Impact of Transport Infrastructure on Gross Regional Products: A Study on Chinese Economic Regions

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Research Article

Abstract
Purpose: *This study examines the impact of transport infrastructure on the Gross Regional Products in Chinese economic regions.*
Methods: *The study analyzes the impact of transport infrastructure on the Gross Regional Products according to the eight economic regions in China by using descriptive statistics and regression analysis methods.*
Results: *The findings are that a) densities of railways and highways have strong impacts on Gross Regional Products per capita according to Chinese economic regions, b) impacts of densities of railways and highways on Gross Regional Products per capita differ among Chinese economic regions and c) construction of new transport infrastructure has a more positive impact on Gross Regional Products per capita compared to regions with already developed transport infrastructure.*
Implications*: Region-specific features ought to be considered in making and implementing the economic development policy according to economic regions.*

Keywords: Transport Infrastructure, Gross Regional Products (GRP), Economic Region, Chinese Economy.

1. Introduction

The Chinese economy achieved surprising growth in the last few decades. However, at present, China's economic growth decreases more and more than before, and differences in economic development levels according to regions produce differences in living standards among regions (Rim & An, 2022). This poses the task of ensuring sustainable economic growth and of reducing the differences in living standards between regions in China. On the other hand, China divides the whole country into eight economic regions according to similarities in economic geography, natural-environmental conditions, and development level and implements the economic development policy according to regions (National Bureau of Statistics of China, 2019). Thus, making and implementing economic development policies based on considering the geographic features and differences in development level according to economic regions are of significance in ensuring sustainable economic growth and reducing the differences between regions.

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In general, it is said that infrastructural facilities including railways, roads, ports, airports, and energy supply are essential in stimulating economic growth and ensuring sustainable economic development, and this is reasonable for China, too. Until now, the interrelation between the development of infrastructure and economic growth has been studied by many scholars in the world and China.

Studies on the influences of infrastructure on the economy have been conducted long ago worldwide or region-wide. Typical studies are those concerned with the impacts of infrastructural investment on economic growth and the impacts of individual elements of infrastructure on various kinds of economic results. First of all, many scholars demonstrated the positive impact of infrastructural investment on economic growth using various econometric methods. The typical scholar is Aschauer (1989), who showed the positive impact of public investment in infrastructure on economic growth with output elasticity between 0.34 and 0.39. Other than him, many researchers demonstrated the positive effects of infrastructural investment on economic performance in different countries using time series data and various approaches. For example, using the production function approach, Bajo & Sosvilla (1993) proved the positive impact of infrastructural investment on economic growth for Spain, Ligthart (2002) – for Portugal, Otto & Voss (1996) – for Australia, Xinmin et al. (2017) – for China, and Pereira & Pereira (2019a,b) – for Portugal. Demetriades & Mamuneas (2000) proved the positive effects of infrastructural investment on economic growth using the cost function approach. On the other hand, some authors demonstrated the positive influences of public infrastructural investment on output in different countries using the Vector Auto Regression (VAR) approach. Mamatzakis (1999) described the positive effects of infrastructural investment in Greece, Pereira & Roca (1999) – for Spain, and Pereira & Pereira (2018) – for Ontario. At the industry level, too, many scholars (for example, Fernald, 1999; Greenstein & Spillar, 1995; Baltagi & Pinnoi, 1995; Nadiri & Manuneas, 1996; and Pereira & Andraz, 2003, 2013) demonstrated the positive impact of infrastructural investment on economic results using various econometric approaches. Also, some scholars studied the influences of infrastructural investment on economic performance in individual countries using other approaches. For example, Ebuh, et al. (2019) examined the link between infrastructure development and output growth in Nigeria, Unnikrishnan & Kattookaran (2020) studied the impact of public and private investment on the economic growth in India, and Ni (2013) and Yingying et al. (2017) analyzed the impact of transport infrastructure on economic growth in China based on Vector Error Correction Model (VECM). And Ylander (2017) demonstrated that "One Belt, One Road" (OBOR) and its infrastructural projects influenced the GRP in China by conducting a regression analysis.

Next, the impacts of the individual elements of infrastructure on the economy have been discussed. For example, Dethier et al. (2008) and Garsous (2012) demonstrated the positive impact of energy infrastructure on output/growth, Binswanger et al. (1993) and Estache et al. (2005) – the impact of water and sanitation on the economy, the authors including Cette et al. (2016), Andre et al. (2016), Arredondo-Trapero et al. (2020), Chakraborty & Nandi (2011), and Colecchia & Schreyer (2003) – the positive impact of telecommunication infrastructure on economic growth, and some scholars (for example, Buys et al. 2010; Estache & Fay, 2010; Wilson et. al 2003; Yoshino & Abidhadjaev, 2017; Thuy, 2018; and Chatterjee et al. 2021) investigated the impact of individual transport infrastructure on the economy in various aspects.

Next, there have been attempts to analyze the impacts of physical transport infrastructure on economic results. For example, Li, et al. (2019, 2020a, 2020b) studied the impacts of individual elements of transport infrastructure on trade, Gross Regional Products (GRP), and employment respectively in some provinces of China. These are of significance in studying the impacts of physical transport infrastructure apart from the impacts of infrastructural investment. As seen from previous studies, infrastructure has positive effects on economic growth and contributes to GDP growth in various aspects. As seen,

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researchers studied the general impact of infrastructure on economic growth, and in the case of Chinese scholars, they did not discuss the impact of infrastructure on GRP according to economic regions. And they used the long-term panel data for a study on conditions that address the impact of infrastructural investment on economic growth. However, those studies have some limitations because investment affects economic growth by its realization. Also, given that China makes and implements the economic development policy considering the features according to economic regions, it is reasonable to analyze the impact of TI's development level on economic development according to economic regions for the significance of the study. In the past, there have been few studies on the impact of transport infrastructure on economic development according to economic regions in China, mostly focusing on natural and climate studies in corresponding regions. Revealing the influences of infrastructure on region-specific economic development is of significance in making policies related to economic development according to economic regions. This study aims to reveal the impact of which development level of transport infrastructure (TI) affects China's region-specific economic development, in particular, region-specific GRP. From the limitations of previous studies and the purpose of the study, the following research questions are raised; 1) In China's economic regions, what is the relationship between physical TI's development level, its growth rate, and economic development? 2) What is the effect of physical TI's development level for each economic region on the GRP? To this end, this paper is written divided into the following sections. In the second section, the authors address the data description and methodology for the study. In this section, first of all, the authors collect the primary data being interested under study by province and aggregate them by economic region. In order to ensure the comparability of the study, the total values for each indicator by economic region are processed as relative values. Next, descriptive statistics are used to elucidate the interrelationship between physical TI's development level, its growth rate, and economic development. Next, the regression analysis explains the effect of physical TI's development level on the region-specific GRP. Necessary calculations are supported by a statistical software package, SPSS. The third and fourth sections of the paper address the discussions, conclusion, and limitations of this study.

2. Material and methods

2.1. Collection of data

According to the National Bureau of Statistics of China (2019), the Chinese government divides the Chinese economy into eight economic regions according to similarities in economic geography and development, which include Chinese provinces as follows (see Table 1).

Table 1: Economic regions of China

No	Economic Region	Province
1	Northeast Region	Liaoning, Jilin, Heilongjiang
2	North Coastal Area	Beijing, Tianjin, Hebei, Shandong
3	Eastern Coastal Area	Shanghai, Jiangsu, Zhejiang
4	South Coastal Area	Fujian, Guangdong, Hainan
5	The Middle Yellow River	Shanxi, Inner Mongolia, Henan, Shaanxi
6	Middle Reaches of The Yangtze River	Anhui, Jiangxi, Hubei, Hunan,
7	Southwest China	Guangxi, Chongqing, Sichuan, Guizhou, Yunnan
8	Big Northeast China	Tibet, Gansu, Qinghai, Ningxia, Xinjiang

Source: National Bureau of Statistics of China (2019).

For this reason, the authors conduct the studies based on data from the year 2009 to 2018 for the eight Chinese economic regions. Data are from the National Bureau of Statistics of China. Primary data for the study are those concerning GRP, railways, and highways, which are TI's important elements, according to economic regions. And data for TI are measured by physical units (km). The reasons for selecting the data

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for the period of 2009 – 2018 are concerned with the fact that in general, many studies were conducted based on data before 2009, and this period may be enough in analyzing the TI's impact. Also, the reason for selecting the physical TI is concerned with the fact that on one hand, the impact of infrastructure on economic development has been considered limited to infrastructural investment until now, and on another hand, data related to investment in TI according to economic regions are inaccessible. Also, as discussed earlier, when considering that infrastructural investment is not a basis for economic development in a given period due to time lags, the data regarding physical infrastructure is acceptable.

