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Time-series economic effect of developing MAGLEV among metropolitan areas in Japan considering urbanization economies

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Abstract

New high-speed rail lines are currently planned or under construction in many countries around the world. In Japan, construction of the Chuo Shinkansen using the MAGLEV technology which connects the three major metropolitan areas (Tokyo, Nagoya and Osaka) started in 2016. In this paper, we proposed an econometric model to analyze time-series effects of developing high-speed rail on regional economy considering migration between regions and urbanization economies due to development of the rail. We also developed an empirical model for four regions along the Chuo Shinkansen and analyzed the time-series impacts of developing the line on population and gross regional product of the four regions. As a result, it is indicated that while the Chuo Shinkansen has a positive effect on the population and gross regional product of the three major metropolitan areas, in Yamanashi Prefecture, it has a negative effect on population but a positive one on gross regional product.

Keywords: High-speed rail, MAGLEV, Urbanization economies, Econometric model ;

1. Introduction

New high-speed rail projects are currently planned in the U.S., India, Southeast Asian countries and other countries around the world. In Europe, China and Japan, a number of high-speed routes are already in operation, while many others are in construction or planning phase. In Japan, the Kyushu Shinkansen (between Hakata and Kagoshima-Chuo) was completed in March 2011, part of the Hokuriku Shinkansen (between Takasaki and Kanazawa) opened in March 2015, and the Shin-Aomori to Shin-Hakodate-Hokuto section of the Hokkaido Shinkansen opened in March 2016. In addition, more lines are planned to open to the public in the near future, including the Hokuriku Shinkansen (between Kanazawa and Tsuruga) in 2025, the Chuo Shinkansen (between Shinagawa which is located in the south end of

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central Tokyo and Nagoya) in 2027, another section of the Hokkaido Shinkansen (between Shin-Hakodate-Hokuto and Sapporo) in 2035, and another section of the Chuo Shinkansen (between Nagoya and Shin-Osaka) in 2037. Fig. 1 shows Japan's current high-speed rail network and its future plans. Of these, the Chuo Shinkansen —using a magnetic levitation (MAGLEV) approach based on superconducting linear technology—is expected to reach maximum speeds of more than 500 km/hour. Examples of high-speed railways using the maglev technology elsewhere in the world include China's Shanghai Transrapid that began operating in 2004 and has a maximum operating speed of 431 km/hour.

Fig. 1. High-speed railway network in Japan in 2018.

While the Shanghai Transrapid is an intra-city transportation link between Pudong International Airport and the outskirts of Shanghai, the Chuo Shinkansen is expected to be the world's first maglev-type, high-speed train linking regions. Construction of the Chuo Shinkansen began in 2016 at the Shinagawa and Nagoya stations. It will take 40 minutes travel time from Shinagawa to Nagoya and 67 minutes from Shinagawa to Shin-Osaka—a huge reduction in travel time compared to that by the existing high-speed rail (Tokaido Shinkansen).

The Chuo Shinkansen will bring Tokyo, Nagoya, and Osaka—the three major metropolitan areas in Japan (with a total population of 58 million people)—within about an hour from each other. This will likely lead to a major economic impact on the regions along the route—particularly the three above-mentioned regions—by attracting industries and people from other parts of Japan and creating the agglomeration economies. The agglomeration economies, which refer to higher production in various industries and a bigger gross regional product due to the clustering of industries and people, can be broadly divided into localization economies and urbanization economies. Localization economies indicate increases in productivity in particular industries in a city or a region which are caused by forming clusters of particular industries, reducing raw material procurement costs and stimulating sharing of information about the industry's future direction, etc. Urbanization economies indicate increases in productivity in various industries in a city or a region which are caused by reducing costs of business services which are common across a wide range of industries and generating new ideas through communication among diverse groups of people, etc.

Spatial computable general equilibrium (SCGE) model and regional econometric model are general methods to measure the impact (indirect impact) of high-speed rail projects.

Previous studies have been conducted on the regional economic impact of high-speed rail projects using SCGE models. Tsuchiya (2009) analyzed the impact of such projects in Taiwan. Miyashita, et al. (2009) performed a comparative analysis of a high-speed rail project in Korea and the Chuo Shinkansen. Sato (2013) analyzed the time-series impact of the Chuo Shinkansen project, taking into account the effect on migration among regions. These studies, however, did not consider the agglomeration economies. An SCGE model addressing high-speed rail projects while considering the agglomeration economics is Shinohara's (2018). Shinohara's SCGE model treated increases in productivity due to increase in numbers of trips and regarded these as the agglomeration economies in analyzing the impact of the Chuo Shinkansen project. The static nature of this model, however, made it incapable of analyzing the time-series impact of high-speed rail projects.

