

Economic Effect of High-Speed Rail: Empirical Analysis of Shinkansen's Impact on Industrial Location

Ji Han¹; Yoshitsugu Hayashi²; Peng Jia³; and Quan Yuan⁴

Abstract: High-speed rail in infrastructure construction has become a priority worldwide, and vast investments have been made; therefore, it has become increasingly necessary to appropriately assess regional economic impact, and more importantly, to deliberate policy to improve regional industrial development. This paper looks at the impacts of Shinkansen lines on industrial locations in Japan. Unlike previous research, this study investigates both socioeconomic factors and physical determinants through an empirical industrial location model and multivariable stepwise regressions. The results indicate that during the period of 1990–2000, the dominant driving force of industrial location has changed from industrial transaction interdependence to population consumption demand. The elasticity of accessibility to the Shinkansen network has also shown an increasing trend from 1990 to 2000. Further expansion of Shinkansen lines would encourage the development of several industries, such as real estate, commerce, and services, and would thus contribute to forming the regional economic structure. DOI: 10.1061/(ASCE)TE.1943-5436.0000467. © 2012 American Society of Civil Engineers.

CE Database subject headings: Rail transportation; Economic factors; Industrial facilities.

Author keywords: Rail transport; Economic factors; Industrial location; Accessibility.

Introduction

The construction of transport infrastructure is often considered to be a primary factor affecting accessibility and industrial location, and hence, the growth of a region. Due to such characteristics as safety, reliability, convenience, time-saving, and environmentally friendliness, high-speed rail (HSR) has been recognized as one of the most important transport modes and has been given increasingly great priority in regional development in the world. However, when regions and cities profit significantly from HSR, some side effects are simultaneously generated, such as the over-agglomeration of economy and population in some megacities and the decrease of economic potential. With more HSR to be introduced or expanded in both developed and developing countries, it is increasingly necessary to have a better understanding of HSR's role in economic organization, and to develop appropriate strategies and policies to reduce its side effects on regional development.

Globally, a good deal of research has been conducted concerning the regional impact of transport infrastructure. Nakamura et al. (1981) classified the direct and indirect impacts of Shinkansen and sorted the causal links among affecting factors through an interpretive structural modeling approach. They also developed a system dynamics model to simulate the impacts of the Sanyo Line on

Hiroshima City. Nakamura and Ueda (1989) analyzed the demographic changes in the area with and without Shinkansen and high-way services in Japan. They found that since the operation of HSR, there is a significant concentration of population into the main metropolitan centers, cities with HSR stations, and areas with high-way services. These are consistent with the findings of Vickerman (1997), who reviewed the experiences of HSR development in Europe and pointed out that nearly all HSR stations are located in major metropolises, which probably results in the expansion of regional divergence. Gutierrez (2001) evaluated the accessibility impacts of the Madrid–Barcelona–French border high-speed line by means of three indicators: weighted average travel times, economic potential, and daily accessibility. Munnell (1992) used an extended production function approach in which US highway capital is added as a public input to evaluate the economic influence of infrastructure. Rietveld et al. (2001) discussed the experiences of Japan and France and conducted a cost-benefit analysis of the planned HSR links in the Netherlands. Kantor (2008) conducted scenario analysis of the benefits with and without the construction of HSR in the Central Valley of the United States, in which population and employment growth, quality of life enhancement, real estate impacts, and other aspects, are projected. Leitham et al. (1999) used the multiregional input-output approach to explain the impacts of transport infrastructure investments on regional economic development. They estimated interindustry/interregional trade flows as a function of transport cost and a fixed matrix of technical interindustry input-output coefficients. Koike et al. (2000) and Ueda et al. (2001) applied the spatial computable general equilibrium (SCGE) model to evaluate the potential economic damage of a catastrophe in the HSR network during the 1995 Kobe earthquake in Japan. The European Observation Network on Territorial Development and Cohesion (ESPON 2011) reviewed the primary literature on global, European, and regional accessibility studies, and presented a set of accessibility indicators and impact indicators to assess the effect of transport infrastructure on accessibility at different levels and its linkage to economic development. These studies provide useful insights into transport

¹Graduate School of Environmental Studies, Nagoya Univ., Furo-cho, Chikusa-ku, Nagoya, Japan 464-8603 (corresponding author). E-mail: hanji_cn@hotmail.com

²Graduate School of Environmental Studies, Nagoya Univ., Furo-cho, Chikusa-ku, Nagoya, Japan 464-8603.

³Transportation Management College, Dalian Maritime Univ., 1# Linghai Rd., Dalian, China 116026.

⁴Graduate School of Environmental Studies, Nagoya Univ., Furo-cho, Chikusa-ku, Nagoya, Japan 464-8603.

Note. This manuscript was submitted on September 13, 2010; approved on June 4, 2012; published online on November 15, 2012. Discussion period open until May 1, 2013; separate discussions must be submitted for individual papers. This paper is part of the *Journal of Transportation Engineering*, Vol. 138, No. 12, December 1, 2012. © ASCE, ISSN 0733-947X/2012/12-1551-1557/\$25.00.

infrastructure, especially the regional impact of HSR. However, most studies either rely on theoretical abstraction and qualitative discussion, or treat the impact on the regional economy as a whole. Although many developments have recently been made in modeling the impact of transport infrastructure on regional economic development, such as extended production function models, multiregional input-output trade models, or SCGE models, these methods are sophisticated in theoretical foundation and complex, non-linear mathematics, but lack detail or sound empirical application. Comprehensive and quantitative investigations have not yet been reported regarding which part of regional economic framework HSR may affect or the extent of the impact of HSR.