For the above reasons, the authors collected province-specific data regarding GRP, the population, length of railways, length of highways, and area. Then, the province-specific data are totaled according to economic regions shown in table 1 as follows (see table 2).

Table 2: Economic region-specific GRP, number of population, length of railways, length of highways, and area

Region	Indicator	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Northeast Region	GRP (100 million yuan)[b]	31,078.24	37,493.45	45,377.53	50,477.25	54,714.53	57,469.10	57,815.82	52,409.79	54,256.45	56,751.59
	Population (10000 persons)	10,907.00	10,955.00	10,966.00	10,973.00	10,976.00	10,976.00	10,947.00	10,910.00	10,875.00	10,836.00
	Railways (10000 km)	1.39	1.41	1.42	1.54	1.55	1.56	1.71	1.69	1.71	1.84
	Highways (10000 km)	34.10	34.38	35.14	35.79	36.54	37.39	38.09	38.76	39.26	39.55
	Area (10000 ㎢)[a]	80.63									
North Coastal Area	GRP (100 million yuan)	70,807.01	82,902.22	97,436.82	107,361.53	117,916.09	125,905.50	132,361.22	143,649.46	153,214.60	161,609.56
	Population (10000 persons)	19,592.00	20,043.00	20,252.00	20,455.00	20,653.00	20,842.00	20,990.00	21,152.00	21,254.00	21,317.00
	Railways (10000 km)	1.06	1.07	1.15	1.21	1.29	1.36	1.47	1.49	1.53	1.62
	Highways (10000 km)	41.39	42.01	42.67	44.45	46.47	47.66	48.65	49.29	50.10	50.75
	Area (10000 ㎢)	36.96									
Eastern Coastal Area	GRP (100 million yuan)	72,494.1	86,313.8	100,624.8	108,905.3	119,328.1	128,829.1	138,126.3	152,818.3	168,271.0	181,472.4
	Population (10000 persons)	15,296.0	15,619.0	15,709.0	15,777.0	15,852.0	15,894.0	15,930.0	16,009.0	16,104.0	16,212.0
	Railways (10000 km)	0.37	0.41	0.47	0.47	0.51	0.55	0.58	0.59	0.59	0.64
	Highways (10000 km)	26.25	27.25	27.61	28.02	28.41	28.68	29.00	28.97	29.19	29.25
	Area (10000 ㎢)	21.09									
South Coastal Area	GRP (100 million yuan)	53,373.3	62,814.7	73,293.1	79,625.2	87,520.8	95,366.3	102,495.1	113,718.7	126,349.9	137,913.9

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	Population (10000 persons)	14,660.0	15,003.0	15,102.0	15,229.0	15,313.0	15,433.0	15,599.0	15,790.0	16,006.0	16,221.0
	Railways (10000 km)	0.50	0.55	0.56	0.58	0.69	0.75	0.82	0.84	0.84	0.90
	Highways (10000 km)	29.45	30.23	30.59	31.39	32.73	33.93	34.75	35.31	35.83	36.16
	Area (10000 km^2)	33.53									
The Middle Yellow River	GRP (100 million yuan)	44,748.82	54,088.70	65,040.76	72,046.40	77,978.50	83,159.86	85,622.02	91,049.89	98,076.27	106,601.51
	Population (10000 persons)	19,099.00	19,186.00	19,206.00	19,260.00	19,305.00	19,364.00	19,448.00	19,547.00	19,625.00	19,721.00
	Railways (10000 km)	1.88	2.11	2.14	2.23	2.33	2.49	2.70	2.78	2.84	2.86
	Highways (10000 km)	66.45	68.22	69.54	71.26	72.19	72.96	73.71	77.81	78.45	79.16
	Area (10000 km^2)	171.19									
Middle Reaches of The Yangtze River	GRP (100 million yuan)	43,738.79	53,816.16	66,305.29	74,565.61	83,053.03	90,979.92	97,181.81	107,123.37	116,405.36	127,783.93
	Population (10000 persons)	22,689.00	22,717.00	22,810.00	22,910.00	23,042.00	23,178.00	23,345.00	23,495.00	23,639.00	23,788.00
	Railways (10000 km)	1.23	1.28	1.30	1.37	1.45	1.59	1.68	1.70	1.75	1.80
	Highways (10000 km)	67.48	72.42	74.10	76.80	78.82	80.31	83.34	85.80	87.48	88.58
	Area (10000 km^2)	71.06									
Southwest China	GRP (100 million yuan)	38,522.88	46,507.25	57,353.88	65,479.17	73,544.40	80,553.13	86,695.22	95,557.92	104,845.38	114,081.40
	Population (10000 persons)	24,008.00	23,621.00	23,714.00	23,846.00	23,985.00	24,107	24,289.00	24,474.00	24,643.00	24,799.00
	Railways (10000 km)	1.22	1.26	1.27	1.29	1.39	1.58	1.71	1.89	1.92	1.99
	Highways (10000 km)	80.93	84.56	87.91	90.57	93.15	96.15	99.66	101.72	103.81	106.43
	Area (10000 km^2)	135.90									
Big Northeast China	GRP (100 million yuan)	10,540.55	13,105.76	16,008.90	18,091.37	20,289.83	22,086.53	22,470.33	23,742.56	25,721.17	28,493.19
	Population (10000 persons)	6,192.00	6,241.00	6,283.00	6,339.00	6,390.00	6,452.00	6,540.00	6,607.00	6,688.00	6,759.00
	Railways (10000 km)	0.92	1.02	1.04	1.09	1.10	1.31	1.41	1.44	1.51	1.52
	Highways (10000 km)	40.04	41.72	43.08	45.48	47.31	49.31	50.55	51.97	53.24	54.75
	Area (10000 km^2)	413.11									

Source: Author's own calculation from the National Bureau of Statistics of China (2019a).
Note: [a] From http://baike.baidu.com.

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[b] Gross domestic product (GDP) calculated in terms of the Chinese currency (RMB=yuan) at a regional level.
For example, indicator-specific data for the Northeast Region are those totaled according to Liaoning, Jilin, and Heilongjiang included in this region concerning GRP (yuan), number of population (person), length of railways (km), length of highways (km), and area (㎢) respectively.

2.2. Processing of data

Data from table 2 need to convert the absolute value into a relative one to ensure the calculative comparability according to economic regions. This is because assessment by absolute value makes errors in judging the impact of infrastructure due to the impact of the scale of certain economic regions. Pre-studies focus on analyzing the impact of infrastructural investment on economic development based on absolute value; however, it does not seem to be a rightful assessment. This study aims to analyze the impact of physical TI's development level on GRP according to economic regions. In international comparison according to countries, development levels of physical TI are described as lengths of railways and highways per 1000 ㎢ of area, and the like, and economic development level – as GDP per capita. Therefore, this paper is interested in the interrelation between GRP per capita and lengths of railways and highways per 1000 ㎢ area (hereafter, the density of railways and the density of highways) according to the economic regions under study. That is;

$$\textbf{GRP per capita (yuan)} = \frac{\textbf{GRP (yuan)}}{\textbf{number of population (person)}}$$

$$\textbf{The density of railways (or highways)}\left(\frac{\textbf{km}}{\textbf{1000}\ \text{km}^2}\right) = \frac{\textbf{Length of railways (or highways)(km)}}{\textbf{Area}\ (\text{km}^2)} \times \textbf{1000}$$

For the study, the results of processing the data from table 2 are as follows (see table 3).