Studies using regional econometric models to measure regional economic impact of high-speed rail projects include Sato (2015) and Sato et al. (2017). Sato (2015) proposed a regional econometric model that enables to analyze the time-series impacts of the increase in the number of tourists from inside and outside the regions on the regional economy resulting from the construction of a high-speed rail, developed the empirical model for Hokkaido region in Japan and measured the regional economic effect of developing the Hokkaido Shinkansen. Sato et al. (2017) developed the similar model as Sato (2015) for Ishikawa prefecture in Japan and measured the regional economic effect of developing the Hokuriku Shinkansen based on actual increases in the number of tourists and unit costs of tourism consumption, both before and after the opening of the Hokuriku Shinkansen in 2015. These studies, however, also did not consider the agglomeration economies.

In this paper, we propose a regional econometric model capable of analyzing time-series economic impacts, which also takes into account migration between regions and urbanization economies stemming from high-speed rail projects. We also construct an empirical model of regions along the Chuo Shinkansen to analyze its time-series impact on the regional economies.

2. The target regions

The target regions for the empirical models and impact analysis of developing the Chuo Shinkansen are four regions along the line; Tokyo metropolitan area (Tokyo, Kanagawa, Chiba and Saitama Prefectures), Yamanashi Prefecture, Nagoya metropolitan area (Aichi, Gifu and Mie Prefectures) and Osaka metropolitan area (Osaka, Kyoto, Hyogo, Nara and Shiga Prefectures). The target regions are shown in Fig. 2.

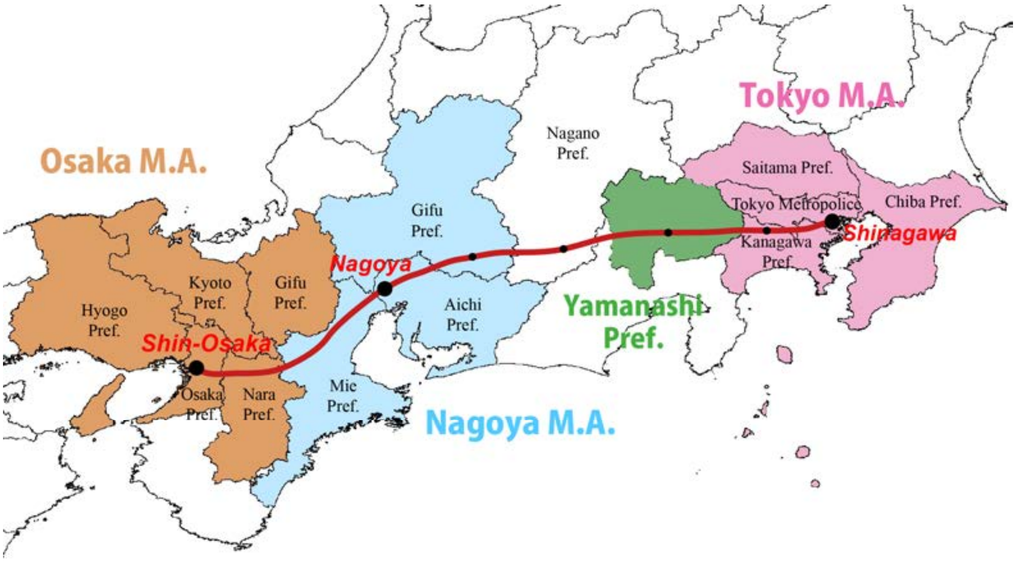

Fig. 2. The target regions.

3. The econometric model considering urbanization economies

3.1. Outline

Shorter travel times between regions, resulting from high-speed rail projects, will change nationwide population distributions (because of migrations) and increase potential productivity of regions along the rail line (due to shorter times required for business-related trips). Furthermore, there is a possibility that changes in populations of regions make productivity of firms in the regions change through urbanization economies. Assumptions in the econometric model in this paper are listed as follows.

- Production factors are labor and capital. Labor is defined as the number of workers multiplied by the average working hour index. Capital is defined as private capital stock multiplied by the rate of capital utilization index.
- Regional population affects potential productivity of the region considering urbanization economies.
- Private capital stock is defined as private capital stock in the previous period, less depreciation, plus private capital investment in the current period.
- The number of workers is determined by gross regional product and 20 to 64-year-old population in the previous period.
- Private capital investment is determined by gross regional product.
- Private consumption expenditure per household or person is determined by household disposable income per household or person and private consumption expenditure per household or person in the previous period.
- Household disposable income is determined by gross regional product.
- Private housing investment is determined by 20 to 64-year-old population.
- Gross regional expenditure is defined as sum of private consumption expenditure, private capital investment, private housing investment, government consumption expenditure, public investment, inventory increase and net export (export minus import).
- Government consumption expenditure, public investment, inventory increase and net export are given exogenously.
- Gross regional product is realized from both side of potential productivity and gross regional expenditure.