Given this background, Shinkansen has been selected for empirical analysis because Japan was the first country in the

world to construct HSR in 1964, and Shinkansen has played an important role in structuring the regional economy and locating industries. This paper consists of four further parts. The next section describes the characteristics of the study area and lists the data used for modeling. A further section presents an industrial location model to evaluate the impact of Shinkansen on 11 major industries concerning their location choice, by which the detailed contribution to regional economic organization is understood. The penultimate section surveys the empirical results, and the final section summarizes the paper with conclusions and discussions.

Study Area and Data

Japan is an East Asian country consisting of 47 prefectures, with a population of 128 million in 2008 in a comparatively small land area of 377,000 km² (Statistics Bureau 2010). It has the second largest economy in the world after the United States, at a GDP of approximately 4.6 trillion USD in 2005 (International Monetary Fund 2006). Because most large cities and industrial zones are located linearly along the coastal plain and the population density is very high, Japan has a favored environment for rail passenger transport, which is dominated by the inter-city railway mode and centered on the Shinkansen. Despite the remarkable development of airlines and highways, Shinkansen held a 6% share of the total domestic and 16% of inter-prefecture transport volume in 2005 (Central Japan Railway Company 2008). Because the Tokaido Line between Tokyo and Osaka, with a distance of 515 km, was first put into operation in 1964, the National Shinkansen Construction Act was introduced in 1970, intending the construction of nationwide HSR network of approximately 7,000 km. By 2010, six primary Shinkansen lines and two Mini-Shinkansens have been completed, with a total network expanded to 2,460 km (Fig. 1).

To study the change of Shinkansen's impact on industrial locations and consider the data availability, materials in 1990 and 2000 are collected from various sources at different scales. As listed in Table 1, data include socioeconomic statistics, travel time and cost, and access time to the Shinkansen network.

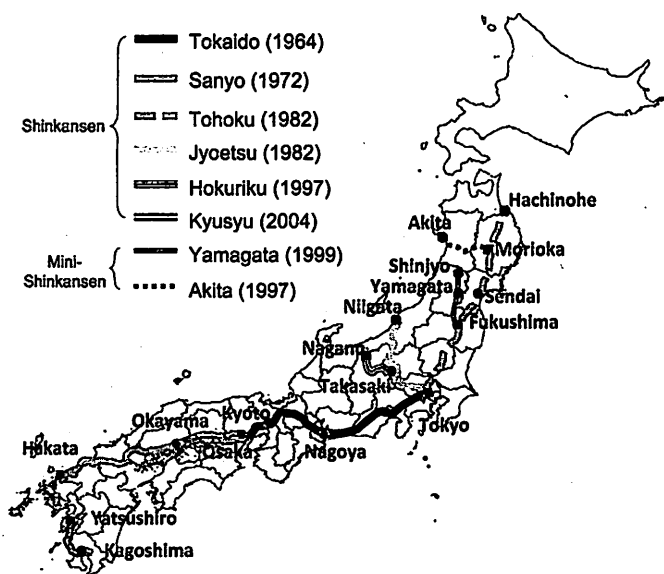


Fig. 1. Study area and existing Shinkansen network in 2010 (figures in parentheses represent the year the Shinkansen line was put into operation)

Table 1. Data Used in This Study

Scale	Data	Year	Source
Country level	Transactions value and labor input among 11 industries	1990, 2000	"Input-Output Tables" (Statistics Bureau 1990, 2000a)
Prefecture level (47 prefectures)	Population	1990, 2000	"Historical Statistics of Japan" (Statistics Bureau 1996, 2008)
	Number of employed persons by industries	1990, 2000	"Population Census" (Statistics Bureau 1995, 2000b)
	Inter-prefecture transport mode share	1990, 2000	"Inter-regional Travel Survey" (Ministry of Land, Infrastructure and Transport 1990, 2000)
	Inter-prefecture travel time	1990, 2000	"JTB Timetable" (JTB 1990, 2000)
City level (761 cities)	Inter-prefecture generalized travel cost	1990, 2000	"Cost-benefit analysis manual for Airport Development Project" (Ministry of Transport Aviation 1999)
			"Cost-benefit analysis manual" (Road Bureau, Ministry of Land, Infrastructure and Transport 2003a, 1999)
			"Evaluation method of travel cost per unit time and per unit value (2003 price)" (Road Bureau, Ministry of Land, Infrastructure and Transport 2003b)
	Population	1995, 2000	"Japan City Yearbook" (Japan Association of City Mayors 1990, 2000)
	Travel time from city center to the nearest Shinkansen station by using conventional railway	1990, 2000	"JTB Timetable" (JTB 1990, 2000)