Table 3. Economic region-specific GRP per capita, the density of railways, and the density of highways

Region	Indicator	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Northeast Region	GRP per capita (yuan)	28493.85	34224.97	41380.20	46001.32	49849.24	52358.8	52814.3	48038.3	49890.9	52373.19
	The density of railways	17.24	17.49	17.61	19.10	19.22	19.35	21.21	20.96	21.21	22.82
	The density of highways	422.92	426.39	435.82	443.88	453.18	463.72	472.40	480.71	486.92	490.51
North Coastal Area	GRP per capita (yuan)	36140.78	41362.18	48112.20	52486.69	57093.93	60409.5	63059.1	67912.9	72087.4	75812.53
	The density of railways	28.68	28.95	31.11	32.74	34.90	36.80	39.77	40.31	41.40	43.83
	The density of highways	1119.86	1136.63	1154.49	1202.65	1257.31	1289.50	1316.29	1333.60	1355.52	1373.11
Eastern	GRP per	47394.16	55262.03	64055.52	69027.87	75276.38	81055.1	86708.3	95457.7	104491	111937.1

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Coastal Area	capita (yuan)										
	The density of railways	17.54	19.44	22.29	22.29	24.18	26.08	27.50	27.98	27.98	30.35
	The density of highways	1244.67	1292.08	1309.15	1328.59	1347.08	1359.89	1375.06	1373.64	1384.07	1386.91
South Coastal Area	GRP per capita (yuan)	36407.44	41868.08	48532.06	52285.27	57154.60	61793.7	65706.2	72019.4	78939	85021.80
	The density of railways	14.91	16.40	16.70	17.30	20.58	22.37	24.46	25.05	25.05	26.84
	The density of highways	878.32	901.58	912.32	936.18	976.14	1011.93	1036.39	1053.09	1068.60	1078.44
The Middle Yellow River	GRP per capita (yuan)	23429.93	28191.75	33864.81	37407.27	40392.90	42945.6	44026.1	46579.9	49975.1	54054.82
	The density of railways	10.98	12.33	12.50	13.03	13.61	14.55	15.77	16.24	16.59	16.71
	The density of highways	388.17	398.50	406.22	416.26	421.70	426.19	430.57	454.52	458.26	462.41
Middle Reaches of The Yangtze River	GRP per capita (yuan)	19277.53	23689.82	29068.52	32547.19	36044.19	39252.7	41628.5	45594.1	49242.9	53717.81
	The density of railways	17.31	18.01	18.29	19.28	20.41	22.38	23.64	23.92	24.63	25.33
	Density of highways	949.62	1019.14	1042.78	1080.78	1109.20	1130.17	1172.81	1207.43	1231.07	1246.55
Southwest China	GRP per capita (yuan)	16045.85	19688.94	24185.66	27459.18	30662.66	33414.8	35693.2	39044.6	42545.7	46002.42
	The density of railways	8.98	9.27	9.35	9.49	10.23	11.63	12.58	13.91	14.13	14.64
	The density of highways	595.51	622.22	646.87	666.45	685.43	707.51	733.33	748.49	763.87	783.15
Big Northeast China	GRP per capita (yuan)	17022.85	20999.46	25479.71	28539.79	31752.47	34232.0	34358.3	35935.4	38458.6	42155.93
	The density of railways	2.23	2.47	2.52	2.64	2.66	3.17	3.41	3.49	3.66	3.68
	The density of highways	96.92	100.99	104.28	110.09	114.52	119.36	122.36	125.80	128.88	132.53

Source: Based on table 2.

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Data from table 3 show that development levels of railways and highways, and level of GRP per capita are different among economic regions. These processed data serve as basic data for analysis in the next subsections.

3. Results

3.1. Discussion of the interrelationship

To analyze the TI's impact on the economic development level according to economic regions, it is necessary to discuss the interrelationship between the economic development level and TI's development level. That is why when there exists interrelation between these indicators, analysis of impact is possible.
In this subsection, the authors primarily discuss whether or not TI affects the economic development level according to economic regions and how much it affects. In general, a test of the interrelationship between two economic events is conducted by statistical hypothesis test, and as above seen from the literature research in the Introduction, previous researchers demonstrated that infrastructure interrelates with economic growth and has a positive impact. Therefore, given that TI has a positive impact on economic growth by previous studies, this paper preconditions that TI's development level affects the GRP.

Table 4: Indicator-specific average values according to economic regions*

Region / Indicator	Northeast Region	North Coastal Area	Eastern Coastal Area	South Coastal Area	The Middle Yellow River	Middle Reaches of The Yangtze River	Southwest China	Big Northeast China
GRP per capita (yuan)	45542.52	57447.74	79066.44	59972.77	40086.84	37006.33	31474.31	30893.47
The density of railways (㎞ /1000 ㎞²)	19.62	35.85	24.56	20.97	14.23	21.32	11.42	2.99
The density of highways (㎞ /1000 ㎞²)	457.65	1253.90	1340.11	985.30	426.28	1118.96	695.28	115.57

Source: Based on table 3.
Note: * The average values for each indicator are calculated by the arithmetic average of the values for each indicator over a 10-year period.

Table 5: Ranking of economic regions by indicator-specific average values

Region / Indicator	Northeast Region	North Coastal Area	Eastern Coastal Area	South Coastal Area	The Middle Yellow River	Middle Reaches of The Yangtze River	Southwest China	Big Northeast China
GRP per capita (yuan)	4	3	1	2	5	7	6	8
The density of railways (㎞ /1000 ㎞²)	5	1	2	4	6	3	7	8
The density of highways (㎞ /1000 ㎞²)	6	2	1	4	7	3	5	8

Source: Based on table 4.

To discuss the interrelationship between the economic development level and TI's development level according to economic regions, it is necessary to conduct a comparison of average values and growth

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rates regarding three indicators. First of all, we have conducted the comparison between economic regions by indicator-specific average values (see tables 4, 5, and fig 1).

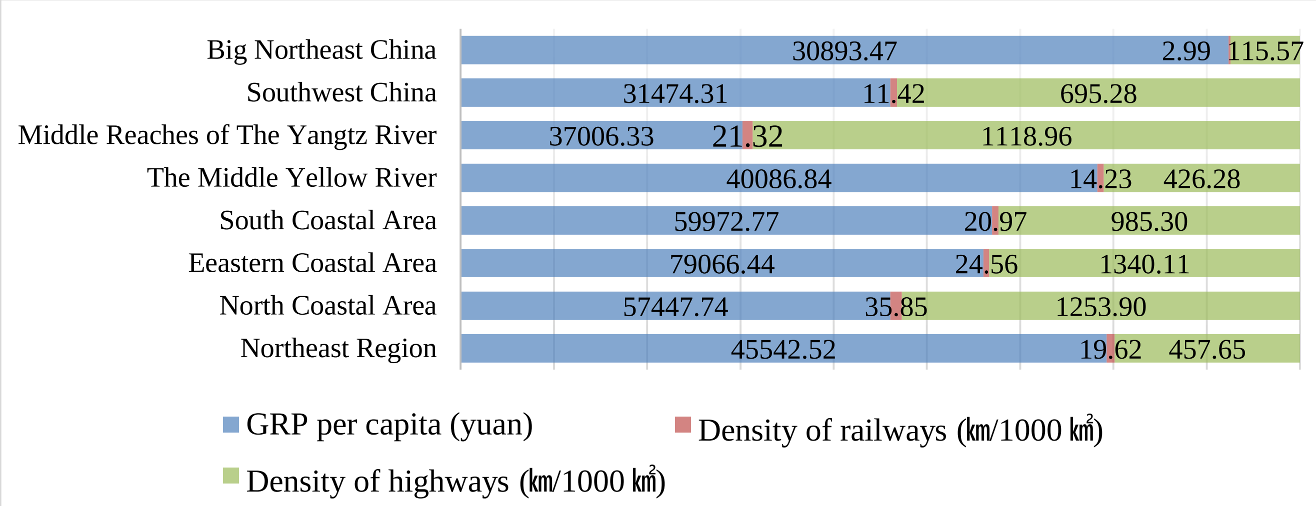

Fig 1. Differences between economic regions regarding indicator-specific development level

Source: Based on table 4

Comparison by indicator-specific average values shows the differences in development level according to economic regions regarding indicators. However, the discussion in this part aims to understand the differences in development level, and thus, the interrelationship is discussed based on rankings of regions by average values. From table 5, the closest regions in ranking in development level of three indicators are Big Northeast China and Eastern Coastal Area. GRP, economic development level, and TI's development level of these regions are the highest among the 8 economic regions. Also, other regions are similar in rankings at the development level except for the Middle Reaches of The Yangtze River. The average GRP per capita of this region is low, but TI's development level is middle among the 8 regions. This may give a theoretical ground that there is a close relationship between the economic development level and TI's development level, and TI has a positive impact on economic development except for special cases. However, this is seen to be conditional, too. This is because the average level has a limitation of not showing the movement in the growth rate of indicators due to summarizing the diverse levels according to years. In other words, the average value in the case that the level of indicator is high in the early period and is low in the late period is similar to one in the case that the level of indicator is low in the early period and is high in the late period, and thus, it says that discussing the interrelationship between indicators based on comparing the differences in indicator-specific averages. For this reason, it is necessary to compare the indicator-specific average growth rates to discuss the interrelationship (see tables 6, 7, and fig 2).

