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Transport infrastructure and regional economic growth: evidence from China

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Abstract This article develops a multi-dimensions measurement of transport infrastructure and examines the linkage between transport infrastructure and regional economic growth. A panel data model is estimated using data from a sample of 31 Chinese provinces from 1998 to 2007. The results provide strong evidence that transport infrastructure plays an important role in economic growth. Both land transport and water transport infrastructure have strong and significant impacts, while the contribution of airway transport infrastructure is weak. Furthermore, land transport infrastructure contributes more to economic growth in locations with poor land transport infrastructure, while the investment in water transport infrastructure contribute positively to economic growth only after the investment scale exceeds a threshold level. These results are robust to a variety of alternative methods, the exclusion of possible outliers, and consideration of endogeneity. A retrospective analysis shows that uneven distribution of transport infrastructure is an important reason behind economic disparities across Chinese regions.

Keywords Transport infrastructure · Economic growth · Regional disparity · China

Introduction

Transport infrastructure leads to economic growth through several ways. First, investing in infrastructure itself increases demand for goods and services. Second, transport infrastructure improvement reduces travel time, and passenger and freight transporters gain directly from time and cost saving (Gunasekera et al. 2008). The time savings induced by improvement of transport infrastructure can yield economic consequences through making producers access to distant markets and draw inputs from a larger area, and hence stimulate local production. In addition, highway infrastructure investment can generate benefits by lowering firms' inventories (Shirley and Winston 2004). Third, better infrastructure attracts

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foreign direct investment (Hong 2007), which is widely regarded as an important engine of economic growth in China. Lastly, lower transport and trade cost can accelerate industrial agglomeration (Baldwin and Forslid 2000; Krugman 1991), and the concentration of economic activities increases labor productivity (Ciccone and Hall 1996). Banister and Berechman (2000) depict a general framework that describes the relationship between the transportation system and economic growth. According to their framework, improved transport accessibility reduces travel time and cost, increases traffic volume, and leads to spatial redistribution of economic activities. It further leads to pecuniary externalities, as well as allocative externalities in environment, transport network economies, labor market and firm agglomeration, and hence cause economic growth.

In theory, the perception of the role of infrastructure as an engine of economic growth has changed over time. Solow's (1956) neoclassical growth model used an aggregate production function approach and assumed exogenous technical changes, while the work of Romer (1986) began a set of theoretical research on the endogeneity of economic growth. During the past two decades, numerous empirical studies have been done to examine the impact of infrastructure on economic development. Following the pioneer study by Aschauer (1989), some economists have estimated neo-classical production function, in which infrastructure investment is treated as an input to production (e.g., Berechman et al. 2006; Evans and Karras 1993; Gillen 1996; Lall 2007; Otto and Voss 1996; Seitz 1994). In recent years, simultaneous approach has been used in the literature (e.g., Roller and Waverman 2001; Yamaguchi 2007). Most previous studies conclude that public investment in transportation infrastructure has a strong and positive effect on output.

Some studies attempt to investigate the impact of transport infrastructure on economic growth in China. Mody and Wang (1997) examined the determinants of coastal China's growth using panel data on 23 industrial sectors between 1985 and 1989, and found that roadway transport infrastructure was an engine of economic growth. Fleisher and Chen (1997) did not find any significant impact of transportation infrastructure on total factor productivity and economic growth during the period of 1978–1993. Demurger (2001) investigated the relationship between public infrastructure and economic growth in China using panel data from a sample of 24 Chinese provinces from 1985 to 1998, and found that infrastructure endowment did contribute to economic development.

While a number of studies have been done in the literature, several questions remain unsolved. First, previous studies normally focus on a certain type of transport infrastructure, such as roadway (e.g., Gunasekera et al. 2008), airports (e.g., Yamaguchi 2007), and hence cannot compare the impacts of various types of infrastructure. Second, most of previous studies use either transportation investment (e.g., Berechman et al. 2006), or roadway length (e.g., Demurger 2001) to measure infrastructure endowment, and hence cannot capture the effect of infrastructure quality. Third, previous studies have ignored that the impacts of infrastructure on economic growth may differ across regions. In a large country like China, substantial regional differences exist. Transport infrastructure may have different impacts on economic growth across regions. Finally, most of existing studies in the literature assumes a linear relationship between infrastructure and economic development. However, transportation gains (e.g., time saved) may be capitalized through agglomeration effects, which implies a non-linear relationship between transportation and growth.[1]

This research attempts to fill the above gaps in the literature. Based on a factor analysis, we develop a comprehensive index to measure both quantitative and qualitative

[1] Thanks for an anonymous referee to raise this point.

characteristics of each type of transport infrastructure. This allows us to capture the impact of both quantity and quality of transport infrastructure, and compare the contribution of different types of infrastructure to economic growth. The square of the transport variables are included to study the nature of returns to scale to transport investment. We also make a growth decomposition analysis, to identify whether the impacts of various modes of transport infrastructure on economic development differ across regions.

