An Impact Analysis of Logistics Accessibility Improvements on the Productivity of Manufacturing Sectors

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Abstract: This study constructs a theoretical production function that incorporates logistics accessibility and analyzes the economic impacts of improvements in freight transport for a regional economy. Using panel data between 1995 and 2010 for Japan, we evaluate the impacts of interregional logistics accessibility, or inbound (outbound) shipping of intermediate (final) goods, on production activity. The results show that the production function has increasing returns to scale, which positively affects production activity, regarding logistics accessibility. In addition, the estimated elasticity of transportation costs changes; that is, logistics improvements in procurements (sales) decrease (increase) with time. Furthermore, the impacts of cost improvements on production activity differ across manufacturing sectors. This empirical analysis supports the logistics strategies of transportation efficiency and relocation of factories and warehouses in manufacturing sectors. In accordance with the Weber location–production problem, this empirical analysis supports production-oriented location for input goods and market-oriented location for output goods.

Key Words: *logistics accessibility, inbound and outbound shipping costs, Weber location–production problem, panel data analysis, Japan*

1. INTRODUCTION

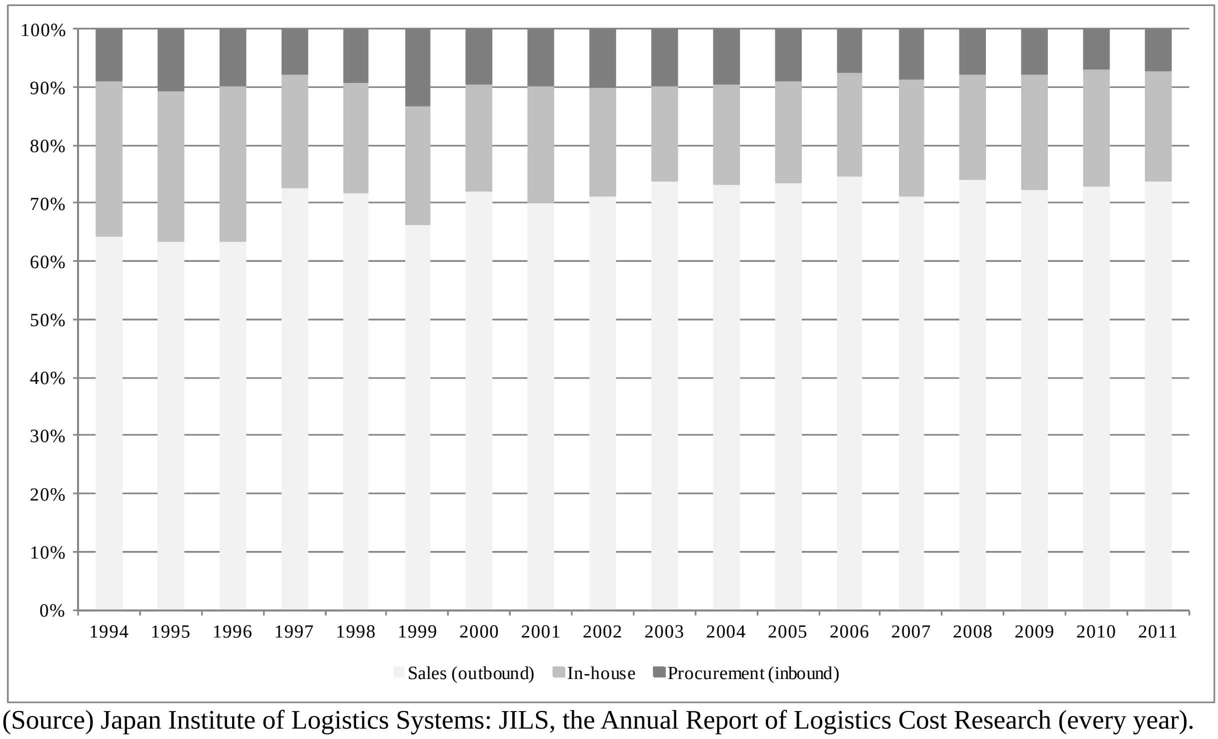
Real economic activity is not spaceless, and some goods are not ubiquitous. Furthermore, shipping goods from one place to another involves transportation costs. Some studies point out that along with the traditional production factors of labor and capital, transportation cost plays an important role in production activity. For example, consider the following remark by the Nobel prizewinner in Economics, Paul Krugman (1991):

We normally model countries as dimensionless points within which factors of production can be instantly and costlessly moved from one activity to another, and even trade among countries is usually given a sort of spaceless representation in which transport costs are zero for all goods that can be traded.

Businesses have continually pursued improvements in logistics; for example, just in time (JIT), supply chain management (SCM), third party logistics (3PL), and e-commerce all result from improving logistics efficiency. Improvement in logistics has also been a subject for research. Most of such research considers logistics activities in intermediate goods transportation and inventory management for raw materials and product components. As compared with shipping networks of finished goods, those of intermediate goods are complex and have room for improvement. Therefore, single manufacturing companies and small groups of affiliated companies must strive for efficient logistics activities in shipping intermediate goods.

In the case of shipping final goods, there is limited room for improvement in logistics efficiency, because final goods transportation is a comparatively simple process. Improvements in final goods transportation are expected in the areas of expansion of product distribution by wholesalers, spread of regionalized cooperative delivery, and shifts in the price system from cost, insurance and freight (c.i.f.) price to free on board (f.o.b.) price. However, these areas have faced difficulties because of related business companies, consumer organizations, various institutions and regulations, and business customs. In addition, one of the logistics strategies to improve efficiency in product distribution is the relocation of companies. However, this can entail long-term efforts if a serious problem is encountered, such as that of overseas transfers due to the appreciating yen, following the Plaza Accord in 1985.

In light of these considerations, it is important to discuss improvements in logistics accessibility separately for intermediate goods transportation (i.e., inbound shipping or procurement logistics) and final goods transportation (i.e., outbound shipping or sales logistics). For example, Figure 1 shows the changes in the composition of logistics costs in Japanese industries, based on the questionnaire surveys conducted by the Japan Institute of Logistics Systems (JILS, every year). Outbound shipping costs (74% in 2011) comprise most of the logistics costs. Furthermore, the share of total logistics costs has been gradually expanding from more than 60% to more than 70% in the last 15 years. This is because of the time pressure delivery on JIT and inventory management to decrease opportunity loss. In this context, the function of sales logistics comes into the picture more than ever.



(Source) Japan Institute of Logistics Systems: JILS, the Annual Report of Logistics Cost Research (every year).

Figure 1 Changes in the Composition of Logistics Costs

The aim of this research is to empirically estimate the effects of improvements in logistics accessibility, based on the data on inter-regional transportation costs collected through questionnaire surveys conducted in Japan in 1995, 2000, 2005, and 2010. We then discuss the economic impacts on production activity of improvements in the cost of inbound (outbound) shipping for intermediate (finished) goods.

The rest of this paper is structured as follows. Section 2 discusses why this research tries to empirically estimate logistics accessibility elasticities by using pooled datasets. Then, the production function estimated in this paper and the economic impacts of logistics accessibility in manufacturing sectors are discussed. In Section 3, the dataset and the analytical framework used in this study are explained. Section 4 shows the estimated elasticities obtained in panel data analysis. It then discusses the key findings from this empirical study and trends in domestic transportation efficiency. Section 5 concludes this paper with a summary of the empirical results and issues for future research.

2. PRODUCTION FUNCTION AND LOGISTICS ACCESSIBILITY

2.1 Previous Studies

Some studies have tried to estimate the effects of transport improvements by incorporating transport distances or costs, instead of social capital stock, in traditional production functions (see Deng (2013) for a recent survey of transport infrastructure and regional economic growth). In addition, a number of studies have considered spatial factors and interdependence of transport infrastructure in the production function. For example, Maurseth (2001) discusses growth regression analysis with market potential as a control variable to indicate geographical convenience. The study analyzes *interregional direct distance* in Europe for the period 1980–1994. Nakazato (2001) applies a growth regression approach to *road investment for intra-regional and interregional traffic* in Japanese prefectures for the period 1960–1988. Yamaguchi and Maku (2004) analyze the effects of inter-prefectural accessibility by using generalized cost based on *regular passenger costs and times* in Japan in 1990 and 1998. In addition, Yamaguchi (2007) presents a cross-sectional analysis of 47 prefectures in 1995 and 2000 by production function and considers the impacts of accessibility, *travel time*, *and air fares* in Japanese air transport. However, these estimations for regression analysis do not accurately reflect or discuss the real situation of production activities, that is, the movement of intermediate and final goods, because there are data constraints for logistics costs. Therefore, research that tries to expressly estimate the effect of logistics accessibility for regional economies is needed.