Fig. 3 shows the flowchart of the econometric model.

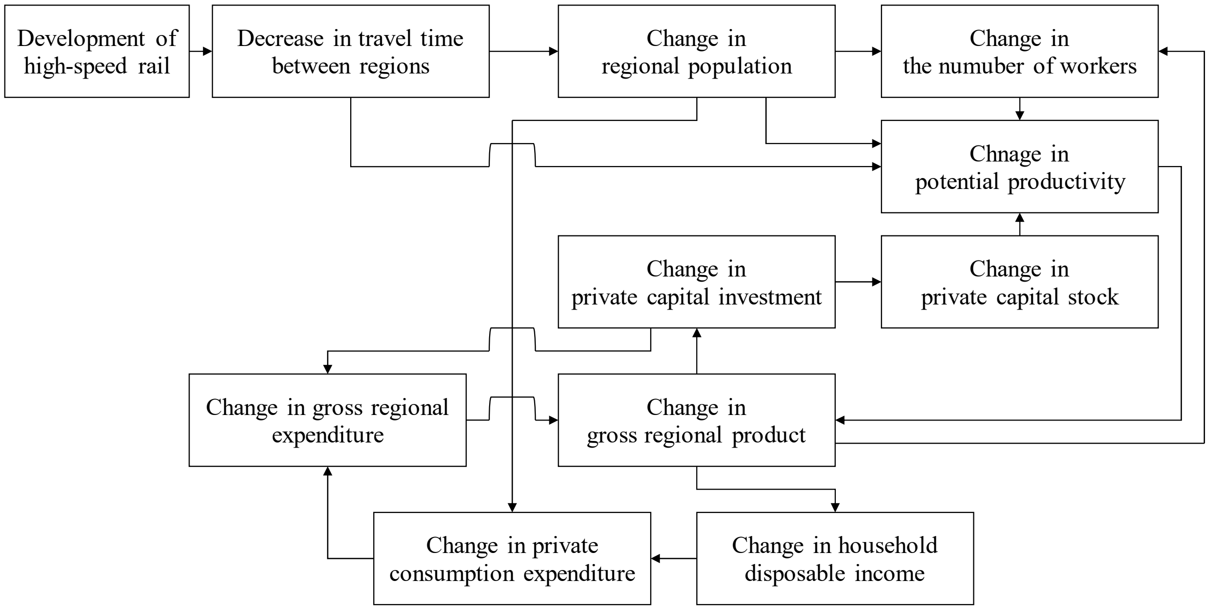

Fig. 3. The flowchart of the econometric model.

3.2. Sub models

Sub models based on the assumptions are expressed by Equations (1)-(10).

$$X_{i,t} = \mathrm{f}(ROW_{i,t} \cdot KP_{i,t}, LHR_{i,t} \cdot NW_{i,t}, POP_t) + \sum_s N_{i,rs} \cdot w_r \cdot dT_{rs} \tag{1}$$

$$KP_{i,t} = (1-\eta_i)KP_{i,t-1} + IP_{i,t} \tag{2}$$

$$NW_t = \mathrm{f}(GRP_{t-1}, POP2064_{t-1}) \tag{3}$$

$$NW_{i,t} = NW_t \frac{NW_{i,t-1}}{NW_{t-1}} \tag{4}$$

$$IP_t = \mathrm{f}(GRP_t) \tag{5}$$

$$\frac{CP_t}{NH_t} = \mathrm{f}\left(\frac{YH_t}{NH_t}, \frac{CP_{t-1}}{NH_{t-1}}\right) \tag{6-1}$$

$$\frac{CP_t}{POP_t} = \mathrm{f}\left(\frac{YH_t}{POP_t}, \frac{CP_{t-1}}{POP_{t-1}}\right) \tag{6-2}$$

$$YH_t = \mathrm{f}(GRP_t) \tag{7}$$

$$IHP_t = \mathrm{f}(POP2064_t) \tag{8}$$

$$GRE_t = CP_t + IP_t + IHP_t + CG_t + IG_t + EM_t + Z_t \tag{9}$$

$$GRP_t = \mathrm{f}(\sum_i X_{i,t}, GRE_t) \tag{10}$$

Here, *i* represents industry. *t* represents year. *r* and *s* represent regions. *X* is potential productivity, *KP* is private capital stock, *NW* is the number of workers, *ROW* is the index which expresses the rate of capital utilization, *LHR* is the index which expresses the average working hours, *POP* is population. *N* is the number of trips for business, *w* is value of time, *dT* is decrease in required travel time by developing high-speed rail. *IP* is private capital investment, *GRP* is gross regional product, *POP*2064 is population of people between 20 and 64 years old, *CP* is private consumption expenditure, *NH* is the number of household, *YH* is household disposable income, *IHP* is private housing investment, *GRE* is gross regional expenditure, *CG* is government consumption expenditure, *IG* is public investment, *EM* is net export, and *Z* is inventory increase.