Table 2. Transaction Values in Input-Output Table

Output Input	1	2	...	r	...	k	Total output	No. of employees
1	x^{11}	x^{12}	...	x^{1r}	...	x^{1k}	X^1	EMPL ¹
2	x^{21}	x^{22}	...	x^{2r}	...	x^{2k}	X^2	EMPL ²
...
m	x^{m1}	x^{m2}	...	x^{mr}	...	x^{mk}	X^m	EMPL ^m
...
k	x^{k1}	x^{k2}	...	x^{kr}	...	x^{kk}	X^k	EMPL ^k
Total input	X^1	X^2	...	X^r	...	X^k		

Table 3. Labor Input Matrix Among Industries

Output Input	1	2	...	r	...	k
1	φ^{11}	φ^{12}	...	φ^{1r}	...	φ^{1k}
2	φ^{21}	φ^{22}	...	φ^{2r}	...	φ^{2k}
...
m	φ^{m1}	φ^{m2}	...	φ^{mr}	...	φ^{mk}
...
k	φ^{k1}	φ^{k2}	...	φ^{kr}	...	φ^{kk}
Sum	$\sum_{mek} \varphi^{m1}$	$\sum_{mek} \varphi^{m2}$...	$\sum_{mek} \varphi^{mr}$...	$\sum_{mek} \varphi^{mk}$

Table 4. Employment Correlation Coefficient

Affecting industries	Affected industries					
	1	2	...	r	...	k
1	θ^{11}	θ^{12}	...	θ^{1r}	...	θ^{1k}
2	θ^{21}	θ^{22}	...	θ^{2r}	...	θ^{2k}
...
m	θ^{m1}	θ^{m2}	...	θ^{mr}	...	θ^{mk}
...
k	θ^{k1}	θ^{k2}	...	θ^{kr}	...	θ^{kk}
Sum	1	1	...	1	...	1

Methodology and Model Setting

Considerable literature has been written on industrial locations from which to develop a model of business location choice. Theoretically, this was first proposed by Weber (1929), who

emphasized transportation cost reduction in a profit-maximizing world; his theory has been modified by many researchers in its level of detail, sophistication, and incorporation of more complexity into the model assumptions (Moses 1958; Greenhut 1963; Hamilton 1967; Greenhut and Ohta 1975). However, compared with such a great volume of literature on industrial location theory, empirical analyses are relatively few. One reason may be data constraints. Most researchers either apply a multinomial logit model in industrial location study, which is commonly used in transportation mode choice analysis (Hansen 1987; Pearmain et al. 1991; McQuaid et al. 1996); or use statistical methods by reducing complex decisions to an algorithm form involving a limited number of explanatory factors such as characteristics of a specific industry, locality and importance of connections with other areas and industries, and agglomeration economies (Porter 1990; Storper 1995; Leitham et al. 2000). In this study, rather than analyzing the impact of Shinkansen on industrial location through defining the explanatory variables while neglecting important determinants, such as transaction correlation among industries in different regions and the population's consumption demand from neighboring areas, this study uses the works of previous studies (Nakamura et al. 1983; Sumitomo Trust Business Research Institute 1991) as a base, because they considered the previously discussed factors, and incorporate local access to the Shinkansen network as another important driving force. Moreover, this method has a relatively loose reliance on data requirements. In modeling, the number of employed persons is used to represent the size of each industry in location choice. Through a stepwise estimation that manages to avoid multicollinearity in selecting the most significant variables, a logarithm-type multivariable stepwise regression model is proposed as follows:

$$\ln(\text{EMPL}_i^k) = \alpha^k \ln(\text{InterD}_i^k) + \beta^k \ln(\text{ConsD}_i^k) - \gamma^k \ln(\text{AT}_i) + C^k \quad (1)$$

where EMPL_i^k = number of employees of a specific industry k in prefecture i ; InterD_i^k = function of industrial interdependence, which indicates the interaction influence of industries in other areas on the industry k in prefecture i ; ConsD_i^k = consumption demand from neighboring areas on the products or services offered by industry k in prefecture i ; AT_i = weighted average access time of prefecture i to the Shinkansen network, which to some extent reflects the difficulty of an area to profit from Shinkansen. It is

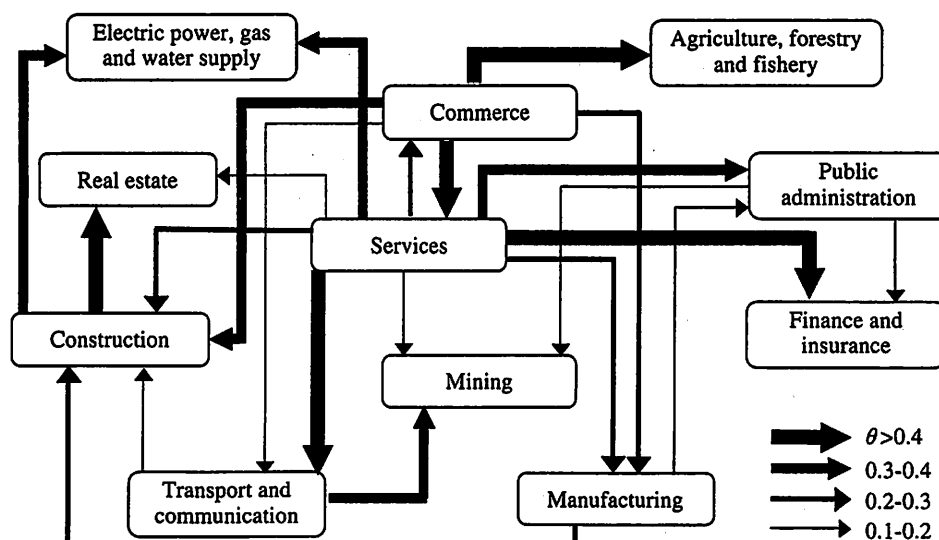
**Fig. 2.** Interdependence mechanism among 11 industries in 2000 (only θ values larger than 0.1 are mapped)

