachments and accessories of internal combustion engines for motor vehicles; Parts of driving, transmission and operating units; Parts of suspension and brake systems; Parts of chassis and bodies; Car air-conditioners; Car heaters; Finished seats; Miscellaneous parts of motor vehicles, including parts of motorcycles; KD sets (passenger cars, buses and trucks); KD sets (motorcycles).

- General economic distance: As described in Section 2.2, we construct three types of economic distance measures: general; relationship; cooperation; or independence. In making these measures, we require to transform into latitude and longitude address information of each plant listed in the *Current Survey of Production*. On a basis of the lat/long information, we use the ArcGIS software to calculate minimum distance d_i^g of plant i from any automobile construction plants affiliated with major 10 motor corporations. The distance measure is 'general' in that technology is potentially accessible for any plants located within a sphere of another plant.

- Relationship distance: We also measure another distance of plants from either core plant of motor corporations, Daihatsu(Head Office and Ikeda Plant, Kyoto Plant, Shiga Plant, or Machinery Engineering Division(Tada Plant)), Hino(Head Office and Hino Plant, Hamura Plant, or Nitta Plant), Honda(Saitama Plant, Suzuka Plant, Kumamoto Plant, Hamamatsu Plant, or Tochigi Plant), Isuzu(Tochigi Plant, or Fujisawa Plant), Matsuda(Plant complex in Head Office, Plant complex in Ujina District, Miyoshi Plant, Hofu Plant(Nishinoura District and Nakanoseki District)), Mitsubishi(Okazaki Plant, Kyoto Plant, Shiga Plant, Mizushima Plant, or Pajero Manufacturing Co., Ltd.), Nissan(Tochigi Plant, Oppama Plant, Kyushu Plant, Nissan Body Shonan Plant, Yokohama Plant, or Iwaki Plant), Subaru(Gunma Main Plant, Gunma Yajima Plant, Gunma Ota North Plant, Gunma Oizumi Plant, or Isesaki Plant), Suzuki(Head Office and Takatsuka Plant, Iwata Plant, Osuka Plant, Kosai Plant, or Sagara Plant), or Toyota(Head Plant, Motomachi Plant, Kamigo Plant, Takaoka Plant, Miyoshi Plant, Tsutsumi Plant, Myochi Plant, Shimoyama Plant, Kinu-ura Plant, Tahara Plant, Teiho Plant, Hirose Plant, Toyota Motor Hokkaido, Inc., or Toyota Motor Tohoku Co., Ltd.). The measure $d_{i,j}^r$ for a plant i and a motor corporation j is called 'relationship' distance, since technology is accessible for plants establishing transactional relationships with either motor assembly company.

- Cooperation distance: The third measure of economic distance is 'cooperation' distance $d_{i,j}^c$, since we focus upon memberships with associations for technological cooperation affiliated with the major 10 motor assembly corporations. According to *the Japanese Auto Parts Industries*(Japan Auto Parts Industries Association), there are some associations for technological cooperation affiliated with major assembly companies: Daihatsu Kyoyu-kai; Hino Kyoryoku-kai; Isuzu Kyowa-kai; Nishi-Nihon Youko-kai, Kanto Youko-kai, and Kansai Youko-kai(all for Matsuda Motor Corporation); Nissho-kai(For Nissan); Subaru Yuhi-kai; Suzuki Kyoryoku-kyodo-kumiai; and Kyoho-kai(for Toyota). A representative association of Toyota, Kyoho-kai says on the website,

"The objective of KYOHOKAI is, together with Toyota Motor Corporation and its member companies, to make world economic and social contributions through activities based upon a global and open partnership. To aim for further sharing of information and the enhancement of 2-way communication with Toyota Motor Corporation based on the policy of Toyota Motor Corporation to "Create solid footing and build a stronger foundation". The member companies shall develop meeting activities for the purpose of mutual study and exchange to strengthen our global competitive edge and to continue growth by focusing on the "Pursuit of quality". To further enhance and improve the efficiency of meeting activities".

In the year 2003 sample, the number of member companies is so limited, as is evident from the number of zero values shown in summary statistics of Table 12. In addition to member companies of the associations, *the Japanese Auto Parts Industries* contains information on business partners with the Honda Motor Co., Ltd. and Mitsubishi Motors Co.. We construct 10 dummy variables dum_j $j = 1, \cdots, 10$ for each plant that take a value of 1 if it is a member company, or a value 0 otherwise. Product terms of the dummy variable $1-dum_j$ and the relationship distance $d^r_{i,j}$ indicate shared technological knowledge among the associated technological cooperation, so we call the distance 'cooperation through relationship'.

- Independence distance: We also construct the other dummy variable dum_{-j} representing neither membership of the 10 major assembly corporations. Product term of the independence dummy dum_{-j} and the general distance d_i is a distance measure d^i_i for independent companies. The independent companies are the majority of the 2003 sample shown in Table 12.

	Materials							
	Total				Raw materials			
Distance order	1st α_1	2nd α_2	3rd α_3	CRTS	1st α_1	2nd α_2	3rd α_3	CRTS
General								
	-.006***	.00008***	-3.01e-07***	54.16	-.007***	.00009***	-3.47e-07***	90.14
	(.001)	(.00002)	(7.31e-08)	(0)	(.002)	(.00002)	(8.63e-08)	(0)
Relationship								
j=1	-.0004	9.10e-07	-5.58e-10	55.57	-.001	4.66e-06	-5.34e-09	92.07
	(.0007)	(4.99e-06)	(1.03e-08)	(0)	(.0008)	(6.14e-06)	(1.26e-08)	(0)
2	-.0003	1.52e-06	-1.87e-09	55.63	.0003	-6.44e-07	-1.98e-10	95.30
	(.0005)	(1.93e-06)	(2.15e-09)	(0)	(.0005)	(2.07e-06)	(2.23e-09)	(0)
3	.0003	-4.94e-07	1.32e-10	55.58	.0006**	-9.58e-07**	2.82e-10	93.82
	(.0002)	(4.32e-07)	(2.45e-10)	(0)	(.0003)	(4.87e-07)	(2.69e-10)	(0)
4	.0003	-7.92e-07	5.54e-10	55.68	.0005*	-1.31e-06*	8.87e-10*	95.30
	(.0002)	(5.69e-07)	(4.18e-10)	(0)	(.0003)	(7.14e-07)	(5.20e-10)	(0)
5	.0001	-6.86e-07	4.01e-10	55.92	.0004	-1.65e-06*	1.04e-09*	94.37
	(.0003)	(8.07e-07)	(5.60e-10)	(0)	(.0003)	(8.92e-07)	(6.13e-10)	(0)
6	-.0005*	7.59e-07	-3.18e-10	56.17	-.001***	1.93e-06**	-9.95e-10	89.80
	(.0003)	(7.67e-07)	(6.14e-10)	(0)	(.0003)	(8.34e-07)	(6.58e-10)	(0)
7	.0002	-7.26e-07	5.46e-10	55.87	.0005*	-1.57e-06**	1.12e-09**	95.38
	(.0002)	(5.83e-07)	(4.26e-10)	(0)	(.0003)	(7.30e-07)	(5.32e-10)	(0)
8	.0001	-5.55e-07	4.35e-10	55.82	.0003	-1.16e-06*	8.48e-10	95.72
	(.0002)	(5.61e-07)	(4.18e-10)	(0)	(.0002)	(7.03e-07)	(5.23e-10)	(0)
9	-.0007	1.72e-06	-1.34e-09	56.03	-.001**	3.56e-06	-2.75e-09	97.29
	(.0005)	(2.26e-06)	(2.26e-09)	(0)	(.0006)	(2.56e-06)	(2.53e-09)	(0)
10	.0002	-1.34e-06	9.87e-10	56.11	.0002	-1.55e-06	1.20e-09	95.16
	(.0003)	(8.85e-07)	(7.31e-10)	(0)	(.0003)	(1.02e-06)	(8.08e-10)	(0)
Cooperation								
j=1	-.001	5.94e-06	-9.27e-09	56.51	-.001*	5.91e-06	-7.44e-09	91.49
	(.0007)	(5.28e-06)	(1.07e-08)	(0)	(.0008)	(6.12e-06)	(1.26e-08)	(0)
2	-.0003	1.37e-06	-1.75e-09	55.52	.0004	-8.51e-07	-1.78e-11	95.53
	(.0004)	(1.91e-06)	(2.13e-09)	(0)	(.0005)	(2.04e-06)	(2.21e-09)	(0)
3	.0003	-4.96e-07	1.32e-10	55.65	.0006**	-9.58e-07**	2.80e-10	94.38
	(.0002)	(4.28e-07)	(2.44e-10)	(0)	(.0002)	(4.81e-07)	(2.67e-10)	(0)
4	.0003	-8.30e-07	5.78e-10	55.67	.0005*	-1.34e-06*	9.11e-10*	95.57
	(.0002)	(5.66e-07)	(4.16e-10)	(0)	(.0003)	(7.09e-07)	(5.17e-10)	(0)
5	.0001	-6.19e-07	3.60e-10	55.90	.0004	-1.51e-06*	9.42e-10	94.57
	(.0003)	(8.00e-07)	(5.56e-10)	(0)	(.0003)	(9.02e-07)	(6.17e-10)	(0)
6	-.0005*	7.58e-07	-3.17e-10	56.17	-.001***	1.93e-06**	-9.93e-10	89.80
	(.0003)	(7.67e-07)	(6.14e-10)	(0)	(.0003)	(8.34e-07)	(6.58e-10)	(0)
7	.0002	-7.79e-07	5.81e-10	55.83	.0005**	-1.64e-06**	1.16e-09**	95.59
	(.0002)	(5.81e-07)	(4.25e-10)	(0)	(.0003)	(7.26e-07)	(5.30e-10)	(0)
8	.0001	-5.63e-07	4.43e-10	55.84	.0003	-1.06e-06	7.94e-10	95.99
	(.0002)	(5.61e-07)	(4.19e-10)	(0)	(.0002)	(7.06e-07)	(5.24e-10)	(0)
9	-.0007	1.53e-06	-1.17e-09	55.93	-.001**	3.28e-06	-2.49e-09	96.62
	(.0005)	(2.22e-06)	(2.23e-09)	(0)	(.0006)	(2.52e-06)	(2.50e-09)	(0)
10	.0002	-1.32e-06	9.66e-10	56.04	.0001	-1.52e-06	1.18e-09	94.93
	(.0002)	(8.81e-07)	(7.28e-10)	(0)	(.0003)	(1.01e-06)	(8.04e-10)	(0)
Independence								
	-.006***	.00008***	-3.03e-07***	53.98	-.008***	.00009***	-3.49e-07***	89.42
	(.001)	(.00002)	(7.27e-08)	(0)	(.002)	(.00002)	(8.55e-08)	(0)