Table 6: Indicator-specific average growth rates according to economic regions*

Region / Indicator	Northeast Region	North Coastal Area	Eastern Coastal Area	South Coastal Area	The Middle Yellow River	Middle Reaches of The Yangtze River	Southwest China	Big Northeast China
GRP per capita (%)	107.00	108.58	110.02	109.88	109.73	112.06	112.41	110.60
The density of railways (%)	103.17	104.83	106.28	106.75	104.77	104.32	105.59	105.74
The density of highways (%)	101.66	102.29	101.21	102.31	101.96	103.07	103.09	103.54

Source: Based on table 3.

Note: * The average growth rates for each indicator are calculated by the average of the growth rate for each indicator over a 10-year period.

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Table 7: Ranking of economic regions by indicator-specific average growth rates

Region / Indicator	Northeast Region	North Coastal Area	Eastern Coastal Area	South Coastal Area	The Middle Yellow River	Middle Reaches of The Yangtze River	Southwest China	Big Northeast China
GRP per capita (%)	8	7	4	5	6	2	1	3
The density of railways (%)	8	6	2	1	5	7	4	3
The density of highways (%)	7	5	8	4	6	3	2	1

Source: Based on table 6.

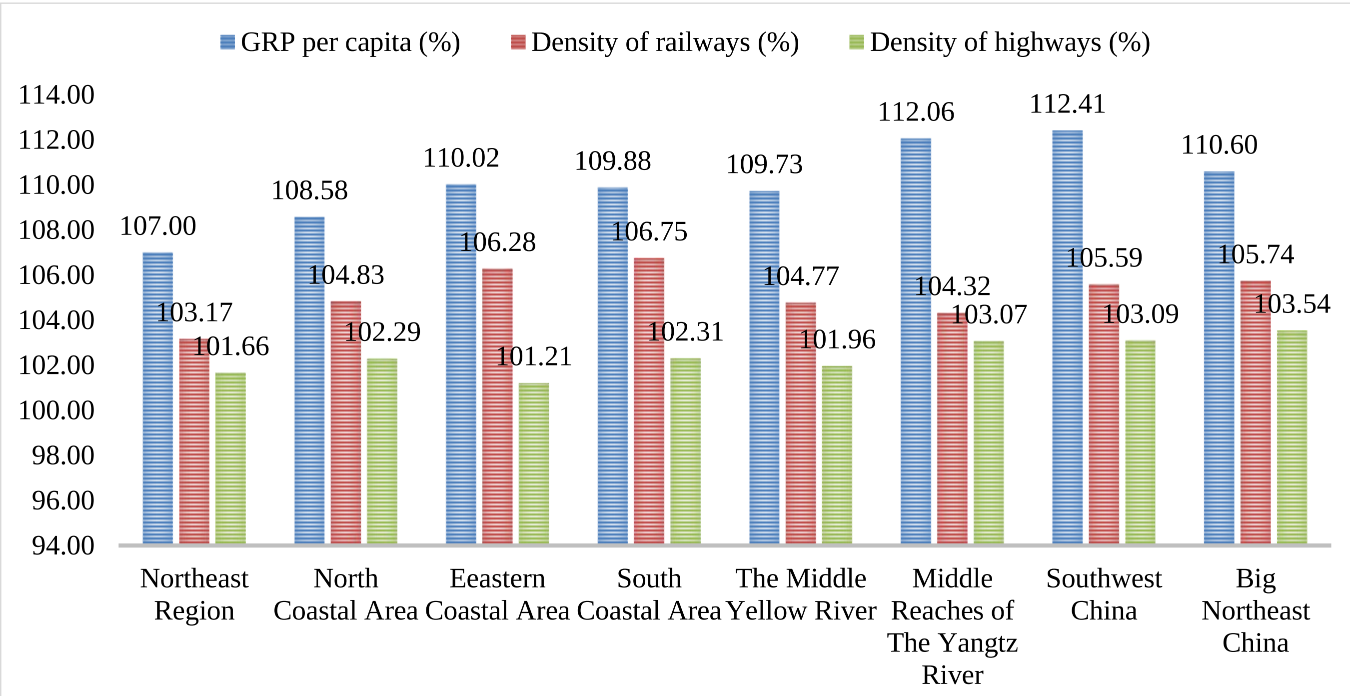

Fig 2. Differences between economic regions regarding indicator-specific growth rate

Source: Based on table 6.

Tables 6 and 7 show that the ranking of economic regions by indicator-specific average growth rates differs from those of economic regions by indicator-specific average values. What is apparent region is Big Northeast China, where its development levels are the lowest, but its growth rates are relatively high among the 8 economic regions. Otherwise, Eastern Coastal Area is the highest in development levels among the 8 economic regions, but in average growth rate, its ranking is 4th in GRP per capita, 2nd in the density of railways, and 8th in the density of highways. The regions where the average growth rates of the three indicators are close are Northeast Region and The Middle Yellow River. Differences in the ranking of indicator-specific growth rates are larger than those in the ranking of indicator-specific averages in most regions. It is too early to conclude that from this situation, the regions where rankings of indicator-specific growth rates are the most similar are those where TI's development level has an active impact on GRP, and vice versa. It is concerned that previous studies demonstrated that although TI's development level affects the economic development level, TI has little impact on economic development compared to the early stage, when TI is in a certain development stage, and highways affect the economic development more strongly than railways depending on natural and geographical conditions of a certain region.

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Therefore, being conditioned that there exists a certain interrelationship, it is necessary to analyze the degree of interrelationship.

3.2. Correlation and regression analysis

To analyze the impacts of railways and highways on GRP in economic regions under study, the authors conducted a linear multiple regression analysis. Applying the linear multiple regression analysis is based on assumption that the interrelation between GRP and individual infrastructural elements are in linear relation and these elements affect the GRP diversely. Also, the degree of changes in GRP corresponding to changes in individual infrastructural elements can easily be estimated by drawing regression models (Li, et al. 2020).
When considering the abovementioned regions-specific features of economic geography and development, regression analysis is conducted according to economic regions, and based on them, regression equations are constructed. For regression analysis, the authors construct the correlation matrix and regression models, and in turn, conduct the statistical forecasts. GRP is selected as the dependent variable, and the density of railways and the density of highways are independent variables for all economic regions.
In the first step, the correlation matrix is calculated, which makes it possible to reveal the impacts of densities of railways and highways on GRP and the correlation between densities of railways and highways. For the whole Chinese economy, correlations of densities of railways and highways with GRP per capita are not strong. However, for economic regions, they are strong. This shows that there exist features among economic regions. In other words, correlations of densities of railways and highways with GRP per capita are, in general, strong in all regions, but their degrees differ. Whereas North Coastal Area has a strong correlation between the density of railways with GRP per capita (0.984), the Northeast Region – weak (0.800). Southwest China has the strongest correlation of density of highways with GRP per capita (0.997), followed by Middle Reaches of The Yangtze River (0.992), Big Northeast China (0.986), and North Coastal Area (0.984). Northeast Region has the weakest correlation of the density of highways with GRP per capita (0.839). And North Coastal Area has the same correlations of two independent variables with GRP per capita (0.984). There is no region that has the strongest correlations of two independent variables with GRP per capita. Correlation coefficients are statistically significant at one percent. These correlations show that there exists a strong interrelation between GRP per capita and densities of railways and highways, but this does not mean that GRP per capita entirely depends on these factors.
In the second step, on the condition that correlations of TI's elements with GRP per capita are revealed, the authors construct and analyze the linear regression models.
For further analysis, the authors conduct the construction and analysis of regression models regarding each economic region as well as the whole Chinese economy. And results of construction and analysis are presented in Appendix. As a result of regression analysis, the significance and availability of regression models were tested, and thus, based on them, influences of densities of railways and highways on GRP per capita according to economic regions are analyzed, and region-specific GRP per capita is estimated (see tables A.1-A.4).
As a result, regression equations regarding individual economic regions and the whole Chinese economy can be described as follows.