Table 5. Estimates with Cross Section Data for 1990 and 2000

Industry	1990					2000				
	InterD	ConsD	AT	C	R ²	InterD	ConsD	AT	C	R ²
Agriculture, forestry, and fishery		0.35 ^b (2.53)		4.86 ^c (3.19)	0.29		0.41 ^c (3.58)		2.27 ^c (4.95)	0.20
Mining	0.25 ^a (1.92)	0.21 ^a (1.77)		0.33 (0.18)	0.35	0.16 ^a (1.93)	0.29 ^c (3.25)		0.47 (0.39)	0.40
Manufacturing	0.44 ^b (2.58)	0.40 ^b (2.49)	-0.04 ^a (-1.69)	0.32 (0.49)	0.96	0.19 ^b (2.04)	0.56 ^c (5.36)	-0.05 ^a (-1.89)	1.05 ^a (1.73)	0.97
Construction	0.89 ^c (15.66)		-0.07 ^b (-2.37)	1.93 ^b (2.27)	0.90	0.79 ^c (12.52)		-0.09 ^a (-1.79)	2.89 ^b (2.97)	0.87
Electric power, gas, and water supply	0.50 ^b (2.48)	0.35 ^a (1.70)	-0.07 ^b (-2.56)	-1.99 ^b (-2.43)	0.93	0.44 ^a (1.97)	0.38 ^a (1.80)	-0.06 ^c (-1.69)	-1.89 ^b (-2.17)	0.91
Transport and communication	0.39 ^a (1.82)	0.56 ^b (2.47)	-0.11 ^c (-4.43)	-1.44 ^a (-2.67)	0.98	0.34 ^a (1.98)	0.73 ^c (4.25)	-0.08 ^c (-1.80)	-3.53 ^c (-5.21)	0.97
Commerce	0.59 ^c (3.62)	0.31 ^a (1.84)	-0.09 ^c (-4.15)	1.34 ^b (2.42)	0.98	0.45 ^a (1.96)	0.49 ^b (2.15)	-0.13 ^b (-2.46)	0.15 (0.20)	0.98
Finance and insurance	0.72 ^c (8.24)	0.17 ^b (2.27)	-0.04 ^c (-2.48)	-0.35 (-0.86)	0.96	0.50 ^b (2.19)	0.37 ^a (1.62)	-0.04 ^a (-1.32)	-2.68 ^c (-3.52)	0.97
Real estate	0.25 ^a (1.76)	0.77 ^c (4.09)	-0.15 ^c (-2.72)	-3.73 ^b (-2.47)	0.89	0.18 ^b (1.86)	0.85 ^c (5.58)	-0.21 ^c (-3.53)	-4.45 ^c (-3.04)	0.90
Services	0.52 ^c (3.05)	0.38 ^b (2.15)	-0.08 ^a (-1.69)	0.63 (0.96)	0.98	0.49 ^b (2.05)	0.47 ^b (2.05)	-0.11 ^a (-2.38)	-0.30 (-0.40)	0.97
Public administration	0.70 ^c (13.82)		-0.09 ^a (-1.98)	2.26 ^b (3.09)	0.89	0.57 ^c (3.78)		-0.14 ^b (-1.84)	5.14 ^b (2.36)	0.84

^aSignificance: 10%.^bSignificance: 5%.^cSignificance: 1%. Figures in parentheses are *t*-values.

assumed that the larger AT_i is, the more difficult prefecture i is to attract employees from other industries and areas. C^k is a constant.

In detail, the explanatory variable InterD is defined by Eqs. (2)–(5). ConsD and AT are expressed by Eqs. (6) and (7) respectively:

$$\text{InterD}_i^k = \sum_m \theta^{mk} \left(\sum_j \text{EMPL}_j^m \cdot \text{PL}_{ji}^{mk} \right) \quad (2)$$

where θ^{mk} = employment correlation between industry m and k ; EMPL_j^m = number of employees of k 's relevant industry m in neighboring prefecture j ; PL_{ji}^{mk} = probability of industry m of prefecture j in choosing prefecture i to trade with industry k , which is further defined by a logit-induced model:

$$\text{PL}_{ji}^{mk} = \frac{\text{EMPL}_i^k \exp(\lambda \cdot \text{GC}_{ji})}{\sum_j \text{EMPL}_j^k \exp(\lambda \cdot \text{GC}_{ji})} \quad (3)$$