Note: F statistics and p-value in a parenthesis for constant-returns-to-scale(CRTS).
* refers to significance at 10%, ** at 5%, and *** at 1% level.

Table 2: OLS estimations with distance

	Materials							
	Total				Raw materials			
Distance order	1st α_1	2nd α_2	3rd α_3	CRTS	1st α_1	2nd α_2	3rd α_3	CRTS
General								
	-.006***	.00008***	-2.96e-07***	54.52	-.007***	.00009***	-3.36e-07***	106.02
	(.001)	(.00002)	(7.19e-08)	(0)	(.002)	(.00002)	(8.43e-08)	(0)
Relationship								
j=1	-.0004	8.16e-07	-3.67e-10	55.31	-.001	4.20e-06	-4.70e-09	109.31
	(.0007)	(4.97e-06)	(1.03e-08)	(0)	(.0008)	(6.09e-06)	(1.26e-08)	(0)
2	-.0003	1.51e-06	-1.87e-09	54.83	.0003	-6.06e-07	-2.21e-10	112.86
	(.0004)	(1.91e-06)	(2.13e-09)	(0)	(.0005)	(2.06e-06)	(2.22e-09)	(0)
3	.0003	-4.92e-07	1.32e-10	55.23	.0006**	-9.03e-07*	2.56e-10	111.40
	(.0002)	(4.30e-07)	(2.44e-10)	(0)	(.0002)	(4.86e-07)	(2.69e-10)	(0)
4	.0003	-7.58e-07	5.29e-10	55.04	.0004*	-1.24e-06*	8.37e-10	112.49
	(.0002)	(5.65e-07)	(4.14e-10)	(0)	(.0003)	(7.07e-07)	(5.15e-10)	(0)
5	.0001	-6.80e-07	3.99e-10	55.38	.0004	-1.62e-06*	1.00e-09*	111.66
	(.0003)	(8.02e-07)	(5.56e-10)	(0)	(.0003)	(8.83e-07)	(6.07e-10)	(0)
6	-.0005*	7.50e-07	-3.12e-10	55.60	-.001***	1.90e-06**	-9.91e-10	106.93
	(.0003)	(7.61e-07)	(6.10e-10)	(0)	(.0003)	(8.25e-07)	(6.48e-10)	(0)
7	.0002	-7.08e-07	5.32e-10	55.14	.0005*	-1.50e-06**	1.06e-09**	112.78
	(.0002)	(5.80e-07)	(4.23e-10)	(0)	(.0003)	(7.27e-07)	(5.29e-10)	(0)
8	.0002	-5.24e-07	4.12e-10	55.11	.0003	-1.10e-06	8.01e-10	112.84
	(.0002)	(5.57e-07)	(4.15e-10)	(0)	(.0002)	(6.96e-07)	(5.17e-10)	(0)
9	-.0008	1.86e-06	-1.47e-09	55.42	-.001**	3.67e-06	-2.87e-09	114.36
	(.0005)	(2.25e-06)	(2.25e-09)	(0)	(.0006)	(2.54e-06)	(2.51e-09)	(0)
10	.0002	-1.36e-06	1.00e-09	55.78	.0002	-1.57e-06	1.20e-09	113.01
	(.0002)	(8.80e-07)	(7.27e-10)	(0)	(.0003)	(1.00e-06)	(7.98e-10)	(0)
Cooperation								
j=1	-.001	5.74e-06	-8.89e-09	55.98	-.001*	5.61e-06	-7.07e-09	108.80
	(.0007)	(5.24e-06)	(1.06e-08)	(0)	(.0008)	(6.10e-06)	(1.26e-08)	(0)
2	-.0003	1.36e-06	-1.74e-09	54.73	.0003	-8.16e-07	-3.77e-11	113.11
	(.0004)	(1.89e-06)	(2.11e-09)	(0)	(.0005)	(2.03e-06)	(2.20e-09)	(0)
3	.0003	-4.98e-07	1.34e-10	55.27	.0006**	-9.06e-07*	2.55e-10	111.98
	(.0002)	(4.27e-07)	(2.43e-10)	(0)	(.0002)	(4.80e-07)	(2.66e-10)	(0)
4	.0003	-7.99e-07	5.56e-10	54.99	.0004*	-1.28e-06*	8.65e-10*	112.74
	(.0002)	(5.62e-07)	(4.13e-10)	(0)	(.0003)	(7.02e-07)	(5.12e-10)	(0)
5	.0001	-6.21e-07	3.63e-10	55.45	.0004	-1.46e-06	9.07e-10	111.98
	(.0003)	(7.94e-07)	(5.52e-10)	(0)	(.0003)	(8.93e-07)	(6.11e-10)	(0)
6	-.0005*	7.49e-07	-3.11e-10	55.60	-.001***	1.89e-06**	-9.89e-10	106.94
	(.0003)	(7.61e-07)	(6.10e-10)	(0)	(.0003)	(8.25e-07)	(6.48e-10)	(0)
7	.0002	-7.63e-07	5.68e-10	55.07	.0005*	-1.56e-06**	1.11e-09**	112.97
	(.0002)	(5.78e-07)	(4.23e-10)	(0)	(.0003)	(7.23e-07)	(5.27e-10)	(0)
8	.0001	-5.34e-07	4.22e-10	55.11	.0003	-9.90e-07	7.43e-10	113.02
	(.0002)	(5.57e-07)	(4.15e-10)	(0)	(.0002)	(6.98e-07)	(5.19e-10)	(0)
9	-.0007	1.65e-06	-1.28e-09	55.41	-.001**	3.38e-06	-2.60e-09	113.58
	(.0005)	(2.21e-06)	(2.21e-09)	(0)	(.0006)	(2.50e-06)	(2.48e-09)	(0)
10	.0002	-1.34e-06	9.86e-10	55.74	.0002	-1.55e-06	1.18e-09	112.80
	(.0002)	(8.76e-07)	(7.24e-10)	(0)	(.0003)	(9.99e-07)	(7.94e-10)	(0)
Independence								
	-.006***	.00008***	-2.98e-07***	54.37	-.007***	.00009***	-3.37e-07***	105.13
	(.001)	(.00002)	(7.15e-08)	(0)	(.002)	(.00002)	(8.35e-08)	(0)

Note: F statistics and p-value in a parenthesis for constant-returns-to-scale(CRTS).
* refers to significance at 10%, ** at 5%, and *** at 1% level.