3.3. Estimation of parameters

To estimate parameters for each function of the regional econometric model, we collect the time-series data of explained variables and explanatory variables for fiscal 2001-2013 from sources such as the Annual Report on Prefectural Accounts (Cabinet Office of Japan). Using time-series data to estimate the parameters for each function requires that data of the explained variable and all explanatory variables are stationary. If the time-series data are not stationary, the result of the parameter estimates has little reliability. We use ADF (Augmented Dickey-Fuller) test to verify stationarity referencing Maddala (1992). If the original data are not stationary, we examine whether the first difference data of the variable are stationary. Table 1 gives the results of the stationarity test.

Table 1. The results of the stationary tests.

	Tokyo M.A.		Yamanashi Pref.		Nagoya M.A.		Osaka M.A.	
	Original	1st difference	Original	1st difference	Original	1st difference	Original	1st difference
$\ln(GRP_2/(LHR_2*NW_2))$	0.0477	-	0.0001	-	0.1755	0.0982	0.0805	-
$\ln(GRP_3/(LHR_3*NW_3))$	0.0001	-	0.0004	-	0.0001	-	0.0114	-
$\ln((ROW_2*KP_2)/(LHR_2*NW_2))$	0.0001	-	0.0160	-	0.0257	-	0.0224	-
$\ln((ROW_3*KP_3)/(LHR_3*NW_3))$	0.0811	-	0.0006	-	0.0001	-	0.0021	-
$\ln POP$	0.0053	-	0.0422	-	0.1506	-	0.0921	-
KP_2-IP_2	0.0470	-	0.0058	-	0.0547	-	0.0571	-
KP_3-IP_3	0.0001	-	0.3744	0.0725	0.1189	0.0716	0.2824	0.1088
KP_2	0.0502	-	0.0001	-	0.0269	-	0.0643	-
KP_3	0.2081	0.0800	0.5724	0.1121	0.5161	0.0832	0.2106	0.1264
NW	0.0570	-	0.0049	-	0.0955	-	0.0499	-
GRP	0.1591	0.0595	0.0972	-	0.2296	0.0323	0.1388	0.0600
POP2064	0.0078	-	0.0002	-	0.0240	-	0.0005	-
IP_2	0.2557	0.0436	0.0023	-	0.1195	0.0173	0.4331	0.0890
IP_3	0.0550	-	0.1392	0.0978	0.1429	0.0904	0.0609	-
GRP_2	0.0447	-	0.1468	0.0235	0.0844	-	0.0067	-
GRP_3	0.0845	-	0.0402	-	0.2664	0.0914	0.0262	-
CP/NH	0.2230	0.0513	0.0001	-	0.0273	-	-	-
YH/NH	0.0057	-	0.0320	-	0.0012	-	-	-
CP/POP	-	-	-	-	-	-	0.0342	-
YH/POP	-	-	-	-	-	-	0.0543	-
YH	0.0564	-	0.1298	0.0275	0.0128	-	0.0501	-
IHP	0.0867	-	0.0468	-	0.0074	-	0.0764	-

Note: Each figure indicates the probability that each variable is not stationary.

[shaded] indicates beeing not stationary at 10% level.

Values in Table 1 indicate the p values for the original data and the first difference data. “2” and “3” accompanied with variables in Table 1 indicate 2nd industry and 3rd industry, respectively. We regard the data as stationary when the p value is less than 0.10.

We specified each function to estimate the parameters considering the results of the test. As for Equations (1) and (2), however, because they are the definitions of production and private capital stock, we estimate the original functions. Estimations were conducted with the ordinary least squares (OLS) method using the reduction method, which removes insignificant variables at the 5% significance level, and repeat estimations, considering sign conditions. The specified functions and the results of estimations of parameters are shown below.