where λ = travel impedance decay parameter, which is estimated by a widely used doubly constrained gravity model shown in Eq. (4) (Kadas and Klafszky 1976; Black 1981; Frost and Spence 1995; Gutierrez 2001). This study uses the "Person Trip Survey in the Tokyo Metropolitan Area 1998" (Tokyo Transport Planning Association 2010) for calculation. Because the study area is the 47 prefectures of Japan, which include the Tokyo metropolitan area, it is assumed that the λ derived from this only available trip survey database can be used as the most approximate impedance decay parameter that can be applied to all Shinkansen-related empirical analyses in Japan:

$$\begin{cases} \text{TP}_{pq} = K_p K_q O_p D_q \exp(-\lambda C_{pq}) \\ K_p = \frac{1}{\sum_{q \in Q} K_q D_q \exp(-\lambda C_{pq})} \\ K_q = \frac{1}{\sum_{p \in P} P_p O_p \exp(-\lambda C_{pq})} \\ \sum_{q \in Q} \text{TP}_{pq} = O_p, \quad p = 1, \dots, P \\ \sum_{p \in P} \text{TP}_{pq} = D_q, \quad q = 1, \dots, Q \end{cases} \quad (4)$$

where TP_{pq} = number of trips between the traffic analysis zone (TAZ) p and q ; O_p = number of trips produced by origin TAZ p ; D_q = number of trips attracted in destination TAZ q ; K_p , K_q = balancing factors solved iteratively in the doubly constrained gravity model; C_{pq} = travel cost between TAZ p and q . Through the previously stated database and equations, λ is estimated as 0.0001.

Here, GC_{ji} is the generalized transport cost from prefecture j to i , for which a number of transport characteristics such as travel costs, parking costs, reliability of travel time, and service level are usually taken into account; all of these components are usually converted into monetary value and then summarized as a whole. As proposed by Williams (1977), a method called Logsums is widely used when multiple transport modes are considered (Ben-Akiva and Lerman 1985). The advantage of Logsums is that it is good for relatively comparing the accessibilities of different locations, and it is a useful tool to calculate the consumer surplus change for cost-benefit analyses of transport projects (Jong et al. 2007). Its disadvantage, however, is that the absolute value by itself does not have an intuitive meaning. In addition, it involves precise parameters that must be estimated based on discrete choice model; particularly the revealed preference and stated preference survey data. Depending on the availability of statistical data, a simple but effective average of modal generalized transport cost weighted by modal shares, shown in Eq. (5), is employed in this study instead of Logsums:

$$\text{GC}_{ji} = \sum_{n \in N} s_{ji}^n \cdot (F_{ji}^n + \omega^n \cdot t_{ji}^n) \quad (5)$$

where n = transport mode, which means airway, highway, and railway (conventional railways and Shinkansen) in this study; s_{ji}^n = modal share of n in the total transport from prefecture j to i ; F_{ji}^n = transport fare of mode n from j to i in Japanese yen (JPY); t_{ji}^n = travel time of mode n from j to i in min; ω^n = time value of mode n in JPY/min.

According to the standard classification, 11 major industries are considered in this study. These are: (1) agriculture, forestry, and fishery, (2) mining, (3) manufacturing, (4) construction, (5) electric power, gas, and water supply, (6) transport and communication, (7) commerce, (8) finance and insurance, (9) real estate, (10) services, and (11) public administration. Table 2 shows a transactions value matrix as an input-output table. For a specific industry r , the necessary labor input from the relevant industry m , φ^{mr} , can be calculated as $(x^{mr}/X^m) \times \text{EMPL}^m$ (Table 3). The share of labor input from each industry m to r , which is the employment correlation coefficient (θ^{mr}) stated in Eq. (2), equals $\varphi^{mr} / \sum_{m \in K} \varphi^{mr}$, as shown in Table 4. This indicates the dependence of industry r on m . The larger the θ^{mr} , the more important the industry m in the production process of r .

As for ConsD, it is assumed to have a positive effect on industrial location, and is defined as

$$\text{ConsD}_i^k = \sum_j \text{POP}_j \cdot \text{PL}_{ji}^k \quad (6)$$

where POP_j = population of prefecture j ; PL_{ji}^k = probability of population of prefecture j in choosing prefecture i to consume the products or services offered by industry k , which is similar with the definition in Eq. (3).

City population is used as the weight for the calculation of AT. Due to the data limitation, only the access time by using conventional Japan Railways (JR) is considered. Here, one of the objectives is to investigate the relative change of the most important factor influencing regional economy, and the properly low accuracy calculated by the only available JR access time was ignored:

$$\text{AT}_i = \sum_z (\text{POP}_z \cdot t_{JR}^z) / \text{POP}_i \quad (7)$$

where POP_z = city population of z in prefecture i ; t_{JR}^z = travel time from city z to the nearest Shinkansen station by using JR.

Results

Based on the value of θ calculated from the input-output table in 2000, Fig. 2 shows the interdependence among the 11 industries, so that the mechanism of industrial location can further be quantitatively analyzed. Taking construction as an example, it is found that real estate and electric power, gas, and water supply are industries that rely heavily on the development of the industry. However, the industry is primarily dependent on the inputs of commerce, services, manufacturing, transportation, and communication. Such a strong correlation suggests that industrial interdependence may play an important role in the location choice of construction.