Table 3: GMM estimations with distance

Distance		Order	OLS estimate	White S.E.	Spatial S.E.
General		1st α_1	-.006	.001***	.002***
		2nd α_2	.00008	.00002***	.00002***
		3rd α_3	-3.007e-07	7.31e-08***	8.785e-08***
Relationship	j=1	1st α_1	-.0004	.0007	.00005***
		2nd α_2	9.102e-07	4.99e-06	3.629e-07**
		3rd α_3	-5.585e-10	1.03e-08	7.281e-10
	j=2	1st α_1	-.0003	.0005	.00003***
		2nd α_2	1.515e-06	1.93e-06	1.395e-07***
		3rd α_3	-1.872e-09	2.15e-09	1.735e-10***
	j=3	1st α_1	.0003	.0002	.00001***
		2nd α_2	-4.944e-07	4.32e-07	2.530e-08***
		3rd α_3	1.317e-10	2.45e-10	1.600e-11***
	j=4	1st α_1	.0003	.0002	.00001***
		2nd α_2	-7.921e-07	5.69e-07	2.312e-08***
		3rd α_3	5.537e-10	4.18e-10	1.512e-11***
	j=5	1st α_1	.0001	.0003	.00002***
		2nd α_2	-6.863e-07	8.07e-07	4.793e-08***
		3rd α_3	4.009e-10	5.60e-10	3.966e-11***
	j=6	1st α_1	-.0005	.0003*	.00002***
		2nd α_2	7.593e-07	7.67e-07	6.968e-08***
		3rd α_3	-3.180e-10	6.14e-10	6.605e-11***
	j=7	1st α_1	.0002	.0002	.00001***
		2nd α_2	-7.264e-07	5.83e-07	2.568e-08***
		3rd α_3	5.464e-10	4.26e-10	1.549e-11***
	j=8	1st α_1	.0001	.0002	.00001***
		2nd α_2	-5.546e-07	5.61e-07	2.290e-08***
		3rd α_3	4.347e-10	4.18e-10	1.514e-11***
	j=9	1st α_1	-.0007	.0005	.00006***
		2nd α_2	1.722e-06	2.26e-06	3.015e-07***
		3rd α_3	-1.341e-09	2.26e-09	3.035e-10***
	j=10	1st α_1	.0002	.0003	.00002***
		2nd α_2	-1.344e-06	8.85e-07	9.401e-08***
		3rd α_3	9.866e-10	7.31e-10	8.532e-11***
Cooperation	j=1	1st α_1	-.001	.0007	.0008
		2nd α_2	5.944e-06	5.28e-06	5.780e-06
		3rd α_3	-9.273e-09	1.07e-08	1.148e-08
	j=2	1st α_1	-.0003	.0004	.0005
		2nd α_2	1.370e-06	1.91e-06	2.077e-06
		3rd α_3	-1.748e-09	2.13e-09	2.268e-09
	j=3	1st α_1	.0003	.0002	.0002
		2nd α_2	-4.961e-07	4.28e-07	4.395e-07
		3rd α_3	1.316e-10	2.44e-10	2.541e-10
	j=4	1st α_1	.0003	.0002	.0002
		2nd α_2	-8.299e-07	5.66e-07	6.064e-07
		3rd α_3	5.783e-10	4.16e-10	4.445e-10
	j=5	1st α_1	.0001	.0003	.0003
		2nd α_2	-6.193e-07	8.00e-07	8.697e-07
		3rd α_3	3.596e-10	5.56e-10	6.006e-10
	j=6	1st α_1	-.0005	.0003*	.0003*
		2nd α_2	7.575e-07	7.67e-07	8.289e-07
		3rd α_3	-3.168e-10	6.14e-10	6.428e-10
	j=7	1st α_1	.0002	.0002	.0002
		2nd α_2	-7.786e-07	5.81e-07	6.309e-07
		3rd α_3	5.810e-10	4.25e-10	4.610e-10
	j=8	1st α_1	.0001	.0002	.0002
		2nd α_2	-5.629e-07	5.61e-07	5.999e-07
		3rd α_3	4.428e-10	4.19e-10	4.498e-10
	j=9	1st α_1	-.0007	.0005	.0006
		2nd α_2	1.528e-06	2.22e-06	2.404e-06
		3rd α_3	-1.165e-09	2.23e-09	2.366e-09
	j=10	1st α_1	.0002	.0002	.0002
		2nd α_2	-1.315e-06	8.81e-07	8.972e-07
		3rd α_3	9.662e-10	7.28e-10	7.474e-10
Independence		1st α_1	-.006	.001***	.0003***
		2nd α_2	.00008	.00002***	5.350e-06***
		3rd α_3	-3.029e-07	7.27e-08***	2.135e-08***

Note: * refers to significance at 10%, ** at 5%, and *** at 1% level.

Table 6: Cross-sectional dependence(2-1): Total materials

Variable(name)		Coefficient(standard error)			
		OLS		GMM	
Labour(lnobe2)	β_l	.68***(.04)	.87***(.02)	.70***(.05)	.88***(.02)
Capital(lkstock2)	β_k	.01***(.006)	.03***(.007)	.01**(.006)	.03***(.007)
Materials	β_m				
Total materials(lmtotal2)		.41***(.03)	–	.41***(.03)	–
Raw materials(lzairyo2)		–	.24***(.01)	–	.25***(.01)
Const.	β_0	-2.38***(.27)	-3.12***(.23)	-2.52***(.30)	-3.23***(.22)
Returns to scale*		55.84(0)	97.63(0)	55.04(0)	114.69(0)
R^2		.92	.89	.92	.89
# of obs.		2346			

Note: F statistics and p-value in a parenthesis for constant-returns-to-scale.

Table 1: OLS and GMM estimations without distance

Variable(name)		OLS estimate	White S.E.	Spatial S.E.
Labour(lnobe2)	β_l	.68	.04***	.04***
Capital(lkstock2)	β_k	.01	.006***	.004***
Materials				
(lmtotals)	β_m	.41	.03***	.03***
Const.	β_0	-2.38	.27***	.26***
# of obs.		2346		

Note: * refers to significance at 10%, ** at 5%, and *** at 1% level.

Table 4: Cross-sectional dependence(1-1): OLS estimates(total materials)

Variable(name)		OLS estimate	White S.E.	Spatial S.E.
Labour(lnobe2)	β_l	.87	.02***	.03***
Capital(lkstock2)	β_k	.03	.007***	.007***
Materials				
(lzairyo2)	β_m	.24	.01***	.01***
Const.	β_0	-3.12	.23***	.27***
# of obs.		2346		

Note: * refers to significance at 10%, ** at 5%, and *** at 1% level.

Table 5: Cross-sectional dependence(1-2): OLS estimates(raw materials)

Distance		Order	OLS estimate	White S.E.	Spatial S.E.
General		1st α_1	-.007	.002***	.002***
		2nd α_2	.00009	.00002***	.00003***
		3rd α_3	-3.474e-07	8.63e-08***	1.016e-07***
Relationship	j=1	1st α_1	-.001	.0008	.00007***
		2nd α_2	4.658e-06	6.14e-06	4.295e-07***
		3rd α_3	-5.342e-09	1.26e-08	7.847e-10***
	j=2	1st α_1	.0003	.0005	.00003***
		2nd α_2	-6.443e-07	2.07e-06	1.487e-07***
		3rd α_3	-1.980e-10	2.23e-09	1.743e-10
	j=3	1st α_1	.0006	.0003**	.00001***
		2nd α_2	-9.580e-07	4.87e-07**	2.289e-08***
		3rd α_3	2.823e-10	2.69e-10	1.391e-11***
	j=4	1st α_1	.0005	.0003*	.00001***
		2nd α_2	-1.307e-06	7.14e-07*	3.232e-08***
		3rd α_3	8.865e-10	5.20e-10*	2.383e-11***
	j=5	1st α_1	.0004	.0003	.00002***
		2nd α_2	-1.655e-06	8.92e-07*	6.397e-08***
		3rd α_3	1.035e-09	6.13e-10*	5.099e-11***
	j=6	1st α_1	-.001	.0003***	.00002***
		2nd α_2	1.933e-06	8.34e-07**	7.194e-08***
		3rd α_3	-9.955e-10	6.58e-10	6.460e-11***
	j=7	1st α_1	.0005	.0003*	.00002***
		2nd α_2	-1.573e-06	7.30e-07**	3.495e-08***
		3rd α_3	1.118e-09	5.32e-10**	2.332e-11***
	j=8	1st α_1	.0003	.0002	.00001***
		2nd α_2	-1.160e-06	7.03e-07*	3.407e-08***
		3rd α_3	8.482e-10	5.23e-10	2.476e-11***
	j=9	1st α_1	-.001	.0006**	.00007***
		2nd α_2	3.561e-06	2.56e-06	3.675e-07***
		3rd α_3	-2.748e-09	2.53e-09	3.656e-10***
	j=10	1st α_1	.0002	.0003	.00003***
		2nd α_2	-1.548e-06	1.02e-06	1.157e-07***
		3rd α_3	1.196e-09	8.08e-10	9.953e-11***
Cooperation	j=1	1st α_1	-.001	.0008*	.0008*
		2nd α_2	5.906e-06	6.12e-06	6.255e-06
		3rd α_3	-7.437e-09	1.26e-08	1.299e-08
	j=2	1st α_1	.0004	.0005	.0005
		2nd α_2	-8.511e-07	2.04e-06	2.168e-06
		3rd α_3	-1.778e-11	2.21e-09	2.328e-09
	j=3	1st α_1	.0006	.0002**	.0002***
		2nd α_2	-9.581e-07	4.81e-07**	4.860e-07**
		3rd α_3	2.800e-10	2.67e-10	2.798e-10
	j=4	1st α_1	.0005	.0003*	.0003*
		2nd α_2	-1.344e-06	7.09e-07*	7.203e-07*
		3rd α_3	9.112e-10	5.17e-10*	5.316e-10*
	j=5	1st α_1	.0004	.0003	.0004
		2nd α_2	-1.508e-06	9.02e-07*	9.410e-07
		3rd α_3	9.420e-10	6.17e-10	6.429e-10
	j=6	1st α_1	-.001	.0003***	.0003***
		2nd α_2	1.929e-06	8.34e-07**	8.304e-07**
		3rd α_3	-9.931e-10	6.58e-10	6.564e-10
	j=7	1st α_1	.0005	.0003**	.0003**
		2nd α_2	-1.639e-06	7.26e-07**	7.479e-07**
		3rd α_3	1.162e-09	5.30e-10**	5.507e-10**
	j=8	1st α_1	.0003	.0002	.0002
		2nd α_2	-1.061e-06	7.06e-07	7.132e-07
		3rd α_3	7.944e-10	5.24e-10	5.384e-10
	j=9	1st α_1	-.001	.0006**	.0006**
		2nd α_2	3.277e-06	2.52e-06	2.585e-06
		3rd α_3	-2.488e-09	2.50e-09	2.551e-09
	j=10	1st α_1	.0001	.0003	.0003
		2nd α_2	-1.522e-06	1.01e-06	1.020e-06
		3rd α_3	1.176e-09	8.04e-10	8.180e-10
Independence		1st α_1	-.008	.002***	.0004***
		2nd α_2	.00009	.00002***	6.961e-06***
		3rd α_3	-3.487e-07	8.55e-08***	2.775e-08***