Table 2. The results of parameter estimations of specified function for Equation (1).

$$\ln \frac{X_{i,t}}{LHR_{i,t} \cdot NW_{i,t}} = \alpha + \alpha' DUM1 + \beta \ln \frac{ROW_{i,t} \cdot KP_{i,t}}{LHR_{i,t} \cdot NW_{i,t}} + \gamma \ln POP_t \tag{1'}$$

	Industry	α	α'	β	γ	R^2
Tokyo M.A.	2nd	-21.118 (-2.6680)		0.524 (4.7086**)	2.859 (2.6332**)	0.9316
	3rd	-15.547 (-2.1136)		0.434 (4.7707**)	2.201 (2.1877*)	0.9701
Yamanashi Pref.	2nd		0.124 (3.6554**)	0.644 (86.1733**)		0.9993
	3rd	0.430 (2.5953)		0.598 (8.8219**)		0.8762
Nagoya M.A.	2nd	-0.304 (-0.5703)		0.741 (4.8526**)		0.6816
	3rd	0.485 (3.2584)		0.574 (9.9190**)		0.8994
Osaka M.A.	2nd	-0.265 (-1.7175)		0.728 (15.4640**)		0.9560
	3rd	-0.062 (-0.2923)		0.791 (10.1044**)		0.9027

Note: The figures in parentheses indicate the t value.
*indicates signficance at 5% level and **indicates signficance at 1%level.
DUM 1:1(2008~2013), 0(other years).

Table 3. The results of parameter estimations of specified function for Equation (2).

$$KP_{i,t} - IP_{i,t} = \beta KP_{i,t-1} \tag{2'}$$

	Industry	β	R^2
Tokyo M.A.	2nd	0.955 (413.0962**)	0.9999
	3rd	0.937 (196.1230**)	0.9997
Yamanashi Pref.	2nd	0.946 (371.0063**)	0.9999
	3rd	0.938 (347.2027**)	0.9999
Nagoya M.A.	2nd	0.952 (520.3008**)	1.0000
	3rd	0.936 (366.3815**)	0.9999
Osaka M.A.	2nd	0.953 (506.9369**)	1.0000
	3rd	0.939 (360.3047**)	0.9999

Note: The figures in parentheses indicate the t value.
*indicates signficance at 5% level and **indicates signficance at 1%level.

Table 4. The results of parameter estimations of specified function for Equation (3).

$$NW_t = \alpha + \beta GRP_{t-1} + \gamma POP2064_{t-1} \tag{3'}$$

$$D\_NW_t = \alpha + \alpha' DUM2 + \alpha'' DUM3 + \alpha''' DUM4 + \gamma D\_POP2064_{t-1} \tag{3''}$$

	Function	α	α'	α''	α'''	β	γ	R^2
Tokyo M.A.	(3)'						0.778 (513.3558**)	1.0000
Yamanashi Pref.	(3)'	-296,071.6 (-5.4778)				0.031 (3.4284**)	1.246976769 (21.3728**)	0.9883
Nagoya M.A.	(3)''	75,782.3 (9.8981)	-80,700.7 (-6.3271**)	-61,380.5 (-3.7598**)	-95,209.6 (-5.2389**)		0.924 (7.8105**)	0.9300
Osaka M.A.	(3)'	175,956.0 (0.3880)					0.736 (19.5306**)	0.9745

Note: The figures in parentheses indicate the t value.
*indicates signficance at 5% level and **indicates signficance at 1%level.
"$D\_$" accompanied with a variable indicates taking 1st difference.
$DUM2$:1(2002-2004), 0(other years), DUM3:1(2009), 0(other years), $DUM4$:1(2012), 0(other years).

Table 5. The results of parameter estimations of specified function for Equation (5).

$$IP_{i,t} = \alpha + \beta GRP_t \tag{5)'}$$

$$D\_IP_{i,t} = \alpha + \alpha' DUM5 + \alpha'' DUM6 + \beta D\_GRP_{i,t} \tag{5)''}$$

	Industry	Function	α	α'	α''	β	R^2
Tokyo M.A.	2nd	(5)''	6,380.6 (0.0579)			0.260 (3.1688**)	0.5010
	3rd	(5)'	-17,721,424.2 (-4.8274)			0.277 (9.4748**)	0.8908
Yamanashi Pref.	2nd	(5)''	-3,334.8 (-0.5202)	62,434.9 (2.9405**)	-58,006.6 (-2.7176*)	0.147 (2.3632*)	0.7826
	3rd	(5)''	-721.2 (-0.1910)	16,669.2 (2.4967*)		0.214 (2.0269*)	0.5169
Nagoya M.A.	2nd	(5)''	-6,222.0 (-0.0398)			0.226 (2.3727*)	0.3602
	3rd	(5)''	61737.3 (1.1795)			0.218 (2.6623*)	0.4148
Osaka M.A.	2nd	(5)''	49,614.8 (0.5739)			0.435 (4.2310**)	0.6416
	3rd	(5)'	-7,614,479.2 (-3.5483)			0.283 (6.9013**)	0.8124

Note: The figures in parentheses indicate the t value.
*indicates signficance at 5% level and **indicates signficance at 1%level.
"$D\_$" accompanied with a variable indicates taking 1st difference.
*DUM*5(2nd industry in Yamanashi Pref.):1(2006), 0(other years), *DUM*6:1(2008), 0(other years),
*DUM*5(3rd industry in Yamanashi Pref.):1(2002-2004), 0(other years).