The rest of the article is organized as follows. Section 2 gives an overview of infrastructure development and the Chinese economy. Section 3 describes research methodology and data source. Then, the results and discussions are reported. The last section provides concluding remarks.

Infrastructure development and regional economy in China

China's economic growth has drawn much attention due to its booming economy with an annual GDP growth rate of about 10% in the past decade. However, the divergence of regional economic development in China appears to be very immense, with eastern China developed and western China lagged. Inequality in China has increased steadily and inexorably since the opening up. In 1983, China's overall Gini coefficient, measured on income, was 0.28, but increased to 0.447 in 2001 (Naughton 2007). The regional inequality has severely restricted the long-term sustainable development of the Chinese economy. Balanced growth is one of the major challenges faced by the government. To achieve this, China's central government puts forward "Go West and Central China Strategy", taking some preferential policies towards lagged areas in order to reduce inter-provincial inequalities. Among these, increasing public investment in transport infrastructure in central and western China is a key policy. As suggested by Cieslik and Kaniewsk (2004), transportation improvement can reduce transaction costs on trade in goods. Considering China's huge size, the availability of an appropriate infrastructure facilitates trade and knowledge-spillovers across regions, and hence is helpful for economic growth in lagged areas.

At the early stage of the economic reform, infrastructure development in many regions has lagged behind economic growth due to low government spending on infrastructure, decreased investment incentives of state-owned enterprises, and diminished capability of local government in mobilizing rural resources (Lin 2001). Since early 1990s, investment in infrastructure has been regarded as a major policy priority, resulting in a substantial increase in the share of transport in state fixed-assets investment.

In order to measure both quantity and quality of infrastructure, we select available attributes of each type of infrastructure, and then do a factor analysis. As indicated by Table 1, density of roadway and railway was used to characterize the quantity of land transport, and the share of highway[2] over total roadway in terms of length was used to characterize the quality of land transport infrastructure. We used area of airport lounge, length and PCN of runway[3] in the largest airport in a province, and number of airports over land area in the province, to measure both quality and quantity of airway transport

[2] Highway is defined as the roadway with high-quality pavement in order to ensure high-speed transportation. It is the highest level in terms of road conditions among three types of roadways in China (i.e., second-class roadway, first-class roadway, and highway).

[3] PCN is a measurement of the pavement condition of runway. It, together with the length of runway, determines what kind of aircraft an airport can service.

Table 1 Measurement of transportation infrastructure using factor analysis

Constructs/measured variables	Mean	Standard deviation	Factor loading	% of variance	Internal consistency
Land transportation					
Density of railway (= railway length/land area)	0.016	0.015	0.878	74.277	0.827
Density of road (= roadway length/land area)	0.427	0.325	0.854		
Quality of road (= highway length/total roadway length)	0.016	0.013	0.853		
Air transportation					
Area of airport lounge	56770.719	73357.425	0.865	68.691	0.845
Length of runway	3306.129	374.522	0.729		
PCN	67.597	17.516	0.908		
Density of airport(= the number of airports/ land area in a province)	0.037	0.055	0.802		
Water transportation					
Sum of number of berth/the distance to seaport	1.120	3.684	0.940	88.323	N/A
Sum of number of deep-berth/the distance to seaport	0.330	0.827	0.940		

Data source: China Statistical Yearbooks, 1999–2008 and Statistical Data on Civil Aviation of China, 1999–2008

infrastructure. With regard to water transportation, the number of berths and deep-water berths (which can berth high-tonnage ships), adjusted by the distance between the provincial capital cities and seaports, were taken to measure the quantitative and qualitative characteristics of water transport infrastructure.

The descriptive statistics of the above variables and the results of factor analysis[4] are reported in Table 1. The indicators are loaded onto their underlying constructs using principal components method, which is particularly appropriate for theory exploration and has been widely used because it is not required that the correlation or covariance matrix is nonsingular (Johnson and Wichern 2008). The Eigenvalues for these factors are above the 1.0 cut-off point, while the percentages of variation are all higher than 68%. The factor loadings are above 0.7, which is larger than the cut-off point 0.5 (Hair et al. 1998). Values of Cronbach's alpha in excess of 0.8 suggest that the measurement scales are sufficiently reliable.