Note: * refers to significance at 10%, ** at 5%, and *** at 1% level.

Table 7: Cross-sectional dependence(2-2): Raw materials

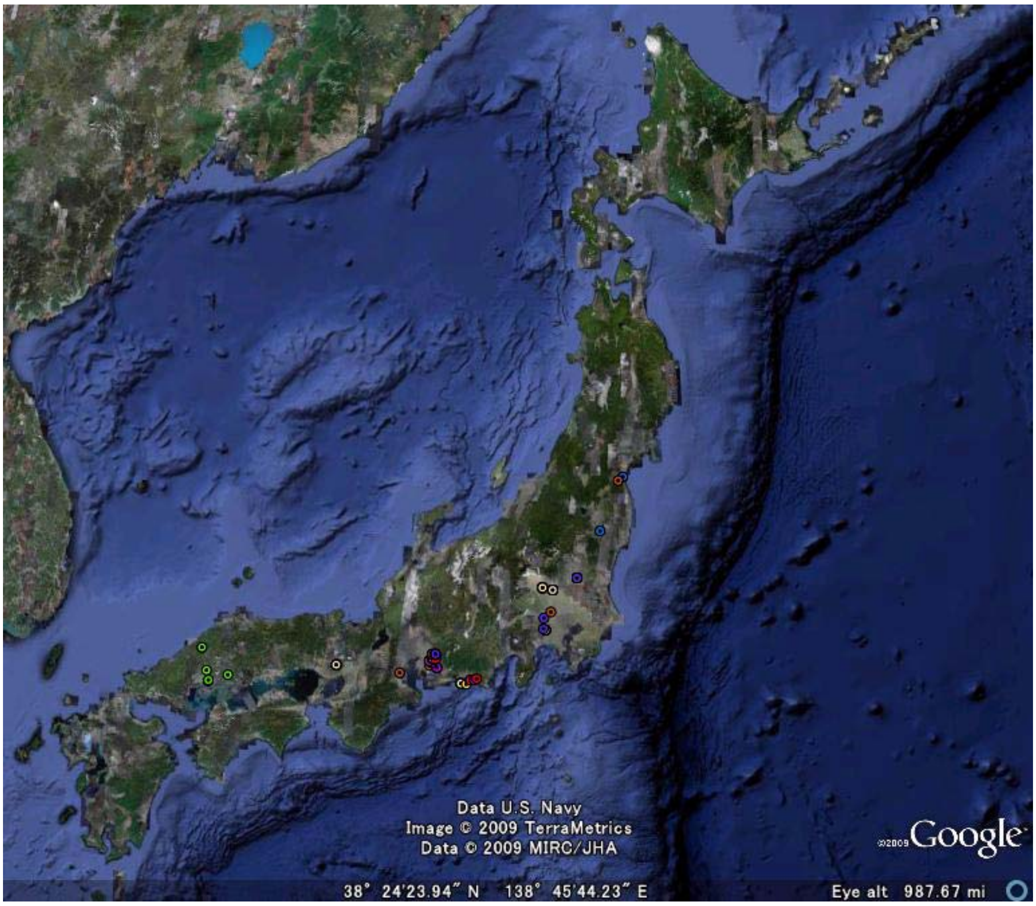

Figure 1: Plants' locations joining any technology cooperation association organized by either automobile assembly company $j = 1, \cdots, 10$.

		Coefficient(standard error)	
Variable(name)		GMM	LP
Labour(lnobe2)	β_l	.70***(.05)	.31***(.02)
Capital(lkstock2)	β_k	.01**(.006)	.10**(.04)
Materials(lmtotal2)	β_m	.41***(.03)	.08(.29)
Const.	β_0	-2.52***(.30)	
Returns to scale*		55.04(0)	3.49(.06)
R^2		.92	
# of obs.		2346	2337

Note: χ^2 statistics and p-value in a parenthesis for constant-returns-to-scale.

Table 8: Simultaneity(1-1): Total materials

		Coefficient(standard error)	
Variable(name)		GMM	LP
Labour(lnobe2)	β_l	.88***(.02)	.40***(.02)
Capital(lkstock2)	β_k	.03***(.007)	.06(.04)
Materials(lzairyo2)	β_m	.25***(.01)	.12(.30)
Const.	β_0	-3.23***(.22)	
Returns to scale*		114.69(0)	.87(.35)
R^2		.89	
# of obs.		2346	2306

Note: χ^2 statistics and p-value in a parenthesis for constant-returns-to-scale.