2.2 Logistics Accessibility

As Hanson and Giuliano (2004) discuss, the "classical" accessibility of a place to other places in an area can be measured by using Equation (1).

$$AI_i = \sum_j \frac{O_j}{d_{ij}}, \quad (1)$$

where AI_i is the accessibility index of zone i, O_j is the number of opportunities available in zone j, and d_{ij} is a measure of the separation between zone i and zone j. This is a general form derived from Newton's law of gravitation and introduced into regional science by Stewart (1947) (see also Hansen (1959) as an early paper). Logistics accessibility indexes can also be constructed as synthetic variables with the (i) economic scale of trade partners and (ii) transportation cost of goods to/from trade partners. In empirical analysis, the population or GDP related to market scale, that is, economic opportunity, is used as the former, whereas total transportation cost between zone i and zone j is used as the latter.

In our analysis, we assume that two types of logistics accessibility affect productivity in manufacturing sectors. $LAII_i$ is the logistics accessibility index that takes into account the cost of inbound transportation of intermediate goods to zone i from zone j; and $LAIO_i$ is the logistics accessibility index that takes into account the cost of outbound transportation of final goods from zone i to zone j (see Doi *et al*., 2006).

$$LAII_i = \sum_j \frac{q_j}{c_{j,i}}, \tag{2}$$

$$LAIO_i = \sum_j \frac{q_j}{c_{i,j}}. \tag{3}$$

Here, q_j is the gross value of output of trade partners in zone j and $c_{i,j}$ is the cost of transportation, or average transportation cost per metric ton, from zone i to zone j.

2.3 Production Function with Logistics Accessibility

The production function to be estimated in this paper is Equation (4). We assume linear homogeneity with respect to capital stock and labor. Equation (4) can be transformed into Equation (5).

$$Y_i = AK_i^{\alpha} L_i^{1-\alpha} \left(\sum_j \frac{q_j}{c_{j,i}} \right)^{\beta_1} \left(\sum_j \frac{q_j}{c_{i,j}} \right)^{\beta_2} = AK_i^{\alpha} L_i^{1-\alpha} LAII_i^{\beta_1} LAIO_i^{\beta_2}, \tag{4}$$

$$\log\left(\frac{Y_i}{L_i}\right) = \log A + \alpha \log\left(\frac{K_i}{L_i}\right) + \beta_1 \log\left(\sum_j \frac{q_j}{c_{j,i}} \right) + \beta_2 \log\left(\sum_j \frac{q_j}{c_{i,j}} \right). \tag{5}$$

Here, α, β_1, and β_2 are the respective elasticities of gross regional product (GRP) per capita with respect to capital, inbound accessibility, and outbound accessibility. The production function, Equation (5), implies that the parameters (β_1 and β_2) for logistics accessibility also express the transportation cost elasticity under the short-term production function (see Doi *et al.*, 2006).

The contribution of this empirical analysis can be summarized in the following three points: (i) We expressly incorporate *transportation costs for movement of goods* in the traditional production function; (ii) the transportation costs are classified as *inbound shipping costs and outbound shipping costs*; and (iii) the empirical testing discusses (a) *the changes in the impacts, or elasticities, of logistics accessibility improvements* between 1995 and 2010 and (b) *the differences in these elasticities among the detailed manufacturing sectors* in the regional economy.

3. DATA AND ANALYTICAL FRAMEWORK

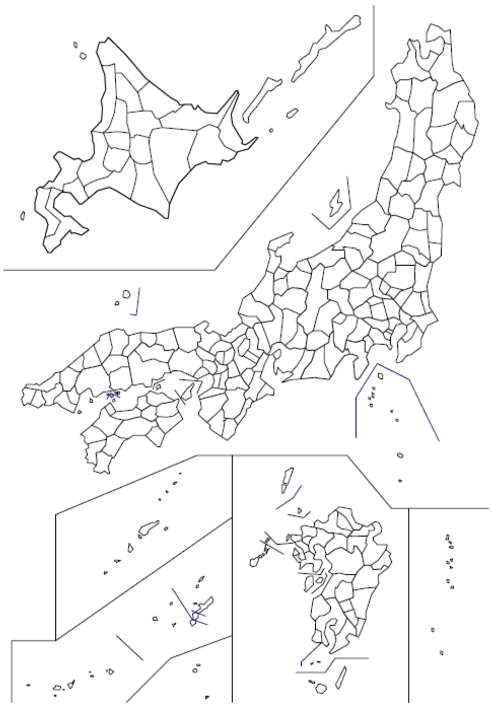
3.1 Data and Source

To measure interregional transportation costs, namely, $c_{i,j}$ and $c_{j,i}$, we use data from a questionnaire survey on cargo flows (Physical Distribution Census by Ministry of Land, Infrastructure, Transport and Tourism (MLIT) of Japan) for 1995, 2000, 2005, and 2010. Unfortunately, this survey is conducted only once in five years and is the only source of data on cargo transportation costs between municipalities in Japan. Although the survey covers a number of shippers for different industrial sectors at the municipality level, it does not have pre-1995 data on cargo transportation costs. The dataset for this panel data analysis is based on 227 “living zones” (*Case 1*) and 47 prefectures (*Case 2*) (see the next subsection for details). Furthermore, we aggregate different manufacturing sectors to arrive at a comparable set of 20 manufacturing sectors for a time-series analysis at four time points. Table 1 lists the 20 manufacturing sectors used in this analysis.

Table 1 Manufacturing Sectors

Sector	Industry
Sector 1	Food
Sector 2	Drink, feed, and tabacco
Sector 3	Textile
Sector 4	Wood, and wood products
Sector 5	Furniture, and fitment
Sector 6	Pulp, paper, and paper goods
Sector 7	Printing and related industry
Sector 8	Chemical
Sector 9	Oil, and coal products
Sector 10	Plastic products
Sector 11	Rubber products
Sector 12	Tannage, tannage products, and fur
Sector 13	Ceramic, soil, and stone products
Sector 14	Steel
Sector 15	Non-ferrous metal
Sector 16	Metal products
Sector 17	General and precision machinery, and apparatus
Sector 18	Electric machinery, and apparatus
Sector 19	Transport machinery, and apparatus
Sector 20	Other industries

(Note) The categories are based on the small classification of the System of National Accounts (SNA) for Japan. Furthermore, this paper aggregates the original industrial classifications in each survey to comparable ones.



(Source) Ministry of Land, Infrastructure, Transport and Tourism (MLIT) of Japan

Figure 2 The 227 Living Zones in Japan

Figure 2 shows the 227 living zones in Japan. Data on fixed assets (capital stock) and the number of workers in manufacturing sectors and municipalities are obtained from the Industrial Statistics for each year. The GRP and gross value of output in the manufacturing sectors and municipalities are obtained from the System of National Accounting (SNA) for each year. Lastly, data on average working time in the manufacturing sectors and prefectures are obtained from the Monthly Labour Survey for each year.

3.2 Analytical Framework

We analyze the economic impacts of improvements in interregional logistics accessibility on production activity. We use a pooled dataset, sometimes called time series cross-sectional data or longitudinal data, for the years 1995, 2000, 2005, and 2010 for Japan. We consider two types of analytical frameworks, because some data (e.g., the number of workers and fixed assets) for manufacturing sectors in the living zone categories are not available, owing to data privacy restrictions. Furthermore, when we use prefecture categories, instead of living zone categories in the estimation, the characteristics of location and transportation mode for the living zones are obscured. Therefore, this paper applies the following two types of frameworks. *Case 1* is the estimation for the overall manufacturing sector, an aggregate of 20 manufacturing sectors that uses data on the 227 living zones for 1995, 2000, 2005, and 2010. That is, the dataset for *Case 1* contains, in theory, 908 observations (227 living zones * 4 years). *Case 2* is the estimation for narrowly defined manufacturing sectors with data on 47 prefectures for 1995, 2000, 2005, and 2010. The dataset for *Case 2* contains, in theory, 3,760 observations (47 prefectures * 20 manufacturing sectors * 4 years). However, because data regarding transportation costs is missing in the questionnaire survey, the dataset is unbalanced panel data. The number of actual observations in the datasets used for estimation is 886 for *Case 1* and 3,176 for *Case 2*.