Table 2 reports the development of transport infrastructure across regions in 2007. It indicates that the infrastructure in eastern region is much better than that in central and western region. This is due to greater demand for transportation, central government's priorities towards eastern region at the early stage of China's opening up, as well as the decentralization process, which gives local government larger autonomy to collect funds and construct infrastructure. The decentralization process increases regional inequality in

[4] Factor analysis is a technique used to reduce a large set of variables to a smaller set of underlying factors, which helps to detect the presence of meaningful patterns among the original variables. Factor analysis is used in this study to develop a comprehensive index that can capture both qualitative and quantitative characteristics of each type of transport infrastructure. In addition, it also helps to avoid the multicolinearity issue in the econometric model.

Table 2 Development of transport infrastructure across regions in 2007

	Land transport	Air transport	Water transport
Eastern China	0.849	0.773	0.731
Central China	−0.114	−0.454	−0.274
Western China	−0.702	−0.406	−0.488

The measures for land, air and water transport infrastructure are based on calculations in Table 1. The values are standardized and range between −1 and 1. A positive number indicates the score is greater than the mean value, while a negative number implies the reverse

The factor analysis in Table 1 is based on 10-year data during the study period. Table 2 only reports the results in 2007. Therefore, the values for each type of transport infrastructure do not sum up to 0 in Table 2

infrastructure endowment because the ability to raise funds mainly depends on local government revenues and their ability to negotiate with the central government (Demurger 2001). The eastern region with stronger ability to raise funds gains more from the decentralization process.

The government's priority towards various types of infrastructure is different across time. Before the economic reform, the Chinese government favored railway construction, which can carry a large volume of raw materials at lower cost. However, after 1990s, the government seems to put more efforts in roadway construction. As indicated by Fig. 1, from 1998 to 2007, the increase rate of road infrastructure was the highest. Airway infrastructure was improved substantially from 1998 to 2000, but slowed down since then. On the other hand, the development of waterway infrastructure was stagnant before 2004, but the investment has been growing fast afterwards. Table 3 reports the market share of various transport modes across regions in 2007. It indicates that roadway transport dominated the passenger transport market. In freight transport market, roadway and waterway accounted for more than 90% of the market in eastern region, while in central and western

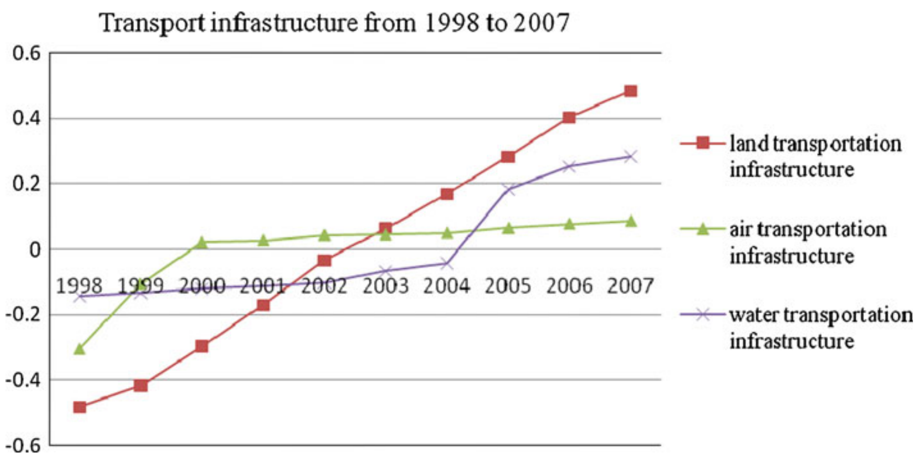

Fig. 1 Development of transport infrastructure from 1998 to 2007. *Note*: The measures for land, air and water transport infrastructure are based on calculations in Table 1. The values are standardized and range between −1 and 1. A *positive number* indicates the score is greater than the mean value, while a *negative number* implies the reverse. There is no unit after standardization

Table 3 Market share of various transport modes across regions in 2007

	Rail transport (%)	Road transport (%)	Water transport (%)	Air transport (%)
Passenger transport				
Eastern China	6.177	90.255	1.109	2.459
Central China	7.352	91.509	0.435	0.704
Western China	4.532	92.537	1.424	1.507
Freight transport				
Eastern China	8.085	71.220	20.629	0.066
Central China	22.182	72.420	5.392	0
Western China	16.377	80.190	3.411	0.022

Data source: China Statistical Yearbooks, 1999–2008 and Statistical Data on Civil Aviation of China, 1999–2008

China, roadway and railway played a dominant role. The market share of air transport was fairly low in both passenger and freight market across all regions during the period.