Northeast Region: $\mathbf{y = -89572.882 - 491.479x_1 + 316.312x_2}$;
North Coastal Area: $\mathbf{y = -69775.598 + 1218.733x_1 + 66.619x_2}$;
Eastern Coastal Area: $\mathbf{y = 31527.476 + 5703.312x_1 - 69.062x_2}$;
South Coastal Area: $\mathbf{y = -214952.576 - 1924.265x_1 + 319.973x_2}$
The Middle Yellow River: $\mathbf{y = -82390.217 + 1719.748x_1 + 229.904x_2}$
Middle Reaches of The Yangtze River: $\mathbf{y = -83280.335 + 467.671x_1 + 98.588x_2}$
Southwest China: $\mathbf{y = -80443.526 - 317.108x_1 + 166.176x_2}$;

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Big Northeast China: $\mathbf{y = -56654.599 - 7027.908x_1 + 939.515x_2}$;

All together: $\mathbf{y = 19800.141 + 1046.107x_1 + 10.193x_2}$

Where, $\mathbf{x_1}$ – Density of railways (km/1000 km²)

$\mathbf{x_2}$ - Density of highways (km/1000 km²)

$\mathbf{y}$ – GRP per capita (yuan)

With constructing the regression models, significance provability, contribution degree, and standard error of estimate are calculated, which are meaningful values. For example, for the whole Chinese economy, significance provability is 0.00, contribution degree (R^2) – 0.486, and standard error of estimate - 14437.81319, respectively. This shows that regression equations are significant and statistically meaningful, $\mathbf{x_1}$ and $\mathbf{x_2}$ explain 48.6% of changes in GRP per capita, and the error interval of GRP per capita is ±14437.81319 (yuan). Also, as a result of constructing the regression equation for the whole Chinese economy, it turns out that the regression equation has plus symbols for two factors, the impact of the density of railways (3.541) is larger than that of the density of highways (1.500) by *t* values, which is in turn reflected in the regression equation. However, the above values differ among economic regions.

4. Discussion

First of all, the authors compared the differences between indicator-specific development levels (comparison by average absolute value) with those of indicator-specific average growth rates (comparison by average growth rate) to test the interrelationship between GRP per capita and densities of railways and highways according to economic regions. The result of the comparison shows that region-specific rankings by average absolute value differ from those by average growth rate. In other words, it does not mean that region with a high indicator-specific development level is higher than other regions concerning indicator-specific growth rate. For example, Eastern Coastal Area is high in indicator-specific average development levels, but – middle in indicator-specific average growth rates compared to other regions. On the other hand, Big Northeast China is the most backward in indicator-specific average development levels but has relatively high indicator-specific average growth rates compared to other regions (see tables 5 and 7). What is the key in the discussion of interrelationship is whether or not there exists an interrelation between GRP per capita and the densities of railways and highways for average development level as well as average growth rate, that is, whether or not the higher the TI's development level is, the higher the level of GRP per capita is, or whether or not the higher the TI's growth rate is, the higher the growth rate of GRP per capita is higher in certain regions. From table 5, it is seen that except for the Middle Reaches of The Yangtze River, all regions do have no large differences in development levels, and this shows that the densities of railways and highways affect GRP per capita strongly. In a view of growth rate, it is seen that regions except for Northeast Region, The Middle Yellow River, and Big Northeast China have certain differences in indicator-specific growth rates. However, this does not mean that there is no interrelation between GRP per capita and the densities of railways and highways. Previous studies only focused on elucidating the impact of investment in TI on economic development, and even in the case of elucidating the impact of physical infrastructure, it was limited to elucidating the relationship between the level of infrastructure development and the level of economic development. As a result, they concluded that the level of development of the transport infrastructure had a positive effect on economic development. Our study more specifically discusses the impact of transport infrastructure on the level of economic development by studying the interrelationship between the existing infrastructure, the construction of new infrastructure, and the level of economic development.

Next, the authors conducted a correlation analysis to reveal the correlation between the densities of railways and highways with GRP per capita. As a result of the analysis, it is seen that for the whole

Chinese economy correlations of densities of railways and highways with GRP per capita are not strong, but for economic regions, they are strong (see table 8). And considering economic regions, in general, degrees of correlation of two indicators with GRP per capita differ in coastal regions, but highways have a stronger correlation with GRP per capita than railways in inland regions (for example, Northeast Region, Northeast Region, Middle Reaches of The Yangtze River, Southwest China, Big Northeast China). And North Coastal Area has the same correlations of two indicators with GRP per capita. This shows that the densities of railways affect GRP per capita strongly. Previous studies have elucidated the effects of individual transport infrastructures on the whole economy and economic development of individual provinces but failed to elucidate the effects of different transport infrastructures on economic development in economic regions, that is, coastal and inland regions.

Next, the authors conducted the regression analysis to analyze and estimate the impacts of densities of railways and highways on GRP per capita (see Appendix). As a result of regression analysis, regression models for the whole Chinese economy, as well as economic regions, were constructed, the significance and availability of regression models were tested, and thus, based on them, the influences of densities of railways and highways on GRP per capita according to economic regions were analyzed, and region-specific GRP per capita was estimated. As a result of constructing the regression equations, the degrees of impact of two factors were accessed by *t* values, and they were reflected in regression equations. For example, whereas railways primarily have a stronger impact on GRP per capita than highways in coastal regions, and these are expressed as minus (-) symbols in regression equations, highways – have a stronger impact on GRP per capita than railways in inland regions, and these are expressed as plus (+) symbols in regression equations according to t values. This confirms Li et al. (2020a)'s conclusion in discussing the TI's impact on the economic development of some inland and coastal provinces in China. However, there are certain points of discussion when analyzing the impact of existing infrastructure and new construction of infrastructure on economic development. In this part, the first discussion is what the impacts of development levels of railways and highways on GRP per capita between regions with developed and underdeveloped TI. According to table 5, whereas Eastern Coastal Area is the highest TI development level, Big Northeast China is the lowest. Considering the regression equations for these regions, the impact of railways is relatively larger than highways in Eastern Coastal Area and vice versa in Big Northeast China. In this part, the second discussion is what the impacts of development levels of railways and highways on GRP per capita between regions with high and low growth rates of TI are. According to table 7, whereas South Coastal Area is the highest, the Northeast Region is the lowest for the growth rate of railways. As for the growth rate of highways, whereas Big Northeast China is the highest, Eastern Coastal Area is the lowest. Considering the regression equations for these regions, it is seen that in South Coastal Area with the highest growth rate of railways, the impact of highways on GRP per capita is stronger than in other coastal regions (*t* value for the density of railways is expressed as minus symbol), and in Northeast Region with the lowest growth rate of railways, too, the impact of highways on GRP per capita is stronger than railways. In Big Northeast China with the highest growth rate of highways, the impact of highways on GRP per capita is the strongest (regression coefficient is 939.515) among other inland regions with relatively high growth rates of highways, and in Northeast Region with the lowest growth rate of highways, impact of highways on GRP per capita is the second (regression coefficient is 316.312). On the other hand, although the impacts of the two factors differ to some degrees, regions with positive impacts of two factors on GRP per capita are North Coastal Area, The Middle Yellow River, and Middle Reaches of The Yangtze River, and the impacts of two factors are expressed as plus (+) symbols in regression equations. North Coastal Area has the highest levels regarding GRP per capita, the density of railways, and the density of highways, but the growth rate is the 4th for GRP per capita, 2nd for the growth rate of the density of railways, and 8th for the growth rate of the density of highways. This shows that the developed TI of this region has a positive impact on GRP per capita, but the construction of new TI (especially, highways) does not affect the growth of GRP per capita strongly (regression coefficient of

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highways is 66.619). Also, although the growth rate of railways is relatively high in this region, the impact of railways is not strong compared to other regions. The Middle Yellow River is relatively low for development levels as well as growth rates of three indicators compared to other regions, and their differences are relatively close. Considering the regression equation for this region, it is seen that densities of railways and highways have positive impacts on GRP per capita, and construction of new TI has a strong impact. It is found from regression coefficients. For this region, the regression coefficient of railways is the second (1719.748), and highways is the fourth (229.904). Middle Reaches of The Yangtze River has a relatively high development level of TI (3^{rd} rank), but it has a low level of GRP per capita (7^{th} rank). However, regarding growth rate, it is 2^{nd} rank for GRP per capita, 7^{th} for density of railways, and 3^{rd} for density of highways. In other words, in this region, TI is developed, but the level of GRP per capita is low. It is seen that in a view of the growth rate, the construction of new TI (highways) supports the growth of GRP per capita. From the regression equation for this region, two indicators have positive impacts on GRP per capita (plus). However, the impact of railways in this region is weaker than in other regions with a strong impact of railways, and the impact of highways is weak, too. On the other hand, the impact of highways is not strong compared to railways (the regression coefficient of railways is 467.671, and highways is 98.588. This shows that in this region, the construction of new TI (in particular, railways) may have a strong impact on the growth of GRP per capita. As a result of estimating the future GRP per capita for 10 years using regression equations, standard residuals are within the limit of allowable error (2.5), and thus, regression equations are acceptable in estimating future GRP per capita (see table A. 4 in Appendix). This discussion through regression analysis was not carried out in previous studies.