This study uses models for panel data analysis, because this approach enables us to change models in order to estimate various assumed “individual effects” (see Baltagi, 2008; Green, 2003 for details). Despite time-series data constraints on the questionnaire survey, this estimation will yield temporal changes in logistics accessibility and the characteristics of manufacturing sectors by applying panel data analysis. Furthermore, this analysis can avoid a lack of statistical significance by using pooled data and provide suggestive findings for discussions on policy.

3.3 Panel Data Analysis

There are several types of panel data analytic models, such as constant coefficients, fixed effects, and random effects. This study focuses on fixed effects models, assuming that each manufacturing sector has unique individual factors because of our short time-series data or only four time points (i.e., five-year intervals across 15 years). In this section, we examine various types of fixed effects models in relation to the estimated model. The application of variable effects and other panel analytic models to this dataset are subjects for future research.

One type of panel data analytic model estimates the model that has constant coefficients for both intercepts and slopes. That is, this type assumes that there are no significant differences between effects related to the manufacturing sector and temporal effects. This model is sometimes called the pooled regression model (or constant coefficients model). Model_0_0 in *Case 1* and *Case 2* is based on this model.

Another type of panel data analytic model assumes that the intercepts differ according to the manufacturing sectors, but the slopes are constant. Thus, this type assumes significant differences or characteristics of total factor productivity (TFP) among the manufacturing sectors, but no significant differences over time. This is called the fixed effects or least squares dummy variable (LSDV) model. In our estimations, 19 (20 minus 1) dummy variables for intercepts are used to indicate particular manufacturing sectors. Model_0_B in *Case 2* is based on this model.

Another type of fixed effects model assumes that the intercepts differ according to time, but the slopes are constant. This model will catch up with the temporal changes in TFP by technological innovations and other factors that affect the production activity excluding labor, capital, and logistics accessibility. We can account for time effects over the four time points with three (4 minus 1) dummy variables in this study. Model_0_A in *Case 1* and *Case 2* is based on this model.

Further, we can also estimate the fixed effects model that has differential intercepts and slopes, both of which change according to manufacturing sector. In this type, we assume that the elasticities of capital (fixed asset) per capita and logistics accessibilities vary with the manufacturing sector. Model_B_B in *Case 2* is based on this model. Similarly, in another type of fixed effects model, the intercepts and slopes vary with time as well as manufacturing sector. This model can estimate not only TFP changes, but also elasticity trends over time. Model_A_A in *Case 1* and *Case 2* is based on this model.

By combining the models discussed above, fixed effects analysis can also provide a type where both intercepts and slopes might vary according to manufacturing sector and time. This will be a full baseline model that includes all of the individual effects, as compared to the pooled regression model (see Appendixes for the estimated function and model fitness testing). If all of these are statistically significant, there will be no reason to adopt the pooled regression model. Model_AB_AB in *Case 2* is based on this model.

Finally, we can discuss the changes in logistics accessibility elasticities according to time and manufacturing sector. In this paper, we try to estimate various fixed effects (or LSDV) models. The estimation results are shown in Tables 2 and 3 in the next section. In our analytical frameworks, we determine the economic impacts of "individual effects" on the intercepts and slopes in estimated functions.

4. ESTIMATION RESULTS AND DISCUSSION

4.1 Estimation Results

Tables 2 and 3 (please see Table 3 at the end of this paper) summarize the estimated production functions based on the dataset focusing on living zones, *Case 1*, and that focusing on manufacturing sectors, *Case 2*, respectively. As we discussed in the previous section, this study attempts to estimate various types of fixed effects panel models that have "individual effects” as intercepts and slopes. This estimation enables us to examine the sectoral differences and temporal changes in logistics accessibility.

Overall, the result shows that this production function has increasing returns to scale, which positively affects manufacturing activity when logistics accessibility is taken into account. For example, the gross regional output (GRP) per capita increases by 0.72% (i.e., β_1, period Average) and 0.57% (i.e., β_2, period Ave.) when there is a 10% reduction of transportation cost on inbound logistics and outbound logistics, respectively, in Model_0_0 in *Case 1*. The elasticity of GRP per capita with respect to capital (i.e., α) differs across manufacturing sectors and time, and most of these estimators are strongly significant. In addition, with the estimated logistics accessibility elasticities, the magnitude of economic impacts of cost improvements in the shipping of intermediate and finished goods on production activity differs across manufacturing sectors (see Table 3). This empirical analysis supports efficient transportation strategies and relocation strategies for factories and warehouses in manufacturing sectors. These strategies should attempt to relocate the production base close to input goods and the market base close to output goods, as seen in the (linear) Weber location–production problem (Weber, 1929).

Table 2 Estimated Production Functions with Logistics Accessibility in *Case 1*

Case 1	**Model_0_0**		**Model_0_A**		**Model_A_0**		**Model_A_A**	
	Estimator	*t* value	Estimator	*t* value	Estimator	*t* value	Estimator	*t* value
Constant	1.621	11.072 ***	1.230	9.045 ***	1.356	9.967 ***	0.979	3.175 ***
α								
K/L	0.379	20.489 ***	0.497	25.837 ***				
y1995					0.504	13.699 ***	0.502	13.682 ***
y2000					0.536	14.670 ***	0.535	14.319 ***
y2005					0.458	12.130 ***	0.467	12.231 ***
y2010					0.500	12.836 ***	0.523	12.361 ***
β1								
LAII	0.072	5.518 ***	0.061	5.129 ***				
y1995					0.136	5.369 ***	0.100	3.444 ***
y2000					0.121	4.941 ***	0.119	4.394 ***
y2005					0.046	2.357 **	0.052	2.622 ***
y2010					0.009	0.442	0.023	1.032
β2								
LAIO	0.057	5.223 ***	0.039	3.920 ***				
y1995					-0.030	-1.194	-0.025	-1.014
y2000					-0.024	-1.104	-0.024	-1.086
y2005					0.070	3.630 ***	0.076	3.871 ***
y2010					0.084	5.103 ***	0.082	4.950 ***
Dummy Variable								
y1995			0.289	11.767 ***			0.992	2.415 **
y2000			0.294	12.941 ***			0.406	0.998
y2005			0.161	7.302 ***			0.081	0.204
y2010			-				-	
Log Likelihood	80.278		-80.106		-56.895		-64.049	
AIC	82.278		-78.106		-54.895		-62.049	

(Note) 2000 year constant price. * significant at 10%, ** significant at 5%, and *** significant at 1%.

4.2 Findings for Logistics Accessibility Elasticities

The key findings from the estimated results for *Case 1* and *Case 2* are as follows:

Case 1: The estimation focused on living zones and an aggregated manufacturing sector.

(1) $\beta 1$ is larger than $\beta 2$ (Model_0_0, and Model_0_A).

(2) The values of $\beta 1$ decrease and become insignificant with time—the values of $\beta 1$ for 1995, 2000, and 2005 are significant, whereas that for 2010 is not significant. On the other hand, the values of $\beta 2$ increase and become significant with time—the values of $\beta 2$ for 2005 and 2010 are significant, whereas those for 1995 and 2000 are not significant (Model_A_0 and Model_A_A). This trend means that over time, there were

improvements in logistics accessibility for intermediate goods. However, the economic impacts of logistics accessibility improvements for final goods are becoming apparent.
(3) Dummy variables as intercepts for time are significant in Model_0_A.

Case 2: The estimation focused on prefectures and different manufacturing sectors.
(1) As with the result for *Case 1*, all in all, $\beta 1$ is larger than $\beta 2$, and most values of $\beta 1$ are highly significant. However, this estimation does not show the clear changes in logistics accessibilities with time, unlike in *Case 1* (Model_A_* in *Case 2*).
(2) All dummy variables as intercepts for time are significant in Model_0_A and Model_A_A.
(3) Most parameters for the dummy variables related to the manufacturing sectors as intercepts are significant and strongly affect the production function relative to time effects. This can be seen in Model_0_B, Model_0_AB, Model_A_B, and Model_A_AB with respect to estimators and model fitting.
(4) Some parameters for logistics accessibility related to manufacturing sectors in Model_B_**s are also significant, especially for sectors 11 (rubber products), 13 (ceramic, soil, and stone products), 18 (electric machinery and apparatus). This means that the logistics accessibility elasticities for GRP per capita differ according to the manufacturing sector (see Figures 3 (a) and (b) in the next subsection for details).

In the next subsection, we discuss the characteristics of manufacturing sectors and logistics accessibility elasticities in more detail.