Econometric model and data source

The impact of infrastructure endowment on economic growth has been examined in the framework of new growth theory (Aschauer 1989; Barro 1990). Better transport infrastructure helps to reduce transaction costs on trade, and leads to pecuniary and allocative externalities (Banister and Berechman 2000). It is easier for entrepreneurs to adopt new technologies where the infrastructure is developed. Following previous studies (e.g., Demurger 2001; Cieslik and Kaniewsk 2004), we assume that transport infrastructure is an input that appears in the production function. We estimate a growth model by using Barro-type framework, which allows us to test conditional convergence.[5] The growth equation at time t in region i is give as follows:

$$g_{it} = a_{it} + \alpha \ln(q_{i,t-1}) + \beta k_{it} + \gamma l_{it} + \phi h_{it} + \tau t_{it} + \varepsilon_{it} \tag{1}$$

where g represents the annual growth rate of real GDP per capita; q represents GDP per capita; k, l and h denote physical capital, labor force and labor quality respectively; t is infrastructure endowment in the region; ε is the error term, and $a, \alpha, \beta, \gamma, \phi, \tau$ are coefficients to be estimated.

Panel data are used from a sample of 31 provinces between 1998 and 2007.[6] Standard fixed and random-effects techniques will be utilized to estimate Eq. 1. Compared to simple

[5] An implicit assumption for new growth theory by Barro (1990) is that the market structure is competitive. The authors believe that this assumption is held in China at the macroeconomic level. According to the first economic census in China, there were 3.25 million enterprises (among them, only 0.192 million were state-owned), and 214.604 million workers at the end of 2004. The huge amount of enterprises, employees and consumers implies a competitive market. Furthermore, the importance of state-owned enterprises becomes weaker in the Chinese economy. Except several strategic sectors (such as telecommunications, oil and petroleum), non-state-owned enterprises have become the driving force and dominant power in most sectors.

[6] The data after 2007 were not available when we did this research. In addition, The Chinese government invested heavily in infrastructure to deal with the Asian financial crisis in 1997. To remove the outliers, we selected the year of 1998–2007 as the study period of this research. Another reason for selecting this study period is that some key variables are not available before 1997.

Table 4 Definitions and descriptive statistics of variables

Variables	Definition[a]	Unit	Mean	Std. deviation
Land transport	A comprehensive index based on density of railway, roadway, and quality of roadway	Standardized using factor analysis	0	1
Air transport	A comprehensive index based on area of airport lounge, length and PCN of runways, and density of airport	Standardized using factor analysis	0	1
Water transport	A comprehensive index based on sum of number of berth/the distance to seaport, and sum of number of deep-berth/the distance to seaport	Standardized using factor analysis	0	1
Per capita GDP	GDP per capita	Chinese yuan per person	5754.913	4444.329
Per capita investment	Real capital stock net of transportation capital per capita	Chinese yuan per person	2431.041	1876.436
Population density	Ratio of total population to land area	10,000 persons/km^2	0.038	0.049
Labor quality	Ratio of population with college-degree or above to total population	Percentage (%)	5.3	4.2

Please refer to Table 1 for the detailed information on definitions of land, air and water transport

OLS methods, panel data model reduces the effects of the omitted variable bias that may arise in cross-section regressions. This is particularly important when we use regional data, since many regional characteristics can not be properly identified. The data used in this research were from two sources, including various issues of China Statistical Yearbook (State Statistical Bureau 1999–2008), and Statistical Data on Civil Aviation of China (Civil Aviation Administration of China 1999–2008).

The dependent variable (g_{it}) was measured by annual growth rate of real GDP per capita. Following previous studies (e.g., Roller and Waverman 2001), real capital stock net of transportation capital per capita was used as a proxy for investment (k_{it}). Per capita GDP and per capita investment were converted into fixed prices.[7] Labor force (l_{it}) was proxied by population density, and human capital (h_{it}) was measured by the share of population with college-degree or above in a province. The measures of transport-related variables were based on the calculations of factor analysis (see Table 1), which allows us to capture both quantity and quality of infrastructure endowment, and compare the impacts of various types of transport infrastructure. Definitions and descriptive statistics of the variables are reported in Table 4.

Results and discussions

General estimation results

Table 5 reports the estimation results based on pooled OLS, random-effect and fixed-effect panel data model, respectively. To control for possible heterogeneity, the estimated

[7] The GDP deflators were obtained from the World Bank official website. Per capita investment at current prices was obtained from China Statistical Yearbook.