Table 6. The results of parameter estimations of specified function for Equation (6).

$$\frac{CP_t}{NH_t} = \alpha + \alpha' DUM7 + \beta \frac{YH_t}{NH_t} + \gamma \frac{CP_{t-1}}{NH_{t-1}} \tag{6-1)'}$$

$$D\_\frac{CP_t}{NH_t} = \alpha + \beta D\_\frac{YH_t}{NH_t} + \gamma D\_\frac{CP_{t-1}}{NH_{t-1}} \tag{6-1)''}$$

$$\frac{CP_t}{POP_t} = \alpha + \alpha' DUM7 + \beta \frac{YH_t}{POP_t} + \gamma \frac{CP_{t-1}}{POP_{t-1}} \tag{6-2)'}$$

	Function	α	α'	β	γ	R^2
Tokyo M.A.	(6-1)''	0.033 (1.7822)		0.751 (4.1988**)	-0.556 (-2.4947*)	0.7001
Yamanashi Pref.	(6-1)'	-2.937 (-1.1559)	-0.344 (-2.2753*)	0.892 (1.9835*)	0.561 (2.8248**)	0.7277
Nagoya M.A.	(6-1)'	1.060 (1.4103)		0.755 (6.7991**)		0.8078
Osaka M.A.	(6-2)'	0.199 (0.4152)		0.401 (2.0905**)	0.457 (1.5435*)	0.6960

Note: The figures in parentheses indicate the t value.
*indicates signficance at 5% level and **indicates signficance at 1%level.
"$D\_$" accompanied with a variable indicates taking 1st difference.
*DUM*7:1(2003), 0(other years).

Table 7. The results of parameter estimations of specified function for Equation (7).

$$D\_YH_t = \alpha + \alpha' DUM8 + \beta D\_GRP_t \quad (7)''$$

	α	α'	β	R^2
Tokyo M.A.	1,300,861.7 (4.0139)	-1,683,517.7 (-1.5757*)	0.265 (3.4330**)	0.5714
Yamanashi Pref.	9,040.7 (1.4001)		0.262 (3.9809**)	0.6131
Nagoya M.A.	552,431.1 (3.3123)	-465,229.0 (-1.4030*)	0.162 (2.0357*)	0.3677
Osaka M.A.	458,002.9 (1.8761)	-1,349,951.0 (-1.5849*)	0.232 (1.5763*)	0.5239

Note: The figures in parentheses indicate the t value.
*indicates signficance at 5% level and **indicates signficance at 1%level.
"$D\_$" accompanied with a variable indicates taking 1st difference.
DUM 8(Tokyo M.A.):1(2004), 0(other years), *DUM* 8(Nagoya M.A.):1(2011-2013), 0(other years),
DUM 8(Osaka M.A.):1(2008), 0(other years).

Table 8. The results of parameter estimations of specified function for Equation (8).

$$IHP_t = \alpha + \alpha' DUM9 + \beta POP2064_t \quad (8)'$$

	α	α'	β	R^2
Tokyo M.A.	-55,041,922.3 (-4.5088)	-1,219,177.5 (-5.0520**)	2.7583 (4.9850**)	0.8383
Yamanashi Pref.	-372,201.8 (-4.0552)		0.9507 (5.2138**)	0.7119
Nagoya M.A.	-3,675,895.0 (-2.4750)	-206,162.8 (-2.6482*)	0.7823 (3.5878**)	0.7191
Osaka M.A.	-10,585,047.4 (-6.4358)		1.0782 (7.8565**)	0.8487

Note: The figures in parentheses indicate the t value.
*indicates signficance at 5% level and **indicates signficance at 1%level.
DUM 9(Tokyo M.A.):1(2010~2012), 0(other years),
DUM 9(Nagoya M.A.):1(2009~2010), 0(other years).

3.4. Comparison of estimated and actual values for GRP

Table 9 shows the mean absolute percentage of error (MAPE) for the estimated values using the model that employs the all functions we estimated and the actual values of gross regional product in each region from 2002 to 2013. Values of MAPE are about 0.69-1.95%, so the models are considered to possess good replicability.