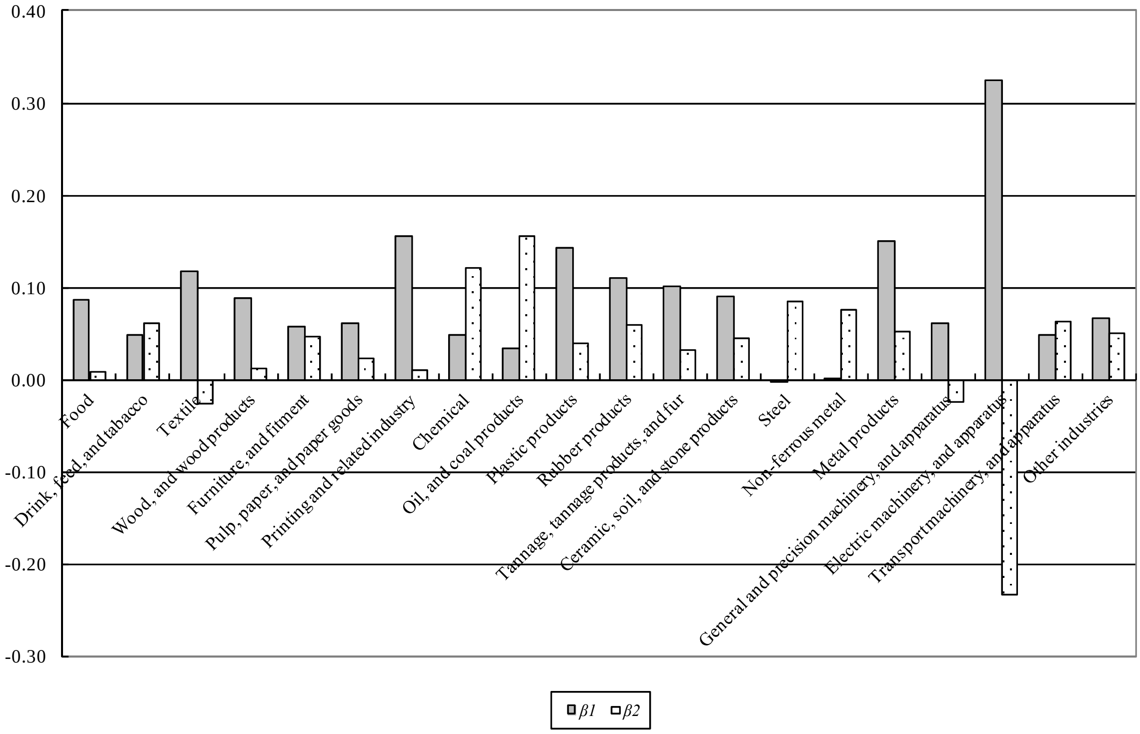
4.3 Discussion

Let us discuss the implications of the estimated models.

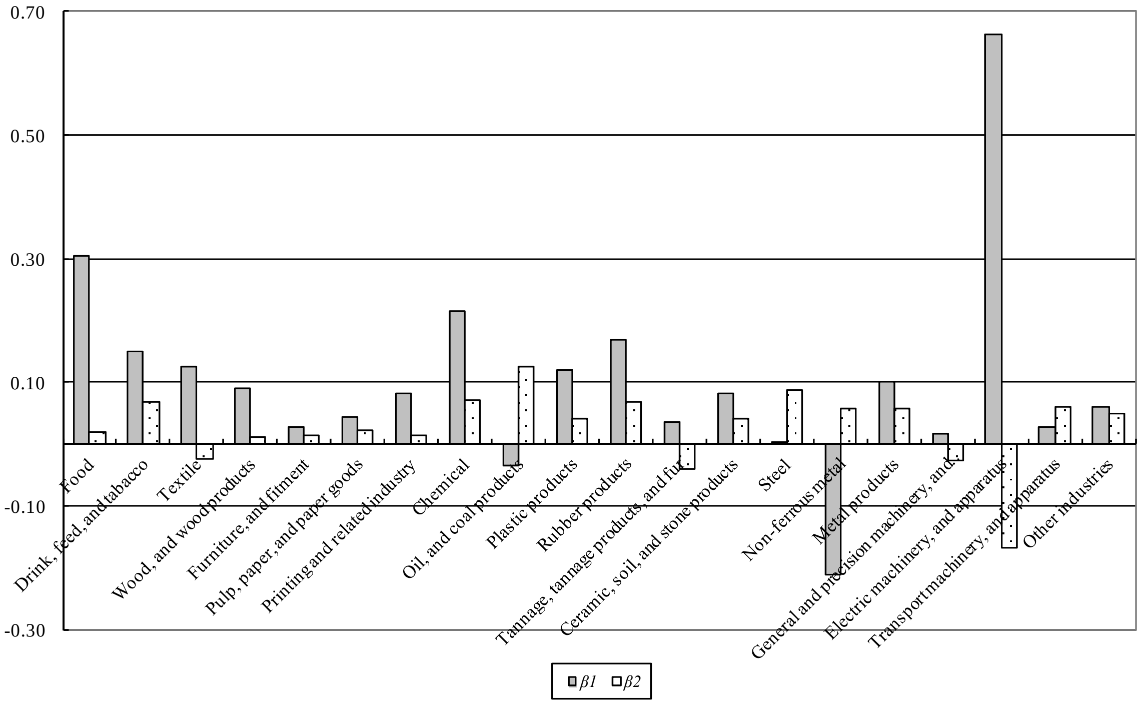
(1) All in all, the cost improvements in inbound shipping for intermediate goods, $\beta 1$, strongly drive up regional value added (GDP per capita), as compared with cost improvements in outbound shipping for final goods based on the short-term production structure; furthermore, these impacts decrease with time. Some producers used relatively transportation systems for high value-added finished goods that need fast outbound shipping; therefore, the economic impacts on GRP per capita were smaller, as compared to those of inbound shipping. In contrast, many suppliers of intermediate goods must ship their goods efficiently and bear the transportation costs because of c.i.f. price. However, the cost improvements in outbound shipping increase with time after 2005 (see Model_A_0 and Model_A_A).

Further investments in express highways that provide connections with other roads and the cooperative delivery system with information technology will provide the benefits of these cost improvements to various consumers. After the collapse of the "bubble economy" in 1989 and of financial institutions in 1997, around the year 2000, manufacturing companies started introducing SCM to ensure efficient logistics management. The economic slump and increasing globalization in Japan (Itoh, 2013) further strengthened this move. Our results will support improvements in sales logistics, which is a comparatively simple process that covers a number of destinations.

To discuss the characteristics of manufacturing sectors, we summarize the estimators for logistics accessibility based on the results for both Model_B_0 and Model_B_B in *Case 2* (because the estimated elasticities for logistics accessibility vary with the type of model used). Figures 3 (a) and (b) show the logistics accessibility elasticities, both $\beta 1$ and $\beta 2$, of GRP per capita, based on the estimation results for (a) Model_B_0 and (b) Model_B_B in *Case 2*, respectively.



(a) Model_B_0



(b) Model_B_B

(Note) These figures include the sectors whose parameters for logistics accessibility are *not* statistically significant. See Table 3 for details.

Figure 3 Logistics Accessibility Elasticities of GRP per capita

(2) The sectors whose estimators for inbound accessibility elasticity (i.e., $\beta 1$) in both models are significant (below the 10% significance level) and are greater than 0.1 are textiles, plastic products, rubber products, metal products, and electric machinery and apparatus. For example, because these industries need to respond quickly to changes in the market, they locate near the market. Furthermore, they enjoy the relative cost advantages of locating near the market or far from the suppliers.

(3) Oil and coal products is the only sector whose estimators for outbound accessibility elasticity (i.e., $\beta 2$) in both models are significant (below the 10% significance level) and greater than 0.1 (the estimator for transport machinery and apparatus is greater than 0.6). There is room for effective utilization of inland transportation in these sectors, for they incur heavy product transportation costs for long distances. Because producers must absorb transportation costs under c.i.f. price contracts, these industries react sensitively to these costs. In addition, because they are located near ports for importing goods, the cost improvements on procurement logistics is limited.