Table 5 Estimation results

	Pooled OLS (1)	Random effect (2)	Fixed effect (3)	Fixed effect, 2SLS (4)	Fixed effect, 2SLS (5)
Constant	9.701*** (26.70)	9.733*** (21.94)	7.727*** (7.05)	8.223*** (6.14)	5.995*** (3.91)
Per capita GDP (−1)	−0.00007 (−1.24)	−0.00015*** (−3.35)	−0.00038*** (−6.36)	−0.00044*** (−4.74)	−0.00006 (−0.46)
Per capita investment	17.383*** (7.91)	18.399*** (12.23)	21.117*** (11.15)	22.099**** (7.05)	18.722*** (5.91)
Population density	−17.654*** (−3.56)	−26.499*** (−4.35)	21.359 (0.68)	13.790 (0.26)	−9.974 (−0.18)
Labor quality	−26.696*** (−5.81)	−7.807 (−1.21)	32.455*** (3.88)	35.016*** (3.37)	29.829*** (3.13)
Land transport	0.554*** (2.65)	0.938*** (3.68)	1.331*** (3.92)	1.456*** (2.64)	2.757*** (4.02)
Air transport	−0.427** (2.40)	−0.287 (−1.17)	0.092 (0.28)	1.846 (0.88)	1.425 (0.72)
Water transport	0.184*** (1.42)	0.318* (1.74)	0.615*** (3.01)	0.938*** (4.12)	−9.015** (−2.48)
Square of land transport					−1.038*** (−5.34)
Square of air transport					−0.289 (−0.65)
Square of water transport					1.234** (2.56)
Hausman test		30.40***			
No. of observations	310	310	310	279	279
R-square	0.580	0.675	0.782	0.698	0.669
Hansen J-statistic of overidentifying restriction (p-value)				2.851 (0.091)	1.015 (0.314)

(The abbreviation 2SLS indicates two-stage least-squares. Instruments are one-year lagged values of land, air and water infrastructure, one and two-year lagged values of real per capita GDP, and other non-transport variables in Eq. 1

*, **, *** Denote significance at the 10, 5 and 1% levels, respectively. t-statistics are in parentheses. The estimated standard deviations have been corrected using a White matrix

standard deviations have been corrected using a White matrix. Although pooled data and simple OLS assume unrealistically that individual effects are constant and equal across regions, we use the results as a point of reference. Fixed effects model relax the assumption of equality of constant terms, while random effects model further assume that individual effects might be randomly generated. The use of different panel data techniques is important to extract as much information as possible from the data. It is also an important way to test the robustness of the estimation results. Hausman statistic of 30.40 indicates that the fixed-effect model (model 3) is preferred.

There is possible causality issue between transportation infrastructure and economic growth. The improvement of transportation infrastructure may cause economic growth through reduction of travel time and cost, increase of traffic volume, and induced spatial redistribution of economic activities (Banister and Berechman 2000). On the other hand, higher economic growth leads to more government revenue and greater demand on good infrastructure, which stimulates further improvement of transport conditions. Therefore, the causality direction can run both ways, and results in endogeneity problem. Following previous studies (e.g., Demurger 2001), a two-stage least-squares (2SLS) procedure[8] (that is, a fixed-effects panel data model with instrumental variables) is used to deal with the possible endogeneity issue.[9] We instrument the transport-related variables with their own one-year lagged values, one and two-year lagged values of per capita GDP, and other exogenous variables[10] in Eq. 1. As shown in column 4 of Table 5, Hansen's *J*-statistic of 2.851 is insignificant at 5% level,[11] indicating that the instruments are acceptable.

The subsequent interpretations and further analyses will be based on the fixed-effect (2SLS) regression results, reported in column 4 of Table 5. The estimation results show that land transport infrastructure has significant impact on economic development. The coefficient for land transport equals to 1.456, indicating a strong impact of land transport. Table 5 also shows that water transport infrastructure has significant and positive effect on economic growth, with coefficient estimate of 0.938 and *t*-value of 4.12. However, the impact of air infrastructure is insignificant. To conclude, after taking both quantitative and qualitative characteristics of transport infrastructure into consideration, we find that land and water transport contributes significantly to regional economic growth, which is consistent with the previous studies (e.g., Demurger 2001; Gunasekera et al. 2008). However, airway transport has insignificant impact, in contrast to the findings by Yamaguchi (2007). It should be noted that in this research, we can only identify the overall impact of each type of transport infrastructure to economic growth, but cannot separately examine the role of quantitative and qualitative attributes of transport infrastructure.

The above estimation results show a clear picture that in China, land transport infrastructure has greatest impact on economic development, followed by water transport, while the impact of airway transport infrastructure is insignificant. This picture is consistent with the market share of various transport modes across Chinese regions. As shown by Table 3, land transport (including both roadway and railway) plays a dominant role in both passenger and freight transport market, followed by water transport, while the market share of air transport is very low. One possible interpretation for the above estimation results is that since land transport dominates the market, an improvement of land transport condition can generate greater impacts in terms of travel time and cost reduction, traffic volume increase, spatial redistribution of economic activities, and hence has strongest influence on economic growth.