Table 9. MAPE for the estimated values and the actual values of GRP.

Tokyo M.A.	Yamanashi Pref.	Nagoya M.A.	Osaka M.A.
0.62%	1.60%	1.30%	0.48%

4. The migration among regions estimation model

Migration between regions is assumed to be determined by the generalized cost required between the regions of origin and destination and the population of the region of origin. The generalized cost is defined as the sum of required travel time multiplied by the value of time and transportation fare. Equations (11) and (12) give the formulas for estimating migration between regions.

$$\ln NM_{rs} = \alpha + \beta \ln(GC_{rs}) + \gamma \ln(POP_r) + \delta D_{rs} \quad (11)$$

$$GC_{rs} = Fare_{rs} + w_r . T_{rs} \quad (12)$$

Here, *r*, *s* represents origin and destination of migrant, respectively. *NM* is the number of migrants. *GC* is generalized travel cost between regions. *POP* is population. *D* is dummy variable which equals 1 for some regions and equals 0 for other regions. *Fare* is fare of transport, *T* is required travel time, and *w* is value of time.

The parameters for Equation (11) are estimated using data in 2013, setting prefectures in the target regions as the destinations and all prefectures in Japan as the origins for inflow migration and setting all prefectures in Japan as the destinations and prefectures in the target regions as the origins for outflow migration. We took the lesser of the generalized costs for rail or air travel between each region's central stations as the generalized cost.

Table 10 and Table 11 show the results of parameter estimation of Equation (11) for inflow migration and outflow migration, respectively.

Table 10. The result of parameter estimation of the migration estimation model for inflow migration.

	s	α	β	γ	δ	R^2
Tokyo M.A.	Saitama Pref.	4854.9 (3.678)	-0.0664 (-6.663**)	0.0007 (13.676**)	-0.0108 (-2.449**)	0.937
	Kanagawa Pref.	4979.3 (4.135)	-0.0628 (-6.600**)	0.0012 (27.075**)	-0.0123 (-3.122**)	0.974
	Chiba Pref.	3137.4 (3.685)	-0.0408 (-6.136**)	0.0007 (23.170**)	-0.0075 (-2.680**)	0.975
	Tokyo Metropolice	7558.7 (3.335)	-0.1300 (-7.029**)	0.0026 (30.938**)	-0.0160 (-2.132*)	0.976
Yamanashi Pref.	Yamanashi Pref.	342.7 (3.368)	-0.0101 (-3.613**)	0.0001 (3.795**)		0.926
Nagoya M.A.	Aichi Pref.	50.1 (0.161)	-0.0164 (-1.525)	0.0009 (15.736**)		0.944
	Gifu Pref.	1.5 (0.697)	-0.7094 (-5.348**)	0.7046 (7.628**)	-0.5271 (-5.502**)	0.944
	Mie Pref.	240.0 (2.690)	-0.0095 (-2.810**)	0.0001 (12.685**)	-63.8632 (-1.370)	0.954
Osaka M.A.	Kyoto Pref.	423.7 (3.618)	-0.0203 (-4.765**)	0.0003 (12.719**)		0.914
	Shiga Pref.	231.2 (4.569)	-0.0091 (-4.812**)	0.0001 (10.293**)		0.908
	Osaka Pref.	4279.8 (6.603)	-0.1139 (-7.388**)	0.0006 (11.428**)	-962.4993 (-4.058**)	0.945
	Nara Pref.	113.2 (2.762)	-0.0060 (-4.313**)	0.0001 (13.976**)		0.935
	Hyogo Pref.	1837.1 (5.730)	-0.0599 (-6.308**)	0.0004 (10.659**)	-465.9226 (-3.280**)	0.926

Note: The figures in parentheses indicate the t value.
*indicates signficance at 5% level and **indicates signficance at 1%level.

Table 11. The result of parameter estimation of the migration estimation model for outflow migration.