5. Conclusion

This study aims to reveal the impact of which TI's development level affects the Gross Regional Products (GRP) per capita according to Chinese economic regions. For the study, the authors calculated the indicators such as GRP per capita, the density of railways, and the density of highways according to economic regions classified by the National Bureau of Statistics of China. Primary data for the study are from the National Bureau of Statistics of China (2019) and several homepages, and the period for collecting data was selected as 10 years (2009-2018). In this study, the authors tested the interrelationship between GRP per capita and densities of railways and highways based on calculations of averages and growth rates regarding the abovementioned indicators, and arguments suggested by previous researchers. And the authors conducted the correlation and regression analysis to analyze the impacts of densities of railways and highways on GRP per capita and to estimate the GRP per capita based on them using the statistical software package SPSS. GRP per capita was selected as the dependent variable, and the densities of railways and highways were independent variables. From the results and discussion, the authors can conclude as follows.

First, the development levels of railways and highways have a strong impact on GRP per capita according to Chinese economic regions. It turns out that in most regions except for some, there are not large differences between GRP per capita and the densities of railways and highways for average development level as well as average growth rate. This conclusion can be reached when discussing the comparison by means of the average values and the results of the correlation matrix creation between the three indicators (see tables 5 and 6, and the second part of the Results and Discussion section).

Second, the impacts of densities of railways and highways on GRP per capita differ among Chinese economic regions. Results of the study show that in general, railways have a stronger impact on GRP per capita than highways in coastal regions, but in inland regions, highways have a stronger impact than railways. As seen from regression analysis, whereas railways primarily have a stronger impact on GRP per capita than highways in coastal regions, and these are expressed as minus (-) symbols in regression

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equations, highways have a stronger impact on GRP per capita than railways in inland regions, and these are expressed as plus (+) symbols in regression equations according to t values.

Third, the construction of new TI has a more positive impact on GRP per capita compared to regions with already developed TI. According to the results of considering the development level and growth rate of TI, it is seen that the densities of railways and highways have positive impacts on GRP per capita in regions with high growth rates of TI compared to regions with already developed TI regarding regression coefficients.

Fourth, region-specific features ought to be considered in making and implementing the economic development policy according to economic regions. It turns out that in the Middle Reaches of The Yangtze River, it seems that the growth rate of GRP per capita (2nd rank) is supported by the growth rate of the density of highways (3rd rank), but regarding regression coefficients, highways are larger than railways. In other words, in this region, the faster growth rate of railways than highways may probably have a more positive impact on GRP per capita.

Of course, this study has some limitations because of the period for collecting data, the selection of factors, and the statistical methodology. When increasing the period for data and number of factors, degrees of impact on GRP per capita will differ from values calculated by our study, and the availability of methodology acceptable must be confirmed by conducting the various tests from statistical viewpoints. However, the methodology suggested by this study may be useful in providing necessary information relating to economic policy-making thanks to its generality and uniqueness.

Authors' Contributions: Gwang-Nam Rim conceived the idea and collected data; Chol-Ju An analyzed the data; Gwang-Nam Rim wrote the paper.

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REFERENCES

Andre, H., Claudio, A., & Vianka, A. (2016). Information and communication technologies and their impact on the economic growth of Latin America, 1990-2013, *Telecommunication Policy, 40*(5), 485-501. https://doi.org/10.1016/j.telpol.2016.02.002.

Arredondo-Trapero , F. G., Vázquez-Parra , J. C., & Guerra-Leal, E. M. (2020). Information and Communication Technologies and Their Impact on Competitiveness in Latin America, *Journal of Technology Management & Innovation*, 15(4), 43-53. https://doi.org/10.4067/S0718-27242020000400043.

Aschauer, D. (1989). Is public expenditure productive? *Journal of Monetary Economics, 23*(1989), 177-200.

Baltagi, B. H. & Pinnoi, N. (1995). Public capital stock and state productivity growth: Further evidence from an error components model, *Empirical Economics*, 20, 351–359. https://doi.org/10.1007/BF01205444.

Bajo-Rubio, O. & Sosvilla–Riviero, S. (1993). Does public capital affect private sector performance? An analysis of the Spanish case 1964-88, *Economic Modelling, 10*(3), 179-185. https://doi.org/10.1016/0264-9993(93)90015-8.

Binswanger, H. P., Khandker, S. R., & Rosenzweig, M. R. (1993). How Infrastructure and Financial Institutions Affect Agricultural Output and Investment in India, *Journal of Development Economics*, *41*(2), 337-366. https://doi.org/10.1016/0304-3878(93)90062-R.

Buys, P., Deichmann, U., & Wheeler, D. (2010). Road Network Upgrading and Overland Trade Expansion in Sub-Saharan Africa, *Journal of African Economies, 19*(3), 399-432. https://doi.org/10.1093/jae/ejq006.

Cette, G., Clerc, C., & Bresson, L. (2016). "Contribution of information and communication technologies (ICT) to growth," Post-Print hal-03565112, HAL.

Chakraborty, C. & Nandi, B. (2011). 'Mainline' telecommunications infrastructure, levels of development and economic growth: Evidence from a panel of developing countries, *Telecommunications Policy*, *35*(5), 441-449. https://doi.org/10.1016/j.telpol.2011.03.004.

Chatterjee, S., Lebesmuehlbacher, T., & Narayanan, A. (2021). How productive is the public investment? Evidence from formal and informal production in India, *Journal of Development Economics,* 151(2021), .https://doi.org/10.1016/j.jdeveco.2021.102625.

Colecchia, A. & Schreyer, P. (2003). The contribution of information and communication technologies to economic growth in nine OECD countries, *OECD Economic Studies*, *2002*(1). 153-171. https://doi.org/10.1787/eco_studies-v2002-art5-en.

Published by *Research & Innovation Initiative Inc.*, registered with the Michigan Department of Licensing & Regulatory Affairs, United States (Reg. No. 802790777).

Demetriades, P. & Mamuneas, T. (2000). Intertemporal output and employment effects of public infrastructure capital: evidence from 12 OECD economies, *The Economic Journal*, *110(465)*, 687-712. https://doi.org/10.1111/1468-0297.00561.

Dethier, J. J., Hirn, M., & Straub, S. (2008). Explaining Enterprise Performance in Developing Countries with Business Climate Survey Data, *Policy Research Working Paper Series*, *4*792, Washington, DC, The World Bank.

Ebuh, G., Ezike, I. B., Shitile, T. S., et al. (2019). The Infrastructure–Growth Nexus in Nigeria: A Reassessment, *Journal of Infrastructure Development*, 11(1-2), 41-58. https://doi.org/10.1177/0974930619872096.

Estache, A., Speciale, B., & Veredas, D. (2005). How much does infrastructure matter to growth in Sub-Saharan Africa, European Center for Advanced Research in Economics, *Working Paper*, Universite Libre de Bruxelles. https://www.researchgate.net/publication/228457801.

Estache, A. & Fay, M. (2010). Current Debates on Infrastructure Policy. In M. Spence & D. Leipziger (Eds.), *Globalization and Growth: Implications for a Post-Crisis World* (pp. 151-193). Commission on Growth and Development. https://doi.org/10.1596/1813-9450-4410.

Fernald, J. G. (1999). Roads to Prosperity? Assessing the link between public capital and productivity, *American Economic Review*, 89(3), 619-638. https://doi.org/10.1257/aer.89.3.619.

Garsous, G. (2012). How Productive is Infrastructure? A Quantitative Survey, *ECARES Working Paper*, Université libre de Bruxelles.

Greenstein, S. M. & Spiller, P. T. (1995). Modern Telecommunications Infrastructure and Economic Activity: An Empirical Investigation, *Industrial and Corporate Change*, 4(4), 647-665. https://doi.org/10.1093/icc/4.4.647.

Li, J., An, C., & Rim, G. (2020a). Impact of Transport Infrastructure on Gross Regional Products: Evidence from Chinese Provinces under "Belt and Road" Initiative, *Business Perspective Review 2*(2), 23-45. https://doi.org/10.38157/business-perspective-review.v2i2.145.