Table 9: Simultaneity(1-2): Raw materials

	Input			Distance			Returns
Distance	Labour	Capital	Materials	1st order	2nd	3rd	to scale
General	.31***	.10**	.08	-.0006	.00001	-6.50e-08	4.26
	(.02)	(.04)	(.29)	(.0008)	(.00001)	(4.99e-08)	(.04)
Relationship	.31***	.10**	.08	.0006	-4.48e-06	8.08e-09	4.22
j=1	(.02)	(.04)	(.26)	(.0005)	(3.53e-06)	(7.41e-09)	(.04)
	.31***	.10**	.08	-.00008	8.01e-07	-1.26e-09	4.24
2	(.02)	(.05)	(.31)	(.0003)	(1.30e-06)	(1.61e-09)	(.04)
	.31***	.10**	.08	.0002	-2.23e-07	4.46e-11	4.90
3	(.02)	(.04)	(.27)	(.0002)	(3.24e-07)	(1.95e-10)	(.03)
	.31***	.10**	.08	.0004***	-1.02e-06**	6.99e-10**	4.46
4	(.02)	(.05)	(.30)	(.0001)	(4.07e-07)	(2.99e-10)	(.03)
	.31***	.10**	.08	-.0002	4.88e-07	-3.75e-10	4.56
5	(.02)	(.05)	(.29)	(.0002)	(5.75e-07)	(4.18e-10)	(.03)
	.31***	.10**	.08	-.0003	6.18e-07	-4.08e-10	4.12
6	(.02)	(.05)	(.30)	(.0002)	(5.69e-07)	(4.88e-10)	(.04)
	.31***	.10**	.08	.0004***	-1.00e-06**	7.02e-10**	4.40
7	(.02)	(.05)	(.30)	(.0001)	(4.06e-07)	(3.05e-10)	(.04)
	.31***	.10**	.08	.0003**	-8.93e-07**	6.34e-10**	3.99
8	(.02)	(.05)	(.30)	(.0001)	(3.75e-07)	(2.85e-10)	(.05)
	.31***	.10**	.08	.00003	-3.49e-07	1.42e-10	5.47
9	(.02)	(.05)	(.28)	(.0003)	(1.55e-06)	(1.64e-09)	(.02)
	.31***	.10**	.08	-.0001	3.22e-07	-3.25e-10	4.41
10	(.02)	(.05)	(.29)	(.0002)	(6.29e-07)	(5.48e-10)	(.04)
Cooperation	.31***	.10**	.08	.0005	-4.20e-06	7.64e-09	3.72
j=1	(.02)	(.05)	(.29)	(.0004)	(3.26e-06)	(6.98e-09)	(.05)
	.31***	.10**	.08	-.00008	8.03e-07	-1.27e-09	4.35
2	(.02)	(.05)	(.30)	(.0003)	(1.27e-06)	(1.54e-09)	(.04)
	.31***	.10**	.08	.0001	-2.16e-07	4.15e-11	3.94
3	(.02)	(.05)	(.33)	(.0001)	(3.17e-07)	(1.99e-10)	(.05)
	.31***	.10**	.08	.0004***	-1.04e-06***	7.11e-10***	3.88
4	(.02)	(.04)	(.31)	(.0001)	(3.44e-07)	(2.53e-10)	(.05)
	.31***	.10**	.08	-.0002	5.22e-07	-3.96e-10	3.79
5	(.02)	(.04)	(.29)	(.0002)	(5.40e-07)	(3.97e-10)	(.05)
	.31***	.10**	.08	-.0003	6.17e-07	-4.07e-10	4.38
6	(.02)	(.04)	(.28)	(.0002)	(5.28e-07)	(4.55e-10)	(.04)
	.31***	.10**	.08	.0004***	-1.01e-06***	7.05e-10**	5.81
7	(.02)	(.04)	(.27)	(.0001)	(3.82e-07)	(2.81e-10)	(.02)
	.31***	.10**	.08	.0003**	-9.01e-07**	6.41e-10**	4.80
8	(.02)	(.04)	(.25)	(.0001)	(3.76e-07)	(2.85e-10)	(.03)
	.31***	.10**	.08	.00007	-5.09e-07	2.86e-10	4.76
9	(.02)	(.05)	(.30)	(.0003)	(1.45e-06)	(1.53e-09)	(.03)
	.31***	.10**	.08	-.0001	3.32e-07	-3.32e-10	4.56
10	(.02)	(.04)	(.29)	(.0002)	(6.35e-07)	(5.33e-10)	(.03)
	.31***	.10**	.08	-.0006	.00001	-6.52e-08	4.12
Independence	(.02)	(.04)	(.29)	(.0008)	(.00001)	(4.72e-08)	(.04)

Table 10: Simultaneity(2-1): Total materials

	Input			Distance			Returns
Distance	Labour	Capital	Materials	1st order	2nd	3rd	to scale
General	.41***	.06	.12	-.002**	.00003*	-1.15e-07*	.93
	(.02)	(.04)	(.28)	(.001)	(.00002)	(6.21e-08)	(.33)
Relationship	.41***	.06	.12	-.0009	3.61e-06	-5.78e-09	.74
j=1	(.02)	(.04)	(.28)	(.0006)	(3.90e-06)	(7.43e-09)	(.39)
	.40***	.06	.12	.0004	-8.70e-07	-6.39e-11	.91
2	(.02)	(.05)	(.32)	(.0003)	(1.36e-06)	(1.59e-09)	(.34)
	.40***	.06	.13	.0006***	-7.98e-07**	2.16e-10	.58
3	(.02)	(.04)	(.33)	(.0002)	(3.47e-07)	(1.96e-10)	(.44)
	.40***	.06	.13	.0007***	-1.99e-06***	1.32e-09***	.60
4	(.02)	(.05)	(.30)	(.0002)	(4.20e-07)	(2.91e-10)	(.44)
	.41***	.06	.12	-.00005	-2.57e-07	1.12e-10	.94
5	(.02)	(.04)	(.31)	(.0002)	(6.46e-07)	(4.71e-10)	(.33)
	.41***	.06	.13	-.0007***	1.04e-06*	-5.35e-10	.68
6	(.02)	(.04)	(.30)	(.0002)	(6.18e-07)	(5.07e-10)	(.41)
	.40***	.06	.13	.0007***	-2.18e-06***	1.49e-09***	.74
7	(.02)	(.05)	(.29)	(.0002)	(4.60e-07)	(3.29e-10)	(.39)
	.40***	.06	.13	.0006***	-1.83e-06***	1.27e-09***	.66
8	(.02)	(.05)	(.30)	(.0002)	(4.36e-07)	(3.16e-10)	(.42)
	.41***	.06	.13	-.0006	4.59e-07	-1.32e-10	.75
9	(.02)	(.05)	(.29)	(.0004)	(1.69e-06)	(1.78e-09)	(.39)
	.41***	.06	.12	-.0002	1.63e-07	-1.71e-10	.84
10	(.02)	(.05)	(.30)	(.0002)	(6.67e-07)	(5.52e-10)	(.36)
Cooperation	.41***	.06	.12	-.001*	3.83e-06	-6.11e-09	.64
j=1	(.02)	(.04)	(.30)	(.0006)	(3.90e-06)	(7.36e-09)	(.43)
	.40***	.06	.12	.0004	-7.82e-07	-1.55e-10	1.05
2	(.02)	(.04)	(.27)	(.0003)	(1.38e-06)	(1.63e-09)	(.31)
	.40***	.06	.13	.0005***	-7.39e-07**	1.88e-10	.62
3	(.02)	(.04)	(.30)	(.0002)	(3.39e-07)	(1.96e-10)	(.43)
	.40***	.06	.13	.0007***	-1.98e-06***	1.32e-09***	.62
4	(.02)	(.04)	(.28)	(.0002)	(4.62e-07)	(3.35e-10)	(.43)
	.41***	.06	.12	-.0002	6.58e-09	-5.40e-11	.64
5	(.02)	(.04)	(.29)	(.0002)	(6.44e-07)	(4.63e-10)	(.43)
	.41***	.06	.13	-.0007***	1.04e-06*	-5.34e-10	.73
6	(.02)	(.04)	(.31)	(.0002)	(5.98e-07)	(4.95e-10)	(.39)
	.40***	.06	.13	.0007***	-2.16e-06***	1.47e-09***	.67
7	(.02)	(.05)	(.29)	(.0002)	(4.49e-07)	(3.21e-10)	(.41)
	.40***	.06	.13	.0005***	-1.62e-06***	1.14e-09***	.75
8	(.02)	(.04)	(.31)	(.0002)	(4.45e-07)	(3.22e-10)	(.39)
	.41***	.06	.13	-.0005	2.90e-07	1.99e-11	.61
9	(.02)	(.04)	(.25)	(.0003)	(1.59e-06)	(1.65e-09)	(.43)
	.41***	.06	.12	-.0003	2.42e-07	-2.26e-10	.75
10	(.02)	(.04)	(.30)	(.0002)	(7.76e-07)	(6.19e-10)	(.39)
	.41***	.06	.12	-.002**	.00003**	-1.18e-07**	.87
Independence	(.02)	(.04)	(.31)	(.001)	(.00001)	(5.53e-08)	(.35)

Table 11: Simultaneity(2-2): Raw materials

Variable	Name	# of obs.	Unit	Mean	S.D.	Min.	Max.	# of zero
Output	lpoutput2	2346	Ten thousand yen(ln, real)	12.46	1.44	9.01	17.99	0
Labour	lnobe2	2346	Man-hours(ln)	14.40	.95	12.78	18.93	0
Capital	lkstock2	2346	Ten thousand yen(ln, real)	11.09	2.62	0	16.56	75
Materials	lmtotal2	2346	Ten thousand yen(ln, real)	11.70	1.95	0	17.73	9
	lzairyo2	2346	Ten thousand yen(ln, real)	11.16	2.56	0	17.72	40
Distance								
General	ttdis	2346	km	28.91	36.22	0	231.56	11
Relationship								
j=1	tdis1	2346	km	143.89	106.62	0	359.73	5
2	tdis2	2346	km	180.83	124.15	0	775.29	2
3	tdis3	2346	km	540.38	245.81	.44	1454.53	0
4	tdis4	2346	km	280.62	242.84	0	1116.71	1
5	tdis5	2346	km	272.62	179.42	.40	1193.00	0
6	tdis6	2346	km	214.86	200.12	0	1105.54	1
7	tdis7	2346	km	269.98	248.08	.52	1117.14	0
8	tdis8	2346	km	267.19	247.40	.59	1112.02	0
9	tdis9	2346	km	92.08	97.85	0	857.94	1
10	tdis10	2346	km	174.41	160.31	0	1102.84	1
Cooperation								
j=1	pdis1	2346	km	143.49	106.80	0	359.73	19
2	pdis2	2346	km	180.22	124.36	0	775.29	12
3	pdis3	2346	km	538.22	247.64	0	1454.53	11
4	pdis4	2346	km	279.85	243.28	0	1116.71	12
5	pdis5	2346	km	272.14	179.87	0	1193.00	7
6	pdis6	2346	km	214.86	200.13	0	1105.54	3
7	pdis7	2346	km	269.40	248.36	0	1117.14	9
8	pdis8	2346	km	266.19	247.65	0	1112.02	11
9	pdis9	2346	km	91.59	98.07	0	857.94	20
10	pdis10	2346	km	173.67	160.53	0	1102.84	14
Independence								
	pdis11	2346	km	28.66	36.26	0	231.56	49