By using the ordinary least square (OLS) technique, the cross section data covering 11 industries and 47 prefectures for 1990 and 2000, respectively, are analyzed. The parameters of regression model are shown in Table 5, from which the following primary points are identified.

- Except for a low value for agriculture, forestry, and fishery and mining, R^2 for most industries is high, which suggests a reasonable explanatory capability of Eq. (1).
- In 1990, the dominant variable that influences industrial location is industrial interdependence (InterD). In eight out of 11 industries, such as construction, finance, and insurance, and public administration, their elasticity is as high as 0.70–0.89, which indicates that a 100% increase of industrial interdependence would result in 70–89% growth of the number of employees in the corresponding industry. However, in 2000, the most important determinant changes to consumption demand from neighboring areas (ConsD) for over half of the industries such as real estate, transport, and communication, manufacturing, the elasticity ranges from 0.29 to 0.85.
- Although the effect of access time to Shinkansen (AT) on industrial location is relatively small compared with the other two explanatory variables, its elasticity at a range from -0.04 to -0.21 in most industries shows a slight increase from 1990 to 2000, which is consistent with the theoretical expectation that the more the Shinkansen network is constructed, the more significant the impact will be on the regional economy, specifically the industrial location choice on which this study focuses.

For a better understanding of Shinkansen's impact on industrial location, Fig. 3 illustrates the change in the number of employees

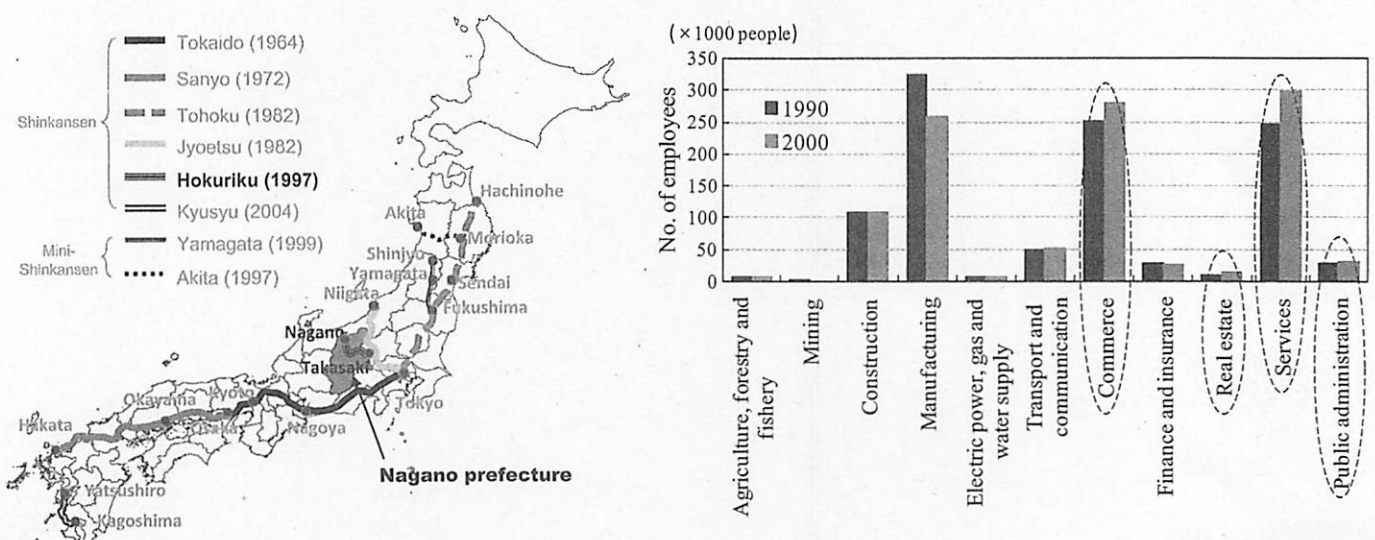


Fig. 3. Number of employees for 11 industries in Nagano prefecture, 1990–2000

for 11 industries in Nagano prefecture during the period of 1990–2000. In 1997, the Hokuriku line, which runs from Takasaki to Nagano with four stations established within Nagano prefecture, was opened for operation. Thus, the access time of Nagano prefecture to the Shinkansen network is expected to decrease significantly from 1990 to 2000. Due to the negative effect of AT shown in Table 5, the number of employees has increased at an annual rate of 2.7, 2.0, 1.1, and 0.4%, respectively, in those industries for which the elasticity of AT is also relatively high, such as real estate, services, commerce, and public administration.

Conclusions and Discussions

This paper has discussed the impact of the Shinkansen network on regional economies, with special focus on industrial locations in Japan. A quantitative investigation has been highlighted regarding driving forces behind changes in the number of employees in industries. In contrast with previous works, socioeconomic factors have been explicitly detected in this study, including transaction interdependence among 11 industries across 47 prefectures and the consumption demand of people, together with physical determinants like access to the Shinkansen network. Through multivariable stepwise regressions based on cross section data, it is found that the most important variable influencing industrial location has changed from industrial interdependence to people's consumption demand in neighboring areas during the period 1990–2000. Although the access time to Shinkansen plays a minor but important role in affecting industrial location, its elasticity for most industries has shown a slight increase with the expansion of the Shinkansen network from 1990 to 2000. The policy implication is that construction of Shinkansen lines will improve the accessibility of an area and encourage development of several industries like real estate, commerce, and services, hence contributing to the formation of regional economic structure.