Table 4 shows the ratio of logistics costs to sales—or the logistics cost-paying capacity—in Japanese industries. This is based on the questionnaire survey conducted by JILS (every year). The ratios for the overall industry, including non-manufacturing sectors, and the aggregated manufacturing sector are 4.84% and 4.80% (Ave.), respectively. The ratio is relatively low for sectors with a large parameter for inbound accessibility elasticity (i.e., $\beta 1$). For example, the ratios for plastic and rubber products and electric machinery and apparatus are 4.65% and 1.91% (Ave.), respectively. Furthermore, the ratio for sectors with a large parameter for outbound accessibility elasticity (i.e., $\beta 2$) is also relatively low. For instance, the ratio for other chemical industry, including oil and coal products (transport machinery and apparatus industry) is 4.68% (3.66%) (Ave.). These values are below the ratio for the industry as a whole. A comparison of these values shows that logistics accessibility improvements have a large positive impact on the manufacturing productivity of a sector whose ratio of logistics cost to sales is low. On the other hand, logistics accessibility improvements do not have significant economic impacts on a sector that has low logistics cost-paying capacity.

Table 4 Ratio of Logistics Costs to Sales

Manufacturing sector	2004	2005	2006	2007	2008	2009	2010	2011	Ave.
Food (Keep Refrigerated)	8.13	8.18	9.10	10.38	9.12	9.43	9.43	8.46	9.03
Ceramic, soil, and stone products	8.41	8.92	8.99	9.11	11.27	11.44	8.77	8.28	9.40
Pulp, paper, and paper goods	9.49	10.17	8.77	7.34	6.79	7.17	6.79	6.53	7.88
Food (Normal Temperature)	5.53	6.05	5.80	6.24	5.79	6.04	6.66	6.47	6.07
Steel	5.19	5.17	6.10	6.32	4.90	6.16	6.57	5.52	5.74
Other industries	3.56	5.71	4.57	3.95	5.04	5.98	5.17	5.37	4.92
Soap, cleanser, and paint	5.55	5.60	5.63	5.61	5.85	5.49	5.65	5.33	5.59
Metal products	4.87	5.71	5.58	5.95	5.68	5.47	4.79	4.83	5.36
Printing and related industry	4.50	3.65	3.99	4.78	-	-	-	4.73	4.33
Non-ferrous metal	4.61	2.67	-	2.07	2.63	2.90	6.11	4.60	3.66
Textile	3.66	4.72	7.29	4.27	4.95	4.74	4.58	4.58	4.85
Other chemical	5.18	5.54	4.57	4.32	4.40	4.47	4.60	4.37	4.68
Plastic, and rubber products	6.02	6.22	3.99	3.95	3.42	5.12	4.28	4.16	4.65
Cosmetic products	4.07	3.56	6.01	-	3.53	3.45	3.83	3.81	4.04
General machinery, and apparatus	4.65	4.48	3.47	3.00	3.87	3.66	4.36	3.77	3.91
Logistics machinery, and apparatus	4.44	3.91	4.36	3.58	3.25	3.60	3.56	3.74	3.81
Transport machinery, and apparatus	4.23	4.21	3.83	4.49	2.97	2.87	3.12	3.59	3.66
Precision machinery, and apparatus	4.03	3.70	2.91	3.52	3.69	4.24	3.33	3.32	3.59
Electric machinery, and apparatus	1.77	1.92	1.80	1.73	1.95	1.90	2.05	2.19	1.91
Medical products	2.00	0.93	1.03	0.85	0.70	1.44	1.67	1.72	1.29
Aggregated manufacturing sector	4.82	4.92	4.79	4.78	4.58	4.79	4.91	-	4.80
All sectors	4.83	5.01	4.84	4.87	4.77	4.79	4.90	4.72	4.84

(Source) Japan Institute of Logistics Systems: JILS, the Annual Report of Logistics Cost Research (every year).

5. CONCLUSION

This empirical study examined the effects of improvements in logistics accessibility on production activity. We used data on interregional transportation costs for inbound and outbound shipping obtained from questionnaire surveys for 1995, 2000, 2005, and 2010; construct a panel dataset; and estimate logistics accessibility elasticities of manufacturing industries. Our results show that the estimated production function has increasing returns to scale, which positively affects production activity when logistics accessibility is taken into account. In general, the economic impacts of inbound logistics accessibility improvements are higher than those of outbound logistics accessibility improvements. However, the elasticity of inbound logistics accessibility decreases, whereas that of outbound accessibility increases with time. In addition, the magnitude of economic impacts of transportation cost improvements in intermediate and finished goods shipping on production activity differs across manufacturing sectors. The sector with high (low) logistics cost-paying capacity enjoys high (low) economic impacts of logistics accessibility improvements on its production function. This study faces difficulties because of the short time-series data and constraints in the questionnaire survey. As for our future research agenda, we plan to estimate the long-term effects of changes in logistics accessibility, by using other variables to measure the economic separation between zones i and j.

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APPENDIXES

Appendix 1

For reference, the equation for the production function with logistics accessibility in Model_AB_AB in *Case 2*, that is, the full baseline model can be expressed as follows:

$$\log y_{i,s,t} = const + \alpha_{s,t} \log k_{i,s,t} + \beta_{1s,t} \log LAII_{i,s,t} + \beta_{2s,t} \log LAIO_{i,s,t} + \sum_{t=1}^{4} const\_Time \bullet d(t)_{i,s} + \sum_{s=1}^{20} const\_Sector \bullet d(s)_{i,t} + \eta_{i,s,t} \quad \text{(A1)}$$

Here, $y_{i,s,t}$ and $k_{i,s,t}$ are GRP and production capital stock per capita in prefecture i, sector s, and time t, respectively. $d(t)_{i,s}$ and $d(s)_{i,t}$ are dummy variables that take the value of 1 for the relevant years and sectors, respectively, and 0 otherwise.

Appendix 2

In this study, we adapt the log likelihood test for fixed effects models. We use the pooled regression model (Model_0_0) as the baseline for our comparison. All of the likelihood ratio (*LR*) tests have the following form:

$$LR = -2\log\left(\frac{l(res)}{l(unres)}\right) = -2\{\log(l(res)) - \log(l(unres))\} \quad \text{(A2)}$$

Here, $l(res)$ denotes the restricted maximum likelihood value (the fixed effects model), and $l(unres)$ denotes the unrestricted maximum likelihood value (the pooled regression model). LR is chi-square distributed with degrees of freedom. For example, the test statistic for Model_0_B in *Case 2* is 2437.8, which is significant at the 1% level, and can be interpreted as the statistical distance between the pooled regression model and the fixed effects model. This log likelihood ratio test statistic indicates that the effort to construct the fixed effects model was worthwhile. Overall, the calculated *LR*s in this empirical study are significant at the 1% level for the models with individual “sectoral” effects in *Case 2*.

Table 3 Estimated Production Functions with Logistics Accessibility in *Case 2*

Case 2	**Model_0_0**			**Model_0_A**			**Model_0_B**			**Model_0_AB**		
	Estimator	*t* value		Estimator	*t* value		Estimator	*t* value		Estimator	*t* value	
Constant	1.475	8.992	***	1.378	8.351	***	1.749	10.563	***	1.675	9.966	***
α												
K/L	0.529	45.824	***	0.540	44.815	***	0.426	32.341	***	0.432	29.637	***
y1995												
y2000												
y2005												
y2010												
Sector 1												
Sector 2												
Sector 3												
Sector 4												
Sector 5												
Sector 6												
Sector 7												
Sector 8												
Sector 9												
Sector 10												
Sector 11												
Sector 12												
Sector 13												
Sector 14												
Sector 15												
Sector 16												
Sector 17												
Sector 18												
Sector 19												
Sector 20												
β1												
LAII	0.071	6.745	***	0.071	6.734	***	0.080	8.238	***	0.081	8.310	***
y1995												
y2000												
y2005												
y2010												
Sector 1												
Sector 2												
Sector 3												
Sector 4												
Sector 5												
Sector 6												
Sector 7												
Sector 8												
Sector 9												
Sector 10												
Sector 11												
Sector 12												
Sector 13												
Sector 14												
Sector 15												
Sector 16												
Sector 17												
Sector 18												
Sector 19												
Sector 20												
β2												
LAIO	0.023	2.796	***	0.021	2.557	**	0.037	5.196	***	0.036	5.121	***
y1995												
y2000												
y2005												
y2010												
Sector 1												
Sector 2												
Sector 3												
Sector 4												
Sector 5												
Sector 6												
Sector 7												
Sector 8												
Sector 9												
Sector 10												
Sector 11												
Sector 12												
Sector 13												
Sector 14												
Sector 15												
Sector 16												
Sector 17												
Sector 18												
Sector 19												
Sector 20												
Dummy Variable												
y1995				0.105	4.149	***				0.045	2.081	**
y2000				0.056	2.241	**				0.021	1.015	
y2005				0.096	3.887	***				0.082	4.035	***
y2010				-						-		
Sector 1							-0.347	-7.399	***	-0.349	-7.458	***
Sector 2							0.406	8.115	***	0.395	7.821	***
Sector 3							-0.451	-9.604	***	-0.450	-9.591	***
Sector 4							-0.289	-5.977	***	-0.291	-6.034	***
Sector 5							-0.109	-2.156	**	-0.112	-2.217	**
Sector 6							-0.266	-5.381	***	-0.274	-5.522	***
Sector 7							0.007	0.140		0.004	0.078	
Sector 8							0.476	9.424	***	0.465	9.115	***
Sector 9							-0.173	-2.690	***	-0.196	-2.975	***
Sector 10							-0.240	-5.134	***	-0.245	-5.233	***
Sector 11							-0.081	-1.659	*	-0.085	-1.735	*
Sector 12							0.004	0.068		0.005	0.077	
Sector 13							-0.149	-3.093	***	-0.156	-3.238	***
Sector 14							-0.246	-4.865	***	-0.255	-5.019	***
Sector 15							-0.159	-3.100	***	-0.168	-3.247	***
Sector 16							-0.310	-6.583	***	-0.314	-6.689	***
Sector 17							0.057	1.209		0.054	1.140	
Sector 18							0.625	13.207	***	0.620	13.128	***
Sector 19							0.051	1.064		0.046	0.959	
Sector 20							-			-		
Log Likelihood	4421.590			4417.186			3202.712			3202.973		
AIC	4423.590			4419.186			3204.712			3204.973		