We now turn to the relationship between non-infrastructure variables and economic growth. As expected, per capita investment and labor quality have significant and positive effects on economic growth, confirming the impact of physical capital and labor quality. On the other hand, population density has insignificant effect on economic growth, as shown in column 4 of Table 5. Population density was used to measure the availability of labor force, but it may capture crowding effect in a province. The insignificant coefficient for population density suggests that the crowding effect offsets the labor-availability effect. Lagged log value of real GDP per capita was included in the model in an attempt to test for conditional convergence. The coefficient is found to be negative and significant, indicating

[8] We use Stata routine *xtivreg2* developed by Schaffer (2007).

[9] The 2SLS fixed-effects estimation is a standard method to deal with causality issue in the literature.

[10] As usual, all other variables except transport-related variables are treated as exogenous.

[11] Hansen's J-statistics are insignificant at 10% level in column 5 of Table 5, columns 4 and 5 of Table 6.

that provinces with lower levels of GDP per capita tend to grow at a higher rate. Therefore, the result here supports the conditional convergence hypothesis, although there is no evidence of absolute convergence between provinces.

The relationship between transportation and growth is likely to be non-linear. Following Datta and Agarwal (2004), we include the square of the transport infrastructure variables into the model to examine the nature of returns to scale of transport infrastructure. Column 5 in Table 5 reports the estimation results. The significant and negative coefficient estimate of the square of land transport indicates diminishing returns. In another words, the effect of land transport infrastructure is inversely related to its prior level. This implies that land transport infrastructure contribute more to economic growth in provinces with poor land transport infrastructure. This result is consistent with previous studies (e.g., Demurger 2001). The estimation results also show that there is a diminishing return to air transport infrastructure, but the effect is insignificant. The significant and positive coefficient estimate of the square of water transport, together with the negative coefficient of water transport, suggests that the relationship between water transport infrastructure and economic growth is U-shaped. A possible interpretation is due to huge amount of setup cost of water transport infrastructure. The investment in water transport infrastructure will contribute positively to economic growth only after the investment scale exceeds a threshold level. Therefore, although column 4 shows that both land transport and water transport have positive contribution to economic growth, column 5 indicates that the relationships between the two types of transport infrastructure and economic development are very different. Further research should be done to identify the exact reasons behind the divergence.

Robustness tests

Table 5 provides some evidence for robustness of our models by applying a variety of methods. To estimate Eq. 1, OLS, 2SLS, standard fixed and random-effects panel data techniques have been utilized. It shows that except pooled OLS, the results based on other estimation techniques are quite consistent, especially the estimations computed through fixed-effect (model 3) and fixed-effect 2SLS procedure (model 4). One possible reason for the inconsistent estimations by pooled OLS is its unrealistic assumption that individual effects are constant and equal across regions.

In order to further test the robustness of models, we apply the same specification to subsamples of our dataset. One concern is that in China, some provinces (including Inner Mongolia, Tibet and Xinjiang) are much larger than others in terms of land area, but are associated with much poorer transport infrastructure due to the weak demand and geographical reasons. For the robustness test, we adjusted the sample by excluding the above three provinces. The estimation results in Table 6 show that despite differences in the number of observations, coefficient estimates are quite consistent in terms of magnitude and significance. Although the coefficient for population density is positive in Table 5 but becomes negative in Table 6, both tables show that its impact is insignificant. Taken together, the above tests lead us to conclude that our results are quite robust, and not merely a result of the methods and sample chosen.

The impact of infrastructure across regions

One of the important characteristics of the Chinese economy is unequal development across regions: the developed eastern region, the developing central region, and the lagging

Table 6 Robustness test: results with the sample excluding Inner Mongolia, Tibet, and Xinjiang province

	Pooled OLS (1)	Random effect (2)	Fixed effect (3)	Fixed effect, 2SLS (4)	Fixed effect, 2SLS (5)
Constant	10.223*** (32.01)	10.194*** (26.36)	9.145*** (7.74)	9.869*** (6.77)	6.529*** (4.01)
Per capita GDP (−1)	−0.00001 (−0.35)	−0.00006 (−1.34)	−0.00028*** (−4.64)	−0.00034*** (-4.23)	−0.000006 (−0.06)
Per capita investment	13.729*** (8.59)	14.792*** (9.14)	16.647*** (7.89)	17.214*** (6.56)	16.326*** (6.29)
Population density	−21.174*** (−5.37)	−26.271*** (−5.29)	−13.566 (−0.44)	−25.176 (−0.52)	−9.621 (−0.20)
Labor quality	−29.515*** (−6.95)	−21.473*** (−3.70)	25.599*** (3.04)	27.146*** (2.84)	20.050** (2.34)
Land transport	0.870*** (4.61)	1.109*** (4.52)	1.749*** (5.08)	2.096*** (3.86)	2.899*** (4.69)
Air transport	−0.199 (−1.24)	−0.183 (−0.87)	0.077 (0.25)	1.915 (0.91)	1.171 (0.60)
Water transport	0.146 (1.27)	0.223 (1.28)	0.542*** (2.80)	0.817*** (3.90)	−7.623** (−2.32)
Square of land transport					−1.015*** (−5.52)
Square of air transport					−0.290 (−0.70)
Square of water transport					1.033** (2.37)
Hausman test		30.40***			
No. of observations	280	280	280	252	279
R-square	0.577	0.653	0.713	0.689	0.669
Hansen J-stat of overidentifying restriction (*p*-value)				2.512 (0.113)	0.803 (0.370)