	r	*α*	*β*	*γ*	*δ*	R^2
Tokyo M.A.	Saitama Pref.	1247.5 (5.389)	-0.0449 (-5.666**)	0.0006 (15.040**)		0.936
	Kanagawa Pref.	957.1 (2.570)	-0.0407 (-3.141**)	0.0010 (17.959**)		0.923
	Chiba Pref.	639.1 (4.144)	-0.0256 (-4.970**)	0.0006 (24.466**)		0.974
	Tokyo Metropolice	2526.4 (6.121)	-0.0984 (-6.912**)	0.0019 (25.429**)		0.957
Yamanashi Pref.	Yamanashi Pref.	330.8 (2.869)	-0.0098 (-3.121**)		0.0000 (3.962**)	0.946
Nagoya M.A.	Aichi Pref.	-311.8 (-0.634)	-0.0177 (-1.041)	0.0010 (16.560**)		0.887
	Gifu Pref.	110.8 (1.418)	-0.0046 (-1.731**)		0.0000 (16.291**)	0.939
	Mie Pref.	205.7 (1.615)	-0.0113 (-2.739**)	0.0002 (4.111**)	0.0000 (1.598)	0.882
Osaka M.A.	Kyoto Pref.	380.7 (4.447)	-0.0137 (-4.380**)		0.0001 (31.998**)	0.966
	Shiga Pref.	181.5 (3.519)	-0.0075 (-4.022**)	0.0000 (2.891**)	0.0000 (5.598**)	0.947
	Osaka Pref.	1215.8 (3.401)	-0.0518 (-3.906**)		0.0002 (19.213**)	0.957
	Nara Pref.	105.4 (2.835)	-0.0049 (-3.790**)	0.0000 (2.228**)	0.0000 (10.754**)	0.975
	Hyogo Pref.	874.2 (3.655)	-0.0363 (-4.211**)		0.0001 (17.880**)	0.954

Note: The figures in parentheses indicate the t value.
*indicates signficance at 5% level and **indicates signficance at 1%level.

5. Impact analysis of developing MAGLEV

When the Chuo Shinkansen goes into operation (in 2027 for the Shinagawa–Nagoya section and in 2037 for the Nagoya–Shin-Osaka section), travel times between regions will be reduced. The migration among regions estimation model and the regional econometric model that we made allow us to analyze the impacts of developing the Chuo Shinkansen on the population and the regional economies of relevant regions. Note that we omit from our estimates the flow effects during construction periods. Table 12 shows the net population inflow to each region accompanied by developing the Chuo Shinkansen which are calculated with Equation (11) and estimated parameters. We can see that developing the Chuo Shinkansen increases the population of all regions other than Yamanashi Prefecture, whose population drops, suggesting a straw-effect.

Table 13 shows the impacts of developing the Chuo Shinkansen on gross regional product of the target regions (i.e., with construction minus without construction). The analysis shows that gross regional product increases in all four regions. Following the extension to Shin-Osaka in 2037, gross regional product growth slows in Yamanashi Prefecture but accelerates in the Tokyo metropolitan area. This is likely due to urbanization economies in the Tokyo metropolitan area.

Table 12. The impacts of developing the Chuo Shinkansen on population.

(person)

	Tokyo M.A.	Yamanashi Pref.	Nagoya M.A.	Osaka M.A.
2027	1,200	-2	311	563
2032	7,198	-13	1,869	3,381
2037	14,383	-38	3,517	7,119
2040	21,542	-91	4,725	11,572

Table 13. The impacts of developing the Chuo Shinkansen on GRP.

(million Yen)

	Tokyo M.A.	Yamanashi Pref.	Nagoya M.A.	Osaka M.A.
2027	25,700	704	7,850	10,050
2028	28,400	831	8,450	11,840
2029	33,900	900	9,080	13,520
2030	37,700	951	9,700	15,170
2031	42,700	992	10,330	16,830
2032	46,900	1,025	10,960	18,530
2033	51,500	1,054	11,590	20,270
2034	55,900	1,078	12,230	22,070
2035	60,300	1,099	12,860	23,890
2036	64,700	1,119	13,500	25,790
2037	82,400	1,164	14,420	37,900
2038	89,500	1,153	15,170	42,360
2039	97,700	1,132	15,910	46,710
2040	105,000	1,106	16,650	51,060

6. Summary

In this paper, we proposed an econometric model to analyze time-series effects of developing high-speed rail on regional economy considering migration between regions and urbanization economies due to development of the rail. We also developed an empirical model for four regions in Japan along the Chuo Shinkansen (MAGLEV) which is expected to be completed in 2027 for the Shinagawa–Nagoya section and in 2037 for the entire line and analyzed the time-series impacts of developing the line on population and gross regional product of the four regions. Our analysis reveals that while the Chuo Shinkansen has a positive effect on the population and gross regional product of the three major metropolitan areas (Tokyo, Nagoya and Osaka), in Yamanashi Prefecture, it has a negative effect on population but a positive one on gross regional product.

While a Chuo Shinkansen station is planned for Iida in Nagano Prefecture, our impact analysis did not cover the population or the regional economy of Nagano Prefecture or the Iida metropolitan area. Topics we hope to address in the future include the construction of models for individual living areas and an analysis of these effects on the Iida metropolitan area.

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