(Note) 2000 year constant price. * significant at 10%, ** significant at 5% and *** significant at 1%.

Table 3 Estimated Production Functions with Logistics Accessibility in *Case 2* (continued)

Case 2	Model_A_0		Model_A_A		Model_A_B		Model_A_AB	
	Estimator	*t* value	Estimator	*t* value	Estimator	*t* value	Estimator	*t* value
Constant	1.406	8.526 ***	0.558	1.613	1.700	10.196 ***	1.471	4.893 ***
α								
K/L								
y1995	0.489	23.686 ***	0.490	23.702 ***	0.388	19.314 ***	0.387	19.174 ***
y2000	0.566	23.450 ***	0.566	23.469 ***	0.447	19.546 ***	0.447	19.510 ***
y2005	0.573	23.040 ***	0.569	22.780 ***	0.462	20.015 ***	0.459	19.738 ***
y2010	0.556	19.299 ***	0.570	19.509 ***	0.456	17.720 ***	0.459	17.562 ***
Sector 1								
Sector 2								
Sector 3								
Sector 4								
Sector 5								
Sector 6								
Sector 7								
Sector 8								
Sector 9								
Sector 10								
Sector 11								
Sector 12								
Sector 13								
Sector 14								
Sector 15								
Sector 16								
Sector 17								
Sector 18								
Sector 19								
Sector 20								
β1								
LAII								
y1995	0.081	4.496 ***	0.071	3.199 ***	0.096	6.161 ***	0.101	5.291 ***
y2000	0.065	3.497 ***	0.060	2.621 ***	0.069	4.376 ***	0.073	3.795 ***
y2005	0.066	4.157 ***	0.052	2.880 ***	0.079	5.770 ***	0.067	4.347 ***
y2010	0.070	3.877 ***	0.104	4.777 ***	0.072	4.580 ***	0.081	4.369 ***
Sector 1								
Sector 2								
Sector 3								
Sector 4								
Sector 5								
Sector 6								
Sector 7								
Sector 8								
Sector 9								
Sector 10								
Sector 11								
Sector 12								
Sector 13								
Sector 14								
Sector 15								
Sector 16								
Sector 17								
Sector 18								
Sector 19								
Sector 20								
β2								
LAIO								
y1995	0.031	1.836 *	0.028	1.627	0.036	2.577 **	0.038	2.624 ***
y2000	0.020	1.125	0.019	1.065	0.043	2.932 ***	0.043	2.954 ***
y2005	0.018	1.264	0.013	0.901	0.031	2.573 **	0.026	2.165 **
y2010	0.014	0.873	0.020	1.246	0.036	2.705 ***	0.037	2.804 ***
Sector 1								
Sector 2								
Sector 3								
Sector 4								
Sector 5								
Sector 6								
Sector 7								
Sector 8								
Sector 9								
Sector 10								
Sector 11								
Sector 12								
Sector 13								
Sector 14								
Sector 15								
Sector 16								
Sector 17								
Sector 18								
Sector 19								
Sector 20								
Dummy Variable								
y1995			1.083	2.210 **			0.105	0.259
y2000			0.960	1.989 **			0.148	0.374
y2005			1.214	2.664 ***			0.546	1.460
y2010			-				-	
Sector 1					-0.342	-7.311 ***	-0.342	-7.289 ***
Sector 2					0.391	7.735 ***	0.390	7.714 ***
Sector 3					-0.451	-9.599 ***	-0.450	-9.583 ***
Sector 4					-0.297	-6.125 ***	-0.295	-6.094 ***
Sector 5					-0.117	-2.307 **	-0.118	-2.330 **
Sector 6					-0.276	-5.554 ***	-0.277	-5.555 ***
Sector 7					0.003	0.063	0.004	0.082
Sector 8					0.465	9.110 ***	0.466	9.109 ***
Sector 9					-0.189	-2.852 ***	-0.186	-2.799 ***
Sector 10					-0.241	-5.140 ***	-0.240	-5.126 ***
Sector 11					-0.081	-1.662 *	-0.080	-1.630
Sector 12					-0.004	-0.056	-0.003	-0.048
Sector 13					-0.160	-3.322 ***	-0.162	-3.353 ***
Sector 14					-0.251	-4.928 ***	-0.251	-4.923 ***
Sector 15					-0.168	-3.250 ***	-0.167	-3.221 ***
Sector 16					-0.312	-6.644 ***	-0.313	-6.648 ***
Sector 17					0.059	1.246	0.057	1.217
Sector 18					0.624	13.192 ***	0.623	13.156 ***
Sector 19					0.052	1.081	0.052	1.083
Sector 20					-		-	
Log Likelihood	4459.903		4451.529		3245.794		3244.064	
AIC	4461.903		4453.529		3247.794		3246.064	

(Note) 2000 year constant price. * significant at 10%, ** significant at 5% and *** significant at 1%.

Table 3 Estimated Production Functions with Logistics Accessibility in *Case 2* (continued)