Although this paper presents an empirical model analyzing the regional economic impact of the Shinkansen, there still exist some limitations to be improved in future work. When estimating the access time of a prefecture to the Shinkansen network, only the travel time using JR is considered, whereas other transport modes like private car, bus, and subway are not considered because of a lack of available data. A comprehensive estimation of the accessibility to Shinkansen will better reflect the regional differences and have a more significant effect on industrial location.

On the other hand, a many potential uses and further studies can be derived. By using the industrial location model and a panel data analysis, the parameters could be used for simulation of industrial location change in the scenarios with and without Shinkansen, or future projection under different socioeconomic and policy settings. The negative effects caused by Shinkansen (for example, the economic potential of Osaka City has been decreasing since the opening of the Sanyo Line in 1972) can also be measured in detail with longer decade data support. Moreover, the methods presented in this study could also be applied in other regions of the world where HSR will be constructed, such as the HSR project in California in the United States, and HSR from Beijing to Shanghai in China.

References

- Ben-Akiva, M., and Lerman, S. R. (1985). *Discrete choice analysis, theory and application to travel demand*, MIT Press, Cambridge, MA.
- Black, J. (1981). *Urban transport planning: theory and practice*, Croom Helm Ltd., London.
- Central Japan Railway Company. (2008). "Summary of the company performance: Transportation data." (<http://english.jr-central.co.jp/company/company/achievement/transportation/index.html>) (Jan. 15, 2010).
- ESPO. (2011). "TRACC transport accessibility at regional/local scale and patterns in Europe." Interim Rep., version 21/02/2011. (http://www.espon.eu/export/sites/default/Documents/Projects/AppliedResearch/TRACC/TRACC_Interim_Report_210211.pdf) (Nov. 9, 2011).
- Frost, M. E., and Spence, N. A. (1995). "The rediscovery of accessibility and economic potential: the critical issue of self-potential." *Environ. Plann. A*, 27(11), 1833–1848.
- Greenhut, M. (1963). *Microeconomics and the space economy*, Scott, Foresman, Chicago.
- Greenhut, M., and Ohta, H. (1975). *Theory of spatial pricing and market areas*, Duke Univ. Press, Durham, NC.
- Gutiérrez, J. (2001). "Location, economic potential and daily accessibility: an analysis of the accessibility impact of the high-speed line." *J. Transp. Geogr.*, 9(4), 229–242.
- Hamilton, F. E. I. (1967). "Models of industrial location." *Models of geography*, R. Charley and P. Haggett, eds., Methuen, London.
- Hansen, E. R. (1987). "Industrial location choice in San Paulo, Brazil: A nested logit model." *Reg. Sci. Urban Econ.*, 17(1), 89–108.
- International Monetary Fund. (2006). "World economic outlook database: country comparisons." (<http://www.imf.org/external/pubs/ft/weo/2006/02/data/index.aspx>) (Jan. 16, 2010).
- Japan Association of City Mayors. (1990, 2000). *Japan City Yearbook*, First Key Press, Tokyo, Japan (in Japanese).
- Jong, G., Daly, A., Pieters, M., and van der Hoorn, T. (2007). "The logsum as an evaluation measure: review of the literature and new results." *Transp. Res. A*, 41(9), 874–889.
- JTB. (1990). *JTB Timetable*, JTB Publishing, Tokyo, Japan (in Japanese).
- JTB. (2000). *JTB Timetable*, JTB Publishing, Tokyo, Japan (in Japanese).
- Kadas, S. A., and Klafszky, E. (1976). "Estimation of the parameters in the gravity model for trip distribution." *Reg. Sci. Urban Econ.*, 6(4), 439–457.
- Kantor, S. (2008). "The economic impact of the California high-speed rail in the Sacramento/Central Valley area." (http://www.cahighspeedrail.ca.gov/images/chsr/20081003135956_HSRCentralValleyReportFINAL-2.pdf) (Feb. 2, 2010).
- Koike, A., Ueda, T., and Miyashita, M. (2000). "Spatial computable general equilibrium model for passenger transport improvement: Evaluation of Japanese New Shinkansen project." *World Conf. of Regional Science Association Int*, The Regional Science Association International, Azores, Portugal.
- Leitham, S., Downing, J., Martino, A., and Fiorello, D. (1999). *European transport forecasts for 2020: The STREAMS model results*, Marcial Echenique & Partners, Cambridge, UK.
- Leitham, S., McQuaid, R. W., and Nelson, J. D. (2000). "The influence of transport on industrial location choice: A stated preference experiment." *Transp. Res. A*, 34(7), 515–535.
- McQuaid, R. W., Leitham, S., and Nelson, J. D. (1996). "Accessibility and location decisions in a peripheral region of Europe—A logit analysis." *Reg. Stud.*, 30(6), 579–588.
- Ministry of Land, Infrastructure, Transport and Tourism. (1990). "Inter-regional travel survey." (<http://www.mlit.go.jp/seisakutokatsu/jyunryuudou/download.html>) (Jan. 22, 2009; in Japanese).
- Ministry of Land, Infrastructure, Transport and Tourism. (2000). "Inter-regional travel survey." (<http://www.mlit.go.jp/seisakutokatsu/jyunryuudou/download.html>) (Jan. 22, 2009; in Japanese).
- Ministry of Transport Aviation. (1999). *Cost-effectiveness analysis manual for airport development project*, Institution for Transport Policy Studies (in Japanese).
- Moses, L. N. (1958). "Location and the theory of production." *Quarterly J. Econ.*, 72(2), 259–272.
- Munnell, A. H. (1992). "Policy watch: Infrastructure investment and economic growth." *J. Econ. Perspect.*, 6(4), 189–198.
- Nakamura, H., Hayashi, Y., Kuniyuki, K., and Makitani, H. (1981). "Analyzing the effects of Shinkansen using a system dynamics model—Findings from a case study of Sanyo Shinkansen." *Transp. Econ.*, 41(4), 33–45 (in Japanese).