The abbreviation 2SLS indicates two-stage least-squares. Instruments are one-year lagged values of land, air and water infrastructure, one and two-year lagged values of real per capita GDP, and other non-transport variables in Eq. 1

*, **, *** Denote significance at the 10, 5 and 1% levels, respectively. *t*-statistics are in parentheses. The estimated standard deviations have been corrected using a White matrix

western region. Since the late 1990s, the government has put much effort to deal with the problem of regional inequality, by taking "Go Western and Central China Strategy". One of the most important policies taken by the government is to develop infrastructure in Western and Central China. Some policy-makers and researchers argue that construction of infrastructure in lagged area may contribute more to economic development and reduce regional inequality (e.g., Demurger 2001). To identify the impact of infrastructure on regional economic growth, we classify all provinces into three regions based on their geographic location. These are Eastern China (Beijing, Tianjin, Hebei, Liaoning, Shanghai, Jiangsu, Zhejiang, Fujian, Shandong, Guangdong, and Hainan), Central China (Shanxi, Jilin, Heilongjiang, Anhui, Jiangxi, Henan, Hubei, and Hunan), and Western China (Inner Mongolia, Guangxi, Chongqing, Sichuan, Guizhou, Yunnan, Tibet, Shaanxi, Gansu, Qinghai, Ningxia, and Xinjiang). A retrospective analysis is used to analyze economic

Table 7 Contribution to regional economic growth gaps relative to the national mean

	Growth (2SLS)	Land transport	Air transport	Water transport	Initial GDP	Investment	Population density	Labor quality	Fixed effect
Eastern China	**0.647**	**1.249**	**1.421**	**0.655**	−1.542	**2.919**	**0.468**	**0.830**	**−3.693**
Beijing	0.276	3.289	4.583	0.161	−3.829	9.397	0.664	5.443	−15.284
Tianjin	2.011	3.504	0.180	2.024	−2.662	5.422	0.727	1.926	−6.239
Hebei	−0.168	0.504	−0.540	−0.144	0.235	−0.804	−0.026	−0.484	0.958
Liaoning	−0.106	0.759	−0.326	−0.156	−0.514	1.301	−0.120	0.653	−1.255
Shanghai	0.307	3.292	6.661	3.019	−6.214	10.958	3.209	3.372	−17.205
Jiangsu	1.462	0.764	1.598	−0.015	−1.001	2.045	0.478	−0.134	−1.252
Zhejiang	1.325	0.310	1.411	0.155	−1.466	4.087	0.122	−0.059	−1.836
Fujian	0.238	−0.284	1.485	−0.295	−0.618	−0.060	−0.119	−0.507	1.471
Shandong	1.499	1.006	0.260	−0.044	−0.391	0.853	0.304	−0.428	0.049
Guangdong	1.187	0.143	−0.080	2.572	−1.108	0.676	0.097	−0.260	0.477
Hainan	−0.917	0.449	0.396	−0.069	0.609	−1.765	−0.191	−0.386	−0.512
Central China	**−0.487**	**−0.202**	**−0.811**	**−0.270**	**0.670**	**−1.884**	**−0.115**	**−0.364**	**1.806**
Shanxi	−0.268	0.077	−0.412	−0.262	0.769	−1.695	−0.225	−0.254	0.916
Jilin	−0.054	−0.442	−2.139	−0.320	0.440	−0.618	−0.318	0.212	2.701
Heilongjiang	−1.039	−1.028	−0.360	−0.386	0.082	−1.758	−0.406	−0.139	3.074
Anhui	−0.953	0.057	−1.448	−0.127	1.002	−2.425	0.101	−0.770	1.567
Jiangxi	−0.311	−0.234	−0.921	−0.251	0.969	−2.161	−0.165	−0.574	1.916
Henan	0.175	0.508	0.647	−0.234	0.783	−2.187	0.264	−0.731	0.328
Hubei	−0.666	−0.188	0.001	−0.278	0.504	−1.741	−0.083	−0.157	0.801
Hunan	−0.782	−0.370	−1.860	−0.305	0.808	−2.487	−0.090	−0.496	3.148
Western China	**−0.268**	**−1.010**	**−0.761**	**−0.421**	**0.967**	**−1.420**	**−0.352**	**−0.519**	**2.181**
Inner Mongolia	3.857	−1.522	−1.727	−0.325	0.435	0.937	−0.489	0.001	5.992
Guangxi	−0.511	−0.488	−1.855	−0.338	1.081	−2.862	−0.241	−0.786	3.853
Chongqing	−0.424	−0.200	−1.654	−0.422	0.827	−0.907	−0.011	−0.752	1.736