Case 2	Model_B_0		Model_B_A		Model_B_B		Model_B_AB	
	Estimator	*t* value	Estimator	*t* value	Estimator	*t* value	Estimator	*t* value
Constant	1.686	9.946 ***	1.625	9.399 ***	1.830	1.852 *	1.689	1.712 *
α								
K/L								
y1995								
y2000								
y2005								
y2010								
Sector 1	0.449	3.759 ***	0.460	3.821 ***	0.324	2.674 ***	0.345	2.820 ***
Sector 2	0.515	10.360 ***	0.514	10.284 ***	0.521	10.751 ***	0.520	10.707 ***
Sector 3	0.436	9.512 ***	0.440	9.381 ***	0.437	9.783 ***	0.443	9.703 ***
Sector 4	0.440	8.237 ***	0.445	8.166 ***	0.440	7.837 ***	0.449	7.804 ***
Sector 5	0.456	8.887 ***	0.459	8.764 ***	0.413	7.842 ***	0.420	7.838 ***
Sector 6	0.485	10.938 ***	0.486	10.942 ***	0.475	9.767 ***	0.479	9.817 ***
Sector 7	0.287	4.271 ***	0.291	4.240 ***	0.262	3.934 ***	0.269	3.970 ***
Sector 8	0.362	5.042 ***	0.369	5.145 ***	0.429	5.865 ***	0.434	5.947 ***
Sector 9	0.240	4.813 ***	0.239	4.810 ***	0.227	4.668 ***	0.226	4.662 ***
Sector 10	0.194	2.530 **	0.203	2.637 ***	0.173	2.176 **	0.185	2.316 **
Sector 11	0.266	4.128 ***	0.274	4.244 ***	0.295	4.620 ***	0.304	4.756 ***
Sector 12	0.384	7.894 ***	0.385	7.900 ***	0.349	7.202 ***	0.352	7.248 ***
Sector 13	0.364	6.867 ***	0.366	6.778 ***	0.353	6.161 ***	0.361	6.191 ***
Sector 14	0.496	11.445 ***	0.499	11.520 ***	0.500	11.604 ***	0.501	11.661 ***
Sector 15	0.522	12.746 ***	0.523	12.790 ***	0.384	8.046 ***	0.381	7.991 ***
Sector 16	0.123	1.633	0.138	1.795 *	0.104	1.380	0.121	1.580
Sector 17	0.700	7.434 ***	0.712	7.495 ***	0.669	7.065 ***	0.690	7.221 ***
Sector 18	0.611	8.186 ***	0.607	8.110 ***	0.884	11.439 ***	0.886	11.394 ***
Sector 19	0.464	6.933 ***	0.473	7.069 ***	0.427	5.593 ***	0.438	5.744 ***
Sector 20	0.436	6.361 ***	0.441	6.348 ***	0.437	6.535 ***	0.444	6.555 ***
β1								
LAII								
y1995								
y2000								
y2005								
y2010								
Sector 1	0.086	1.568	0.083	1.508	0.305	3.771 ***	0.290	3.576 ***
Sector 2	0.047	1.414	0.049	1.477	0.150	3.231 ***	0.154	3.322 ***
Sector 3	0.118	3.406 ***	0.116	3.368 ***	0.125	2.980 ***	0.120	2.849 ***
Sector 4	0.089	3.505 ***	0.086	3.405 ***	0.090	2.897 ***	0.086	2.792 ***
Sector 5	0.058	1.928 *	0.062	2.068 **	0.028	0.907	0.034	1.068
Sector 6	0.061	1.977 **	0.062	1.997 **	0.044	0.913	0.049	1.006
Sector 7	0.155	4.705 ***	0.156	4.693 ***	0.081	1.704 *	0.080	1.683 *
Sector 8	0.048	1.109	0.046	1.060	0.215	3.131 ***	0.205	3.001 ***
Sector 9	0.034	0.982	0.036	1.051	-0.035	-0.825	-0.033	-0.793
Sector 10	0.143	3.655 ***	0.141	3.601 ***	0.119	2.432 **	0.117	2.390 **
Sector 11	0.109	3.508 ***	0.111	3.561 ***	0.170	4.299 ***	0.169	4.281 ***
Sector 12	0.101	3.354 ***	0.103	3.449 ***	0.036	1.043	0.041	1.162
Sector 13	0.089	3.546 ***	0.091	3.626 ***	0.082	2.697 ***	0.086	2.826 ***
Sector 14	-0.003	-0.079	0.003	0.090	0.004	0.119	0.009	0.248
Sector 15	0.000	0.012	-0.002	-0.057	-0.212	-4.072 ***	-0.220	-4.237 ***
Sector 16	0.149	4.007 ***	0.143	3.834 ***	0.101	1.813 *	0.090	1.611
Sector 17	0.060	1.344	0.052	1.146	0.016	0.285	0.012	0.221
Sector 18	0.325	6.621 ***	0.332	6.767 ***	0.664	11.439 ***	0.679	11.639 ***
Sector 19	0.048	1.426	0.048	1.446	0.028	0.714	0.029	0.744
Sector 20	0.067	2.039 **	0.071	2.153 **	0.059	0.916	0.067	1.038
β2								
LAIO								
y1995								
y2000								
y2005								
y2010								
Sector 1	0.009	0.201	0.010	0.233	0.019	0.461	0.020	0.490
Sector 2	0.061	2.480 **	0.061	2.492 **	0.069	2.853 ***	0.069	2.871 ***
Sector 3	-0.026	-0.799	-0.024	-0.736	-0.024	-0.753	-0.023	-0.721
Sector 4	0.012	0.408	0.014	0.490	0.012	0.405	0.014	0.461
Sector 5	0.046	1.511	0.043	1.403	0.015	0.481	0.013	0.421
Sector 6	0.024	0.723	0.024	0.736	0.022	0.696	0.022	0.681
Sector 7	0.009	0.407	0.010	0.422	0.014	0.610	0.014	0.632
Sector 8	0.121	2.826 ***	0.122	2.858 ***	0.071	1.590	0.074	1.665 *
Sector 9	0.155	4.354 ***	0.154	4.338 ***	0.125	3.440 ***	0.124	3.413 ***
Sector 10	0.040	1.238	0.040	1.270	0.042	1.356	0.043	1.384
Sector 11	0.059	2.157 **	0.056	2.061 **	0.069	2.576 **	0.066	2.454 **
Sector 12	0.033	1.069	0.031	1.023	-0.041	-1.103	-0.041	-1.102
Sector 13	0.044	1.739 *	0.043	1.687 *	0.042	1.661 *	0.041	1.613
Sector 14	0.084	2.842 ***	0.079	2.682 ***	0.087	2.916 ***	0.082	2.744 ***
Sector 15	0.076	2.255 **	0.080	2.359 **	0.058	1.758 *	0.061	1.845 *
Sector 16	0.051	1.544	0.054	1.645	0.058	1.763 *	0.061	1.883 *
Sector 17	-0.025	-0.671	-0.019	-0.495	-0.026	-0.717	-0.019	-0.523
Sector 18	-0.235	-5.299 ***	-0.239	-5.395 ***	-0.169	-3.879 ***	-0.173	-3.986 ***
Sector 19	0.063	2.150 **	0.061	2.083 **	0.060	2.119 **	0.059	2.055 **
Sector 20	0.050	1.717 *	0.047	1.597	0.051	1.771 *	0.046	1.614
Dummy Variable								
y1995			0.035	1.527			0.041	1.794 *
y2000			0.016	0.767			0.027	1.289
y2005			0.077	3.827 ***			0.084	4.255 ***
y2010			-				-	
Sector 1					-3.758	-2.649 ***	-3.513	-2.481 **
Sector 2					-2.255	-1.863 *	-2.234	-1.850 *
Sector 3					-0.320	-0.275	-0.166	-0.143
Sector 4					-0.170	-0.141	-0.084	-0.069
Sector 5					1.167	1.038	1.175	1.047
Sector 6					0.278	0.202	0.276	0.200
Sector 7					1.327	1.094	1.396	1.151
Sector 8					-2.860	-2.146 **	-2.675	-2.010 **
Sector 9					1.791	1.441	1.889	1.522
Sector 10					0.387	0.319	0.445	0.367
Sector 11					-1.630	-1.382	-1.503	-1.277
Sector 12					2.308	1.853 *	2.326	1.872 *
Sector 13					0.109	0.093	0.111	0.094
Sector 14					-0.361	-0.313	-0.255	-0.222
Sector 15					5.216	3.658 ***	5.451	3.822 ***
Sector 16					0.785	0.606	0.931	0.719
Sector 17					0.921	0.717	0.828	0.644
Sector 18					-9.551	-7.028 ***	-9.642	-7.066 ***
Sector 19					0.517	0.421	0.568	0.463
Sector 20					-		-	
Log Likelihood	3314.597		3316.094		3094.366		3093.387	
AIC	3316.597		3318.094		3096.366		3095.387	

(Note) 2000 year constant price. * significant at 10%, ** significant at 5% and *** significant at 1%.