Table 12: Summary statistics(year 2003)

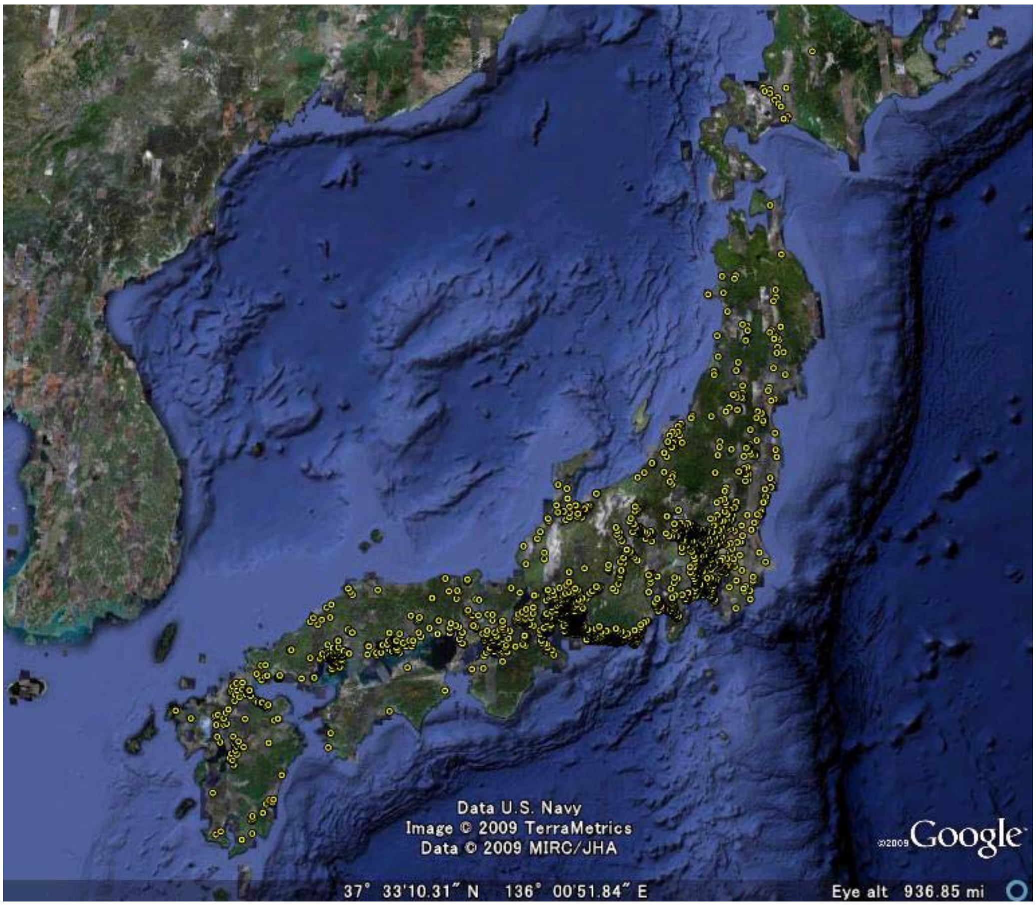

Figure 2: Locations for plants independent of any technology cooperation association organized by either automobile assembly company $j = 1, \cdots, 10$.