Table 7 continued

	Growth (2SLS)	Land transport	Air transport	Water transport	Initial GDP	Investment	Population density	Labor quality	Fixed effect
Sichuan	−0.355	−0.940	0.559	−0.437	1.001	−2.284	−0.278	−0.766	1.530
Guizhou	−0.979	−0.774	−0.352	−0.413	1.588	−3.403	−0.213	−0.863	1.779
Yunnan	−2.180	−0.919	−0.422	−0.452	1.120	−2.527	−0.365	−1.043	1.321
Tibet	0.695	−2.006	−0.325	−0.513	1.032	−0.547	−0.514	−1.559	4.039
Shaanxi	−0.243	−0.448	−0.804	−0.354	1.003	−1.664	−0.270	−0.065	1.219
Gansu	−1.075	−1.300	−0.241	−0.433	1.266	−2.831	−0.438	−0.701	2.185
Qinghai	0.060	−1.809	−1.580	−0.446	0.893	−0.562	−0.507	−0.336	3.485
Ningxia	−0.428	−0.048	−1.023	−0.398	0.950	−0.197	−0.398	−0.102	−0.413
Xinjiang	−1.631	−1.663	0.286	−0.514	0.405	−0.192	−0.501	0.748	−0.551

The above results are based on the fixed effect panel data model (2SLS) in Table 4

The bold numbers are computed by averaging the values of all provinces included in the region growth of Chinese regions in light of their infrastructure. We firstly compute the gap between the predicted per capita GDP growth rate of each province and the national average, and then decompose this gap into the independent variables.

The estimation results are presented in Table 7. It shows that eastern China has had much higher per capita GDP than the national average level. The above-average performance comes from a relatively developed transport infrastructure as well as higher investment and labor quality. Beijing, Tianjin and Shanghai are the biggest beneficiary in developing land transport network, while water transport contributes most to economic growth in Shanghai, Tianjin and Guangdong province. Per-capita GDP growth rate in Central and western China is lower than the national average. Poor transport network has affected negatively their economic performances. For instance, four remote provinces (Tibet, Qinghai, Xinjiang and Inner Mongolia) have suffered most from poor land transport conditions. The above results suggest that in the past decade, the lack of adequate transport infrastructure endowment is an important reason behind lagged economic development in Western and Central China.

Conclusions

This article investigates the impact of infrastructure on economic growth in China. Using panel data from a sample of 31 Chinese provinces from 1998 to 2007, the estimation results provided strong evidence that differences in transport infrastructure, physical capital and labor quality did account for a significant part of the observed variation in the economic growth of provinces. Both land transport (including roadway and railway) and water transport infrastructure had significant impacts, but the contribution of airway transport infrastructure was weak. Furthermore, land transport infrastructure contributed more to economic growth in provinces with poor land transport conditions, while the investment in water transport infrastructure contributed positively to economic growth only after the investment scale exceeded a threshold level. The above results were robust to a variety of alternative methods, the exclusion of possible outliers, and consideration of endogeneity.

We also found that various modes of infrastructure contributed to economic performance differently across regions. Improved transport conditions (including land, and water transport) played an important role in economic success in eastern region. In lagged western region, poor land infrastructure were important factors behind its weak economic performance. The above results suggested that economic policies that improve transport infrastructure had a nonnegligible impact in promoting per capita income convergence among Chinese regions. Moreover, expanding and upgrading the network of land transportation in lagged areas might have higher growth payoff, and would be particularly useful to allow for the development of efficient market and knowledge diffusion in China.

The relationship between China's transport improvement and its economic performance is worth examining, not only because the formulation of its own future policies may depend on these experiences, but also because China is the stellar example for other developing countries to emulate. The results in this article imply that in a developing country like China, the improvement of transport conditions does play an important role in developing regional economy, and uneven distribution of transport infrastructure results in regional disparities. Of course, there is a need for future research to establish the validity of the findings reported here in different country and temporal contexts. Due to data limitation, the exact economic process through which transportation improvement induces economic growth is left for future research agenda as well.

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