- Nakamura, H., Hayashi, Y., and Miyamoto, K. (1983). "A land use-transport model for metropolitan areas." *Paper. Reg. Sci.*, 51(1), 43–63.
- Nakamura, H., and Ueda, T. (1989). "The impacts of Shinkansen on regional development." *Proc., World Conf. of Transport Research*, Vol. 3, World Conference on Transport Research Society, Lyon, France, 95–109.
- Pearmain, D., Swanson, J., Kroes, E., and Bradley, M. (1991). *Stated preference techniques: A guide to practice*, 2nd Ed., Steer Davies Gleave, London.
- Porter, M. (1990). *The competitive advantage of nations*, Macmillan, London.
- Rietveld, P., Bruinsma, F. R., Delft, H. T., and Ubbels, B. (2001). "Economic impacts of high speed trains. Experiences in Japan and France: Expectations in The Netherlands." (<ftp://zappa.uvu.nl/20010020.pdf>) (Sep. 11, 2009).
- Road Bureau, Ministry of Land, Infrastructure and Transport. (2003a). "Evaluation method of travel cost per unit time and per unit value in 2003 price." (<http://www.mlit.go.jp/road/ir/iinkai/1pdf/s1-56.pdf>) (Apr. 7, 2010; in Japanese).
- Road Bureau, Ministry of Land, Infrastructure and Transport. (2003b). "Cost-benefit analysis manual." (<http://www.mlit.go.jp/road/ir/ir-council/hyouka-syuhou/1pdf/s1-1.pdf>) (Apr. 7, 2010; in Japanese).
- Statistics Bureau. (1990). *Input-output tables*, Statistics Bureau of Ministry of Internal Affairs and Communications, Tokyo, Japan.
- Statistics Bureau. (1995). *Population census*, (<http://www.stat.go.jp/english/data/kokusei/index.htm>) (Jun. 2, 2010).
- Statistics Bureau. (1996). *Historical statistics of Japan*, (<http://www.stat.go.jp/english/data/chouki/index.htm>) (Jun. 2, 2010).
- Statistics Bureau. (2000a). *Input-output tables*, Statistics Bureau of Ministry of Internal Affairs and Communications, Tokyo, Japan.
- Statistics Bureau. (2000b). *Population census*, (<http://www.stat.go.jp/english/data/kokusei/index.htm>) (Jun. 2, 2010).
- Statistics Bureau. (2008). *Historical statistics of Japan*, (<http://www.stat.go.jp/english/data/chouki/index.htm>) (Jun. 2, 2010).
- Statistics Bureau. (2010). *Japan statistical yearbook*, (<http://www.stat.go.jp/english/data/nenkan/index.htm>) (Jun. 1, 2010).
- Storper, M. (1995). "The resurgence of regional economies, ten years later: The region as a nexus of untraded interdependencies." *Eur. Urban Reg. Stud.*, 2(3), 191–221.
- Sumitomo Trust Business Research Institute. (1991). *Survey report on land use plan of mega-cities* (in Japanese).
- Tokyo Transport Planning Association. (2010). "Person trip survey in the Tokyo Metropolitan Area 1998." (<http://www.tokyo-pt.jp/index.html>) (Aug. 13, 2009), in Japanese.
- Ueda, T., Koike, A., and Iwakami, Y. (2001). "Economic damage assessment of catastrophe in high speed rail network." (http://www.sse.tottori-u.ac.jp/keikaku_source/berkeley2001/koi2001.pdf) (Nov. 10, 2011).
- Vickerman, R. (1997). "High-speed rail in Europe: Experience and issues for future development." *Ann. Reg. Sci.*, 31(1), 21–38.
- Weber, A. (1929). *Alfred Weber's theory of the location of industries*, trans. C. Ffiedrich, ed. Univ. of Chicago Press, Chicago.
- Williams, H. C. W. L. (1977). "On the formation of travel demand models and economic evaluation measures of user benefit." *Environ. Plann. A*, 9(3), 285–344.