Li, J. H., Rim, G. N., & An, C. J. (2020b). Relationship between Transport Infrastructure and Employment: Evidence from the Chinese Inland Provinces under the "One Belt, One Road" Initiative, *Business Perspective Review*, *2*(1), 13-28. https://doi.org/10.38157/business-perspective-review.v2i1.103.

Li, J. H., Rim, G.-N., & An, C.-J. (2019). Impact of Transport Infrastructure on Trade: Evidence from the Chinese Inland Provinces under "One Belt, One Road", *Open Journal of Business and Management*, *7*(4), 2030-2046, https://doi.org/10.4236/ojbm.2019.74140.

Ligthart, J. E. (2000). Public capital and output growth in Portugal: An Empirical Analysis, *IMF Working Paper No. 00/11*. Available at SSRN: https://ssrn.com/abstract=879331.

Mamatzakis, E. C. (1999). Testing for the long run relationship between infrastructure and private capital productivity: a time series analysis for the Greek industry, *Applied Economics Letter*, *6* (4), 243-246. https://doi.org/10.1080/135048599353438.

Nadiri, M. I. & Mamuneas, T. P. (1996). *Contribution of highway capital to industry and national productivity growth*, Report prepared for Apogee Research, Inc., for the Federal Highway Administration Office of Police Development. Work Order Number BAT-94-008. https://www.researchgate.net/publication/239657902_Contribution_of_highway_capital_to_industry_and_national_productivity_growth.

National Bureau of Statistics of China. (2019). National data. Accessed: 2019-09-18, Available at: http://www.stats.gov.cn/english/easyquery.htm?cn=E0103

Ni, A. (2013). The Analysis of the Impact of Transportation Infrastructure Investment on China's Economic Growth, *Economic Research Guide*, Serial No.194. http://en.cnki.com.cn/Article_en/CJFDTOTAL-JJYD201312003.htm.

Otto, G. D. & Voss, G. M. (1996). Public capital and private production in Australia, *Southern Economic Journal*, *3*(62). 723-738.

Pereira, A. M. & Roca-Sagales, O. (1999). Public capital formation and regional development in Spain, *Review of Development Economics*, *3*(3), 281-294. https://doi.org/10.1111/1467-9361.00068.

Pereira, A. M. & Andraz, J. M. (2003), On the impact of public investment on the performance of US industries, *Public Finance Review*, *31*(1), 66-90. https://doi.org/10.1177/1091142102239135.

Pereira, A. M. & Andraz, J. M. (2013). On the economic effects of public infrastructure investment: A survey of the international evidence, *Journal of Economic Development*, *38*(4), 1-37.

Pereira, A. M. & Pereira, R. M. (2018). On the effects of infrastructure investment on economic performance in Ontario, *Journal of Infrastructure, Policy, and Development*, *2*(2), 286-300. https://doi.org/10.24294/jipd.v2i2.839.

Pereira, A. M. & Pereira, R. M. (2019a). On the Effects of Infrastructure Investments on the Regional Economic Mix in Portugal, *Journal of Economics and Public Finance*, *5*(3), https://doi.org/10.22158/jepf.v5n3p375.

Published by *Research & Innovation Initiative Inc.*, registered with the Michigan Department of Licensing & Regulatory Affairs, United States (Reg. No. 802790777).

Pereira, A. M. & Pereira, R. M. (2019b). How Does Infrastructure Investment Affect Macroeconomic Performance? Evidence from Portugal, *Journal of Infrastructure Development, 11*(1-2), 14–40. https://doi.org/10.1177/0974930619872083.

Rim, G. N. & An, C. J. (2022). Impact of Transport Infrastructure on Living Standards: Evidence from the Chinese Provinces Directly Affected by the "One Belt, One Road" Initiative. *Business Perspective Review* 4(1), 51-69. https://doi.org/10.38157/bpr.v4i1.431.

Thuy, C. T. (2018). The Role of Investment and Development Road Traffic Infrastructure for Vietnam's Economic Development, *Journal of Business Management and Economic Research, 2*(12), 37-42. https://doi.org/10.29226/TR1001.2019.96.

Unnikrishnan, N. & Kattookaran, T. K. (2020). Impact of Public and Private Infrastructure Investment on Economic Growth: Evidence from India, *Journal of Infrastructure Development,12(2),* 119–138. https://doi.org/10.1177/0974930620961477.

Wilson, J. S., Mann, C. L., & Tsunehiro, O. (2003). Trade facilitation and economic development: measuring the impact (03/07/2003). Available at SSRN: https://ssrn.com/abstract=636350.

Yingying, S., Shen, G., & Puyang, S. (2017). The role of infrastructure in China's regional economic growth, *Journal of Asian Economics, 49* (2017), 26–41. https://doi.org/10.1016/j.asieco.2017.02.004.

Ylander, A. (2017). The impact of 'On Belt, One Road' and its Effects on GDP growth in China, Retrieved at: https://gupea.ub.gu.se/handle/2077/52800

Yoshino, N. & Abidhadjaev, U. (2017), An impact evaluation of investment in infrastructure: The case of a railway connection in Uzbekistan, *Journal of Asian Economics, 49*(2017), 1-11. https://doi.org/10.1016/j.asieco.2017.02.001.

Xinmin, C., Jinquan L., & Yi, F. (2017). A Study on the Impact of China's Transportation Infrastructure Construction on Economic Growth, https://doi.org/10. 16528 /j. cnki. 22 - 1054 /f. 201704068.

Appendix 1

Appendix A: Results of regression analysis

Table A.1. Model Summary[b]

Model	**R**	R^2	Adjusted R^2	**Standard error of estimate**
Northeast Region	.839[a]	.704	.620	5142.79991
North Coastal Area	.986[a]	.973	.965	2424.93770
Eastern Coastal Area	.975[a]	.951	.937	5271.17565
South Coastal Area	.979[a]	.959	.947	3650.44775
The Middle Yellow River	.974[a]	.948	.933	2468.76676
Middle Reaches of The Yangtzee River	.993[a]	.985	.981	1523.98279
Southwest China	.997[a]	.994	.993	837.94307
Big Northeast China	.992[a]	.984	.979	1138.41654
Whole	.697[a]	.486	.473	14437.81319

Note: [a] Predictors: (Constant), the density of highways (㎞/1000 ㎢), the density of railways (㎞/1000 ㎢), [b] Dependent Variable: GRP per capita (yuan),

Table A.2. ANOVA[b]

14		Sum of Squares	**Degree of freedom**	Mean Square	**F**	**Significance**
Northeast	Regression	4.408E8	2	2.204E8	8.334	.014[a]

Region	Residual Total	1.851E8 6.260E88	7 9	2.645E7		
North Coastal Area	Regression Residual Total	1.485E9 4.116E7 1.526E9	2 7 9	7.424E8 5880322.863	126.254	.000[a]
Eastern Coastal Area	Regression Residual Total	3.774E9 1.945E8 3.968E9	2 7 9	1.887E9 2.779E7	67.907	.000[a]
South Coastal Area	Regression Residual Total	2.156E9 9.328E7 2.250E9	2 7 9	1.078E9 1.333E7	80.905	.000[a]
The Middle Yellow River	Regression Residual Total	7.810E8 4.266E7 8.237E	2 7 9	3.905E8 6094809.332	64.071	.000[a]
Middle Reaches of The Yangtze River	Regression Residual Total	1.088E9 1.626E7 1.105E9	2 7 9	5.442E8 2322523.543	234.308	.000[a]
Southwest China	Regression Residual Total	8.544E8 4915040.122 8.594E8	2 7 9	4.272E8 702148.589	608.446	.000[a]
Big Northeast China	Regression Residual Total	5.494E8 9071945.456 5.585E8	2 7 9	2.747E8 1295992.208	211.980	.000[a]
Whole	Regression Residual Total	1.519E10 1.605E10 3.124E10	2 77 79	7.594E9 2.085E8	36.428	.000[a]

Note: [a] Predictors: (Constant), the density of highways (㎞/1000 ㎢), the density of railways (㎞/1000 ㎢), [b] Dependent Variable: GRP per capita (yuan),