Table 3 Estimated Production Functions with Logistics Accessibility in *Case 2* (continued)

Case 2	Model_AB		Model_AB_A		Model_AB_B		Model_AB_AB	
	Estimator	*t* value	Estimator	*t* value	Estimator	*t* value	Estimator	*t* value
Constant	1.643	9.597 ***	1.472	4.781 ***	1.800	1.829 *	2.026	1.985 **
α								
K/L								
y1995	0.414	5.888 ***	0.412	5.842 ***	0.414	6.039 ***	0.408	5.940 ***
y2000	0.468	6.510 ***	0.467	6.469 ***	0.469	6.696 ***	0.463	6.588 ***
y2005	0.498	6.803 ***	0.494	6.720 ***	0.512	7.173 ***	0.504	7.034 ***
y2010	0.486	6.592 ***	0.487	6.570 ***	0.511	7.108 ***	0.501	6.922 ***
Sector 1	0.030	0.220	0.034	0.245	-0.077	-0.554	-0.077	-0.554
Sector 2	0.033	0.385	0.035	0.407	0.025	0.294	0.032	0.379
Sector 3	0.014	0.166	0.018	0.213	0.019	0.235	0.020	0.248
Sector 4	-0.001	-0.010	0.003	0.031	0.004	0.045	0.000	0.003
Sector 5	0.009	0.099	0.006	0.073	-0.035	-0.412	-0.046	-0.537
Sector 6	0.013	0.156	0.015	0.178	-0.005	-0.065	0.003	0.034
Sector 7	-0.174	-1.808 *	-0.175	-1.819 *	-0.207	-2.189 **	-0.211	-2.234 **
Sector 8	-0.105	-1.046	-0.101	-1.009	-0.054	-0.545	-0.043	-0.434
Sector 9	-0.231	-2.685 ***	-0.228	-2.644 ***	-0.254	-3.032 ***	-0.246	-2.927 ***
Sector 10	-0.258	-2.504 **	-0.260	-2.521 **	-0.280	-2.703 ***	-0.277	-2.672 ***
Sector 11	-0.181	-1.919 *	-0.175	-1.857 *	-0.157	-1.703 *	-0.154	-1.670 *
Sector 12	-0.058	-0.690	-0.059	-0.702	-0.098	-1.183	-0.105	-1.267
Sector 13	-0.098	-1.123	-0.094	-1.073	-0.111	-1.264	-0.099	-1.121
Sector 14	0.032	0.394	0.034	0.407	0.025	0.309	0.032	0.400
Sector 15	0.056	0.697	0.058	0.713	-0.100	-1.207	-0.091	-1.089
Sector 16	-0.305	-2.997 ***	-0.303	-2.969 ***	-0.322	-3.205 ***	-0.312	-3.099 ***
Sector 17	0.266	2.282 **	0.268	2.300 **	0.245	2.119 **	0.256	2.207 **
Sector 18	0.148	1.454	0.149	1.461	0.425	4.165 ***	0.433	4.238 ***
Sector 19	0.009	0.092	0.010	0.099	-0.034	-0.336	-0.025	-0.241
Sector 20	-		-		-		-	
β1								
LAII								
y1995	0.087	2.440 **	0.093	2.477 **	0.083	1.274	0.096	1.441
y2000	0.061	1.746 *	0.064	1.749 *	0.049	0.749	0.054	0.815
y2005	0.066	1.889 *	0.058	1.633	0.061	0.937	0.060	0.907
y2010	0.062	1.797 *	0.070	1.934 *	0.048	0.745	0.040	0.602
Sector 1	0.002	0.040	0.001	0.012	0.209	2.023 **	0.212	2.049 **
Sector 2	-0.018	-0.387	-0.019	-0.423	0.100	1.264	0.099	1.255
Sector 3	0.041	0.894	0.037	0.784	0.046	0.595	0.051	0.654
Sector 4	0.015	0.364	0.013	0.314	0.028	0.391	0.025	0.355
Sector 5	-0.011	-0.250	-0.010	-0.228	-0.032	-0.446	-0.030	-0.426
Sector 6	-0.006	-0.147	-0.008	-0.179	-0.010	-0.124	-0.011	-0.134
Sector 7	0.086	1.908 *	0.086	1.893 *	0.022	0.274	0.020	0.255
Sector 8	-0.016	-0.297	-0.016	-0.294	0.148	1.577	0.152	1.616
Sector 9	-0.033	-0.701	-0.033	-0.713	-0.106	-1.370	-0.110	-1.426
Sector 10	0.069	1.375	0.068	1.363	0.054	0.665	0.054	0.661
Sector 11	0.037	0.850	0.036	0.824	0.102	1.360	0.102	1.348
Sector 12	0.028	0.649	0.030	0.681	-0.031	-0.425	-0.034	-0.461
Sector 13	0.020	0.501	0.019	0.465	0.022	0.313	0.022	0.304
Sector 14	-0.062	-1.382	-0.063	-1.399	-0.049	-0.660	-0.048	-0.655
Sector 15	-0.080	-1.740 *	-0.082	-1.769 *	-0.298	-3.595 ***	-0.299	-3.596 ***
Sector 16	0.068	1.405	0.066	1.367	0.027	0.316	0.024	0.276
Sector 17	-0.025	-0.450	-0.027	-0.494	-0.058	-0.681	-0.060	-0.703
Sector 18	0.260	4.488 ***	0.259	4.461 ***	0.624	7.178 ***	0.624	7.173 ***
Sector 19	-0.019	-0.414	-0.017	-0.370	-0.031	-0.414	-0.031	-0.405
Sector 20	-		-		-		-	
β2								
LAIO								
y1995	0.040	1.205	0.041	1.226	0.035	1.100	0.040	1.223
y2000	0.048	1.495	0.048	1.492	0.051	1.651 *	0.054	1.725 *
y2005	0.035	1.122	0.032	0.996	0.027	0.871	0.027	0.885
y2010	0.039	1.277	0.040	1.296	0.035	1.177	0.035	1.181
Sector 1	-0.030	-0.585	-0.030	-0.570	-0.017	-0.333	-0.021	-0.405
Sector 2	0.024	0.632	0.025	0.657	0.037	0.991	0.036	0.955
Sector 3	-0.070	-1.610	-0.067	-1.516	-0.068	-1.596	-0.070	-1.633
Sector 4	-0.031	-0.749	-0.030	-0.726	-0.025	-0.612	-0.027	-0.647
Sector 5	0.001	0.014	0.000	0.010	-0.024	-0.568	-0.026	-0.597
Sector 6	-0.014	-0.324	-0.013	-0.305	-0.010	-0.242	-0.013	-0.294
Sector 7	-0.031	-0.823	-0.030	-0.793	-0.023	-0.631	-0.024	-0.668
Sector 8	0.078	1.492	0.077	1.465	0.035	0.657	0.030	0.562
Sector 9	0.116	2.460 **	0.115	2.453 **	0.084	1.782 *	0.081	1.716 *
Sector 10	0.002	0.047	0.003	0.076	0.009	0.223	0.008	0.182
Sector 11	0.017	0.412	0.016	0.397	0.029	0.750	0.029	0.732
Sector 12	-0.011	-0.254	-0.012	-0.275	-0.082	-1.741 *	-0.079	-1.684 *
Sector 13	0.004	0.091	0.004	0.093	0.007	0.187	0.005	0.135
Sector 14	0.035	0.848	0.036	0.858	0.039	0.944	0.035	0.850
Sector 15	0.049	1.086	0.050	1.108	0.037	0.838	0.036	0.808
Sector 16	0.013	0.286	0.014	0.313	0.023	0.533	0.021	0.489
Sector 17	-0.058	-1.202	-0.056	-1.168	-0.052	-1.117	-0.053	-1.138
Sector 18	-0.279	-5.263 ***	-0.278	-5.237 ***	-0.209	-4.019 ***	-0.210	-4.032 ***
Sector 19	0.019	0.448	0.016	0.393	0.019	0.473	0.017	0.429
Sector 20	-		-		-		-	
Dummy Variable								
y1995			0.057	0.135			-0.510	-1.205
y2000			0.123	0.308			-0.331	-0.837
y2005			0.416	1.110			-0.155	-0.415
y2010			-				-	
Sector 1					-3.528	-2.496 **	-3.519	-2.485 **
Sector 2					-2.407	-1.995 **	-2.414	-1.999 **
Sector 3					-0.139	-0.120	-0.206	-0.177
Sector 4					-0.375	-0.311	-0.280	-0.231
Sector 5					1.057	0.942	1.119	0.996
Sector 6					0.119	0.087	0.127	0.092
Sector 7					1.258	1.039	1.343	1.107
Sector 8					-2.690	-2.026 **	-2.739	-2.060 **
Sector 9					2.133	1.720 *	2.226	1.790 *
Sector 10					0.279	0.231	0.301	0.248
Sector 11					-1.584	-1.348	-1.574	-1.337
Sector 12					2.337	1.880 *	2.382	1.912 *
Sector 13					-0.017	-0.014	-0.043	-0.037
Sector 14					-0.279	-0.243	-0.258	-0.225
Sector 15					5.480	3.848 ***	5.452	3.826 ***
Sector 16					0.707	0.547	0.749	0.579
Sector 17					0.657	0.512	0.649	0.505
Sector 18					-9.959	-7.297 ***	-9.993	-7.317 ***
Sector 19					0.501	0.409	0.462	0.377
Sector 20					-		-	
Log Likelihood	3358.124		3357.377		3128.240		3127.479	
AIC	3360.124		3359.377		3130.240		3129.479	

(Note) 2000 year constant price. * significant at 10%, ** significant at 5% and *** significant at 1%.