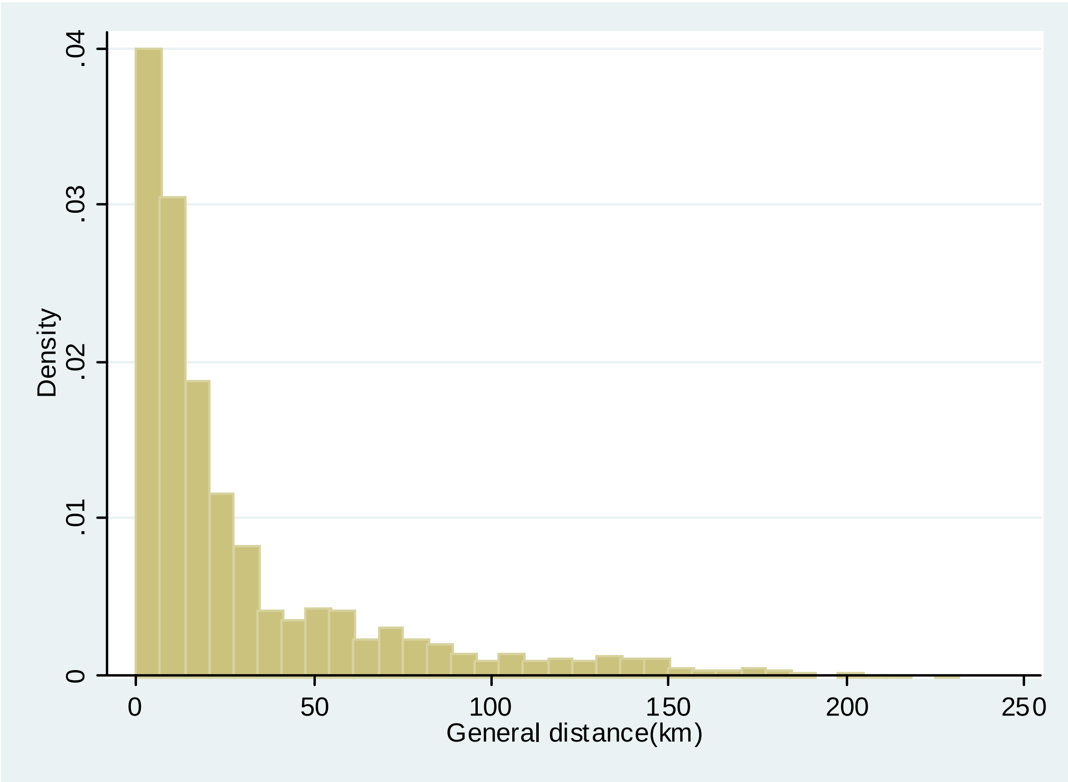

Figure 3: Histogram of 'general' distance

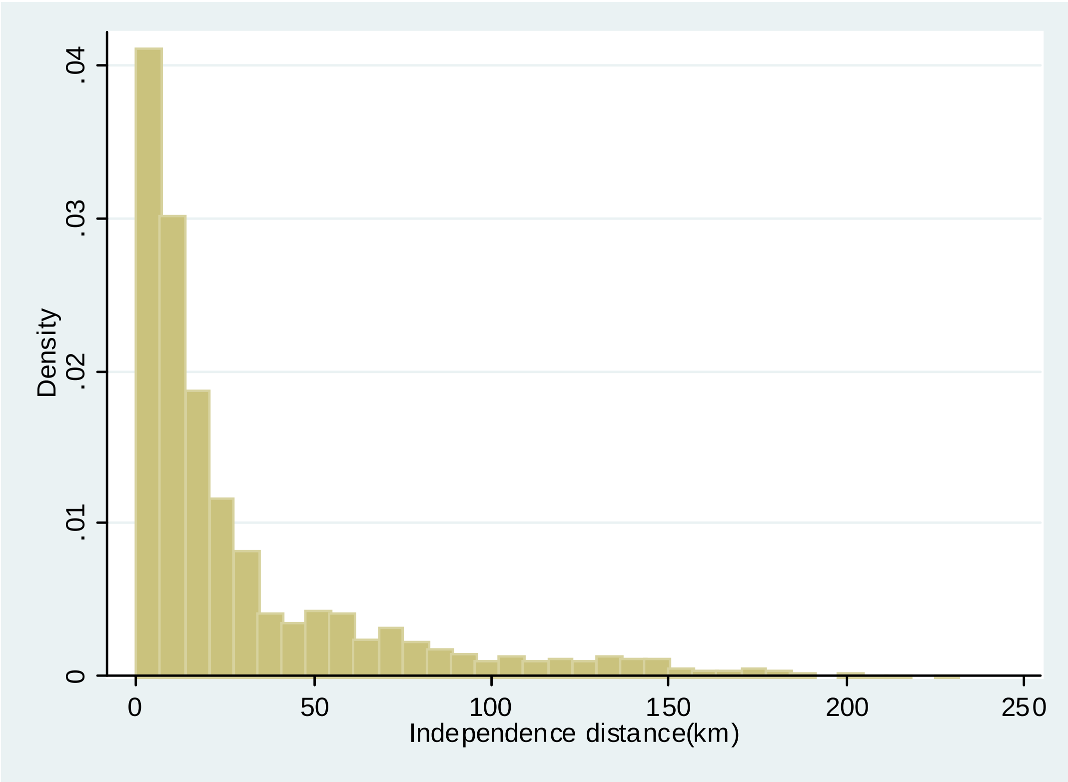

Figure 4: Histogram of 'independence' distance

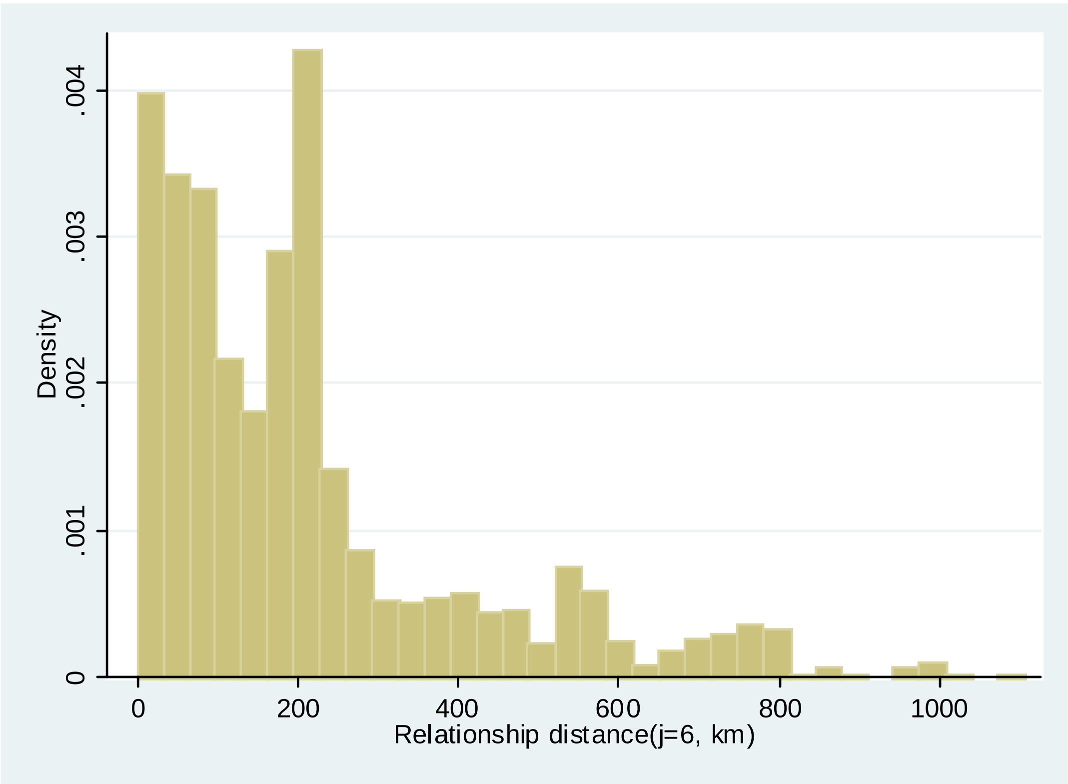

Figure 5: Histogram of 'relationship' distance($j = 6$)

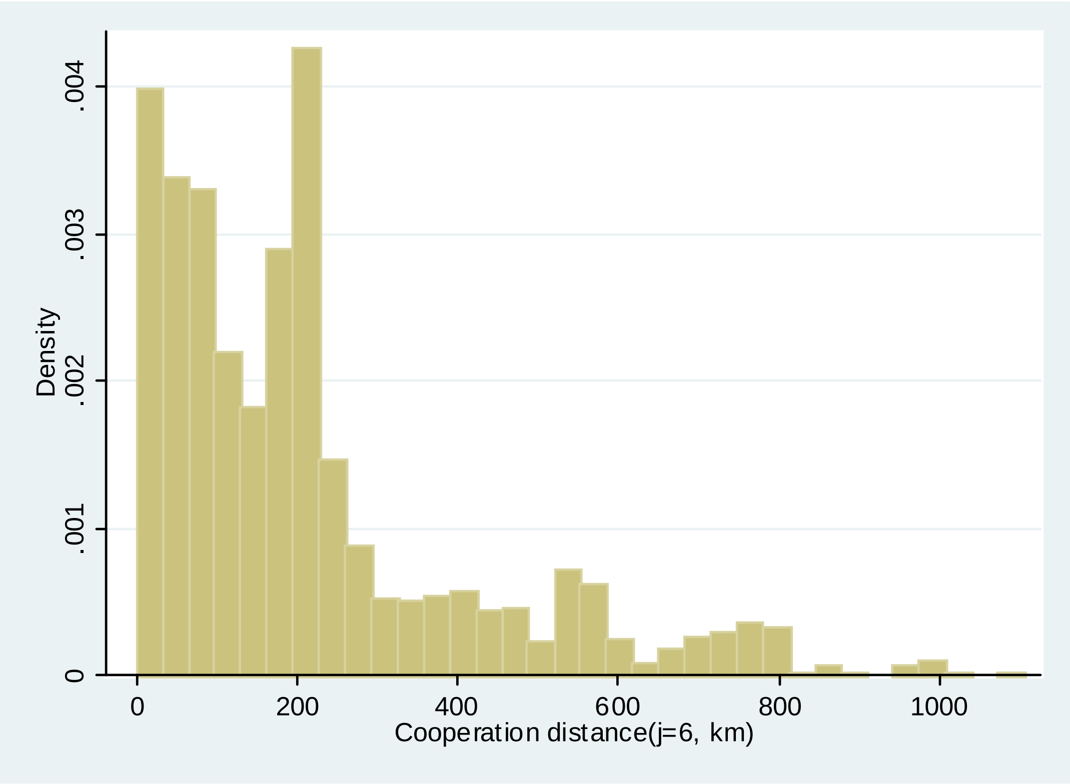

Figure 6: Histogram of 'cooperation' distance($j = 6$)

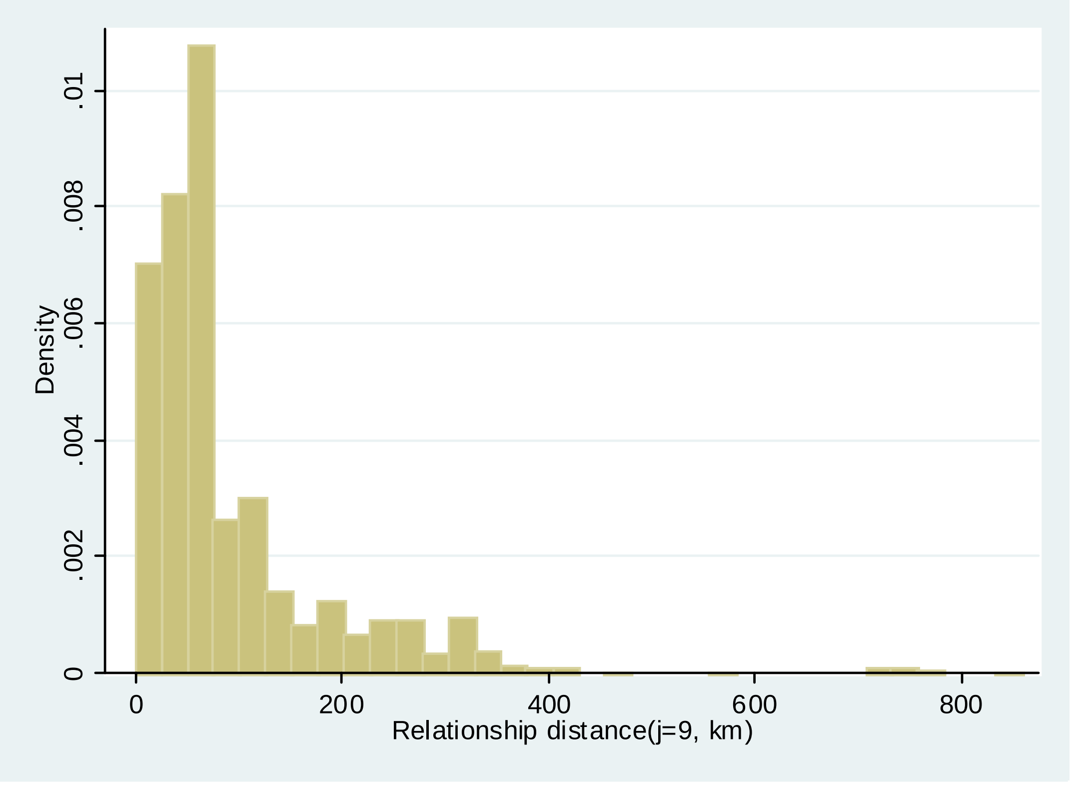

Figure 7: Histogram of 'relationship' distance($j = 9$)