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Table A.3. Coefficients

Model		Unstandardized Coefficients B	Unstandardized Coefficients Standard Error	Standardized Coefficients Beta	t	Significance	95% Confidence Interval for B Lower Bound	95% Confidence Interval for B Upper Bound
Northeast Region	(Constant)	-89572.882	56049.301		-1.598	.154	-222108.420	42962.655
	density of highways (㎞/1000 ㎢)	-491.479	3397.267	-.111	-.145	.889	-8524.739	7541.782
	density of railways (㎞/1000 ㎢)	316.312	256.331	.945	1.234	.257	-289.815	. 922.439
North Coastal Area	(Constant)	-69775.598	38812.058		-1.798	.115	-161551.53	22000.337
	density of highways (㎞/1000 ㎢)	1218.733	1060.667	. .506	1.149	.288	-1289.347	3726.813
	density of railways (㎞/1000 ㎢)	66.619	60.671	.483	1.098	.309	-76.847	210.084
Eastern Coastal Area	(Constant)	31527.476	170793.506		.185	.859	-372334.991	435389.943
	density of highways (㎞/1000 ㎢)	5703.312	1786.420	1.123	3.193	.015	1479.100	9927.524
	density of railways (㎞/1000 ㎢)	-69.062	159.006	-.153	-.434	.677	-445.051	306.926
South Coastal Area	(Constant)	-214952.576	98112.098		-2.191	.065	-446950.823	17045.671
	density of highways (㎞/1000 ㎢)	-1924.265	2650.844	-.531	-.726	.491	-8192.516	4343.986
	density of railways (㎞/1000 ㎢)	319.973	155.486	1.506	2.058	.079	-47.692	687.639
The Middle Yellow River	(Constant)	-82390.217	34323.500		-2.400	.047	-163552.397	-1228.036
	density of highways (㎞/1000 ㎢)	1719.748	1685.682	.366	1.020	.342	-2266.257	5705.754
	density of railways (㎞/1000 ㎢)	229.904	133.986	.615	1.716	.130	-86.923	546.730
Middle Reaches of The Yangtze River	(Constant)	-83280.335	11022.028		-7.556	.000	-109343.290	-57217.380
	density of highways (㎞/1000 ㎢)	467.671	758.288	.127	.617	.557	-1325.396	2260.739
	density of railways (㎞/1000 ㎢)	98.588	23.386	.868	4.216	.004	43.289	153.887
Southwest China	(Constant)	-80443.526	6351.359		-12.666	.000	-95462.104	-65424.948
	density of highways (㎞/1000 ㎢)	-317.108	444.860	-.073	-.713	.499	-1369.034	734.818
	density of railways (㎞							

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	/1000 ㎢)	166.176	15.910	1.067	10.445	.000	128.554	203.798
Big Northeast China	(Constant)	-56654.599	7167.377		-7.905	.000	-73602.751	-39706.446
	density of highways (㎞/1000 ㎢)	-7027.908	3056.904	-.487	-2.299	.055	-14256.338	200.521
	density of railways (㎞ /1000 ㎢)	939.515	136.358	1.460	6.890	.000	617.079	1261.951
Whole	(Constant)	19800.141	3654.151		5.419	.000	12523.796	27076.486
	density of highways (㎞/1000 ㎢)	1046.107	295.468	.509	3.541	.001	457.756	1634.458
	density of railways (㎞ /1000 ㎢)	10.193	6.794	.216	1.500	.138	-3.335	23.722

a. Dependent Variable: GRP per capita (yuan)

Table A.4. Casewise Diagnostics[a]

Region	Indicator	Case Number									
		1	2	3	4	5	6	7	8	9	10
Northeast Region	Standard residual	-1.407	-.482	.341	.886	1.074	.926	.658	-.805	-.803	-.387
	GRP per capita (yuan)	28493.85	34224.97	41380.20	46001.32	49849.24	52358.87	52814.31	48038.30	49890.99	52373.19
	Predicted value	35728.7926	36703.5264	39627.3732	41444.5466	44327.2729	47597.3115	49428.7513	52180.1756	54021.6049	54365.8851
	Residual	-7.23494	-2.4785	1.75283E3	4.55677	5.52197	4.76156	3.38556	-4.14188	-4.13061	-1.99270
North Coastal Area	Standard residual	-1.501	.056	1.263	.925	.237	-.235	-1.371	-.116	.455	.287
	GRP per capita (yuan)	36140.78	41362.18	48112.20	52486.69	57093.93	60409.51	63059.18	67912.94	72087.42	75812.5
	Predicted value	39781.3303	41227.5846	45049.8582	50244.7515	56518.5951	60978.6448	66382.9973	68194.2835	70982.9852	75116.3295
	Residual	-3.64055E	1.34595E2	3.06234E3	2.24194E3	5.75335E2	-5.69135E2	-3.32382E3	-2.81344E2	1.10443E3	6.96201E2
Eastern Coastal Area	Standard residual	.340	.398	-.794	.404	-.213	-1.005	-1.270	-.148	1.702	.588
	GRP per capita (yuan)	47394.1	55262.03	64055.52	69027.87	75276.38	81055.15	86708.30	95457.74	104490.19	111937.10
	Predicted value	45603.67	53165.7193	68241.2637	66898.6906	76400.9868	86352.5905	93403.6171	96239.2755	95518.9547	108839.6672
	Residual	1.79049E3	2.09631E3	-4.18574E3	2.12918E3	-1.12461E3	-5.29744E3	-6.69532E3	-7.81536E2	8.97124E3	3.09743E3
South Coastal Area	Standard residual	-.271	-.028	1.014	.267	-.173	-1.095	-1.066	-.489	.047	1.794
	GRP per	36407.44	36407.44	48532.06	52285.27	57154.60	61793.77	65706.22	72019.44	78939.06	85021.80

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	capita (yuan)										
	Predicted value	37395.6857	41971.1127	44830.3478	51310.3546	57784.9037	65792.3182	69597.1545	73805.3943	78768.1820	78472.2864
	Residual	-9.88246E2	-1.03033E2	3.70171E3	9.74915E2	-6.30304E2	-3.99855E3	-3.89093E3	-1.78595E3	1.70878E2	6.54951E3
The Middle Yellow River	Standard residual	-.933	-.907	.554	.684	.983	.944	.124	-1.399	-.616	.566
	GRP per capita (yuan)	23429.93	28191.75	33864.81	37407.27	40392.90	42945.60	44026.13	46579.98	49975.17	54054.82
	Predicted value	25734.3070	30430.8718	32498.0849	35717.7839	37965.9136	40614.7444	43719.8154	50034.2887	51496.0402	52656.5100
	Residual	-2.30438E3	-2.23912E3	1.36673E3	1.68949E3	2.42699E3	2.33086E3	3.06315E2	-3.45431E3	-1.52087E3	1.39831E3
Middle Reaches of The Yangtze River	Standard residual	.552	-1.265	.649	.170	.279	.423	-1.163	-.886	-.239	1.481
	GRP per capita (yuan)	19277.53	23689.82	29068.52	32547.19	36044.19	39252.71	41628.53	45594.11	49242.93	53717.81
	Predicted value	18436.5153	25617.7467	28079.3230	32288.6746	35619.0238	38607.7339	43400.8066	46944.8829	49607.5579	51461.0754
	Residual	8.41015E2	-1.92793E3	9.89197E2	2.58515E2	4.25166E2	6.44976E2	-1.77228E3	-1.35077E3	-3.64628E2	2.25673E3
Southwest China	Standard residual	.450	-.389	.119	.196	.535	-.030	-2.072	-.575	.636	1.131
	GRP per capita (yuan)	16045.85	19688.94	24185.66	27459.18	30662.66	33414.83	35693.20	39044.67	42545.70	46002.42
	Predicted value	15668.4676	20015.07	24085.9502	27295.2862	30214.6518	33439.8725	37429.2910	39526.7697	42012.7968	45054.9500
	Residual	3.77382E2	-3.26134E2	9.97098E1	1.63894E2	4.48008E2	-2.50425E1	-1.73609E3	-4.82100E2	5.32903E2	9.47470E2
Big Northeast China	Standard residual	-1.500	.115	1.644	.278	-.432	.900	.017	-.943	-.219	.140
	GRP per capita (yuan)	17022.85	20999.46	25479.71	28539.79	31752.47	34232.07	34358.30	35935.46	38458.69	42155.93
	Predicted value	18730.9882	20868.1175	23607.7274	28222.9622	32244.4568	33207.4777	34339.3256	37009.0255	38707.9882	41996.6609
	Residual	-1.70814E3	1.31343E2	1.87198E3	3.16828E2	-4.91987E2	1.02459E3	1.89744E1	-1.07357E3	-2.49298E2	1.59269E2

a. Dependent Variable: GRP per capita (yuan)
Source: Own calculation

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