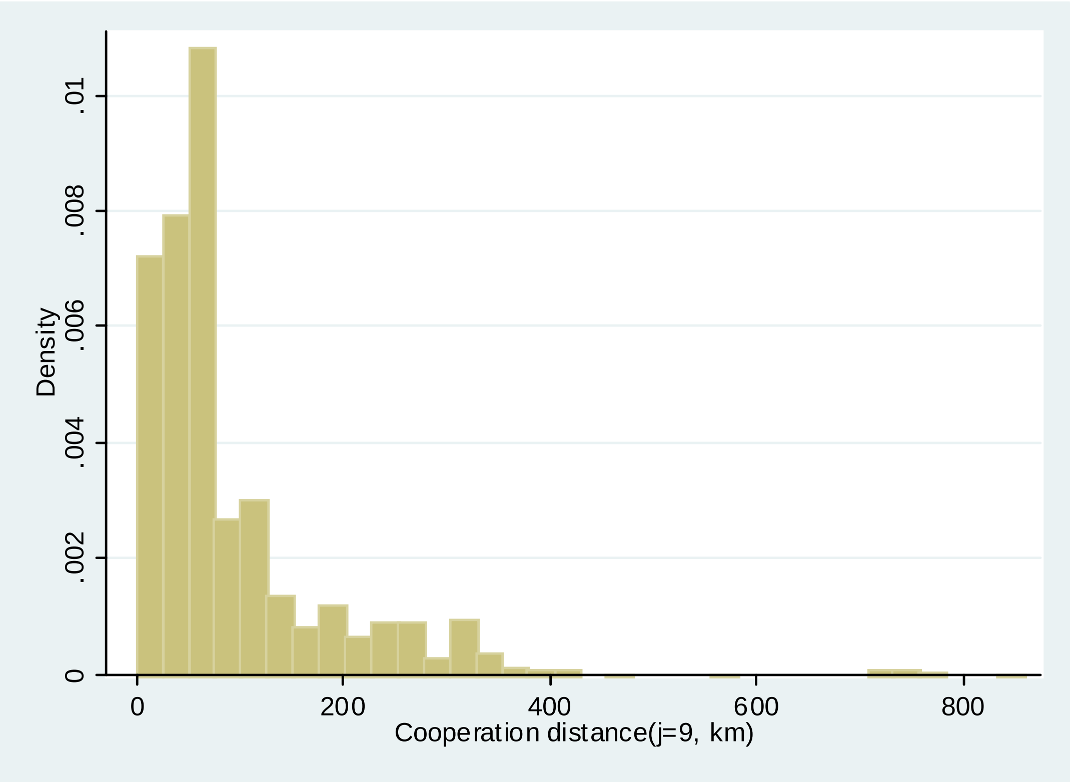

Figure 8: Histogram of 'cooperation' distance($j = 9$)

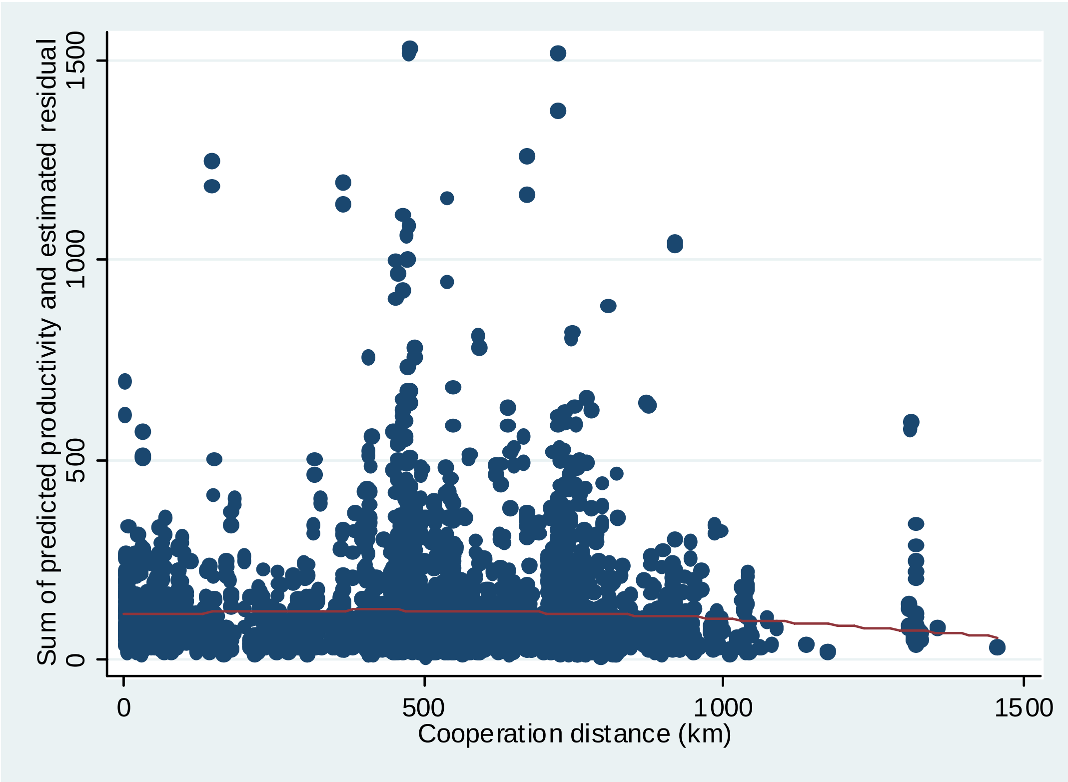

Figure 9: Productivity estimates(cooperation distance, j=3) with quadratic polynomial predictions

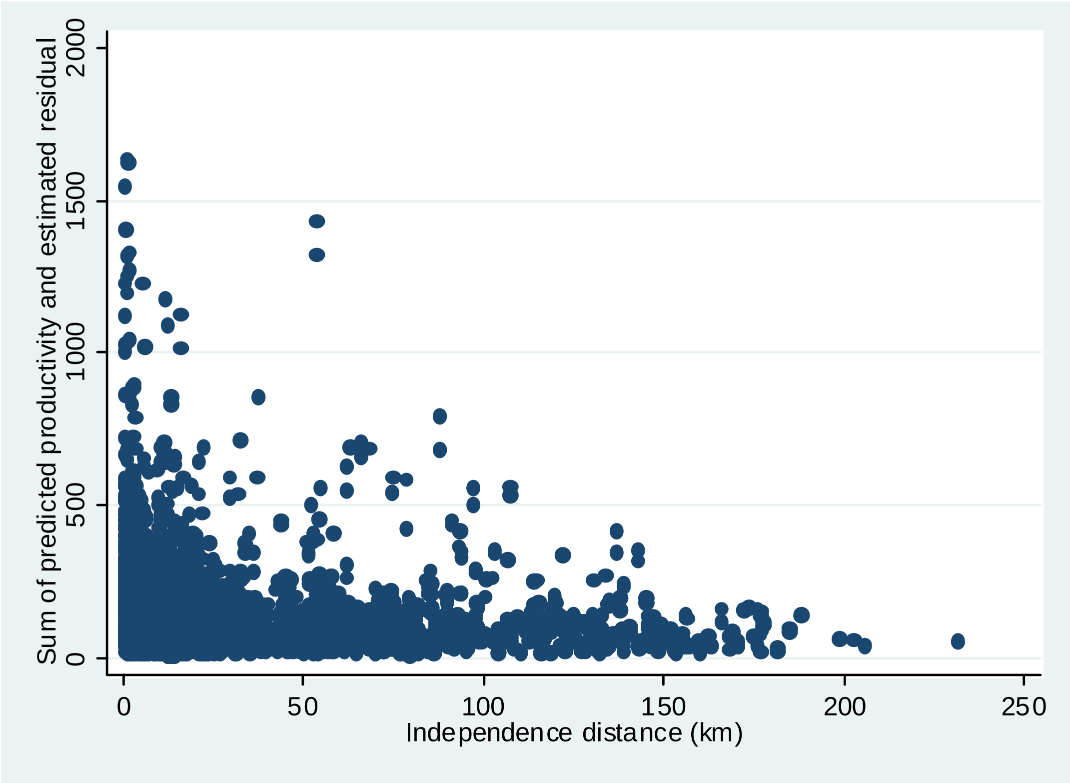

Figure 10: Productivity estimates(independence distance)