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HIGHWAY ACCESS AND HUMAN CAPITAL INVESTMENTS IN THE RURAL REGIONS OF THE PEOPLE'S REPUBLIC OF CHINA

Han Li, Guochang Zhao,
and Zhaoyue Teng

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Han Li is a professor of economics, Guochang Zhao is an associate professor of economics, and Zhaoyue Teng is a PhD candidate at the Research Institute of Economics and Management of the Southwestern University of Finance and Economics.

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Please contact the authors for information about this paper.

Email: guochangzhao@swufe.edu.cn

Asian Development Bank Institute
Kasumigaseki Building, 8th Floor
3-2-5 Kasumigaseki, Chiyoda-ku
Tokyo 100-6008, Japan

Tel: +81-3-3593-5500
Fax: +81-3-3593-5571
URL: www.adbi.org
E-mail: info@adbi.org

Abstract

The People's Republic of China (PRC) has made massive investments since the late 1990s in highway infrastructure, connecting its rural and urban regions. In this paper, we study the impact of highway investments on the educational choices in rural PRC. Because enhanced connectivity facilitates people's move, the poor in rural regions can gain access to a larger labor market, altering the opportunity costs of educational investment. Using 2005 population census data, we find that highway access significantly reduces the enrollment rate of senior high schools in rural PRC by 9%, but it does not affect the enrollment rates of both junior high and elementary schools, whose students are typically under the age of 16. This negative effect is more significant on students in rural regions than in urban regions.

Keywords: connectivity, educational investment, enrollment rate, highway investment, transport infrastructure, People's Republic of China

JEL Classification: R41, R42, I26

Contents

1. INTRODUCTION

Poor transport infrastructure is considered a major obstacle hindering the economic growth of developing economies. Because roads and other transport utilities reduce transportation costs of both goods and people, it facilitates trade flow among regions, which leads to better integration and higher well-being of an economy. Thus, policy makers tend to make transport infrastructure investments a priority area to boost regional development and reduce poverty.

There is a large body of literature on the economic impact of transport infrastructure investments. Many early studies find a positive relation between economic growth and transport infrastructure stock (Antle 1983; Aschauer 1989; Binswanger et al. 1987; Binswanger 1989; Easterly and Rebelo 1993; Baffes and Shah 1998; Morrison and Schwartz 1996; Cohen and Morrison Paul 2004; Mamuneas and Nadiri 1996). Most of these studies specified an aggregated production function and included road stock as an input to estimate its contribution to the output growth. Yet one limitation of these studies is the reverse causality problem. On the one hand, better transport infrastructure may facilitate economic growth. On the other hand, a better economy also demands more transport infrastructure.

More recent studies have used detailed geographic data of transport infrastructure and micro-level data to identify the channels through which the transport infrastructure affects regional economic growth. To estimate the causal effect of transportation improvement, ordinary least squares (OLS) regression comparing treated and untreated locations faces an endogeneity problem. The main empirical challenge is that locations in the treatment group covered by transport networks are not randomly selected. In particular, many studies find that locations with greater economic potential are more likely to be connected by transport infrastructure. With detailed geographic information, there are few approaches to address this selection problem. First, because old routes are less likely to be associated with current economic and social conditions of locations, some researchers have used historical routes as instrumental variables. Duranton and Turner (2012) used the US railroad network in 1898 and the routes of major expeditions of exploration of the US between 1535 and 1850 as instruments for the current US interstate highway network. Baum-Snow et al. (2017) used Chinese road and rail networks in 1962 as an instrument for road and rail networks after 2000. Second, some other studies have adopted the inconsequential units approach to address this selection issue. Transport infrastructure often connects large cities with smaller units such as counties and villages lying between them. Although these large cities are selected for certain purposes, smaller units lying on the route are often the result of route planning. In other words, they are inconsequential to the choices of routes. Thus, by restricting the analysis to regions between large cities, researchers can largely mitigate the selection problem. Using this approach, Chandra and Thompson (2000) studied the effect of access to the interstate highway system on rural counties between large cities in the US. In this paper we will use the inconsequential units approach, similar to Chandra and Thompson (2000).

With the identification strategies mentioned above, a growing body of recent literature has studied the causal effect of transport infrastructure improvements. Some researchers have studied the effect of the highway network on the redistribution of population. Baum-Snow (2007) finds that each radial segment of interstate highway network in 1950 leads to a roughly 9% decrease in central city population in the US. And the development of the interstate highway system can explain almost the entire decline in old central city population densities during that period. Baum-Snow et al. (2017) also find that each radial highway causes a decline of central city population in the PRC between 1990 and 2010 by 4%. Chandra and Thompson (2000) investigated the effect of the interstate highway system on 185 US counties connected by highway after 1969, and 391 neighboring nonmetropolitan counties that are unconnected. By restricting attention to nonmetropolitan counties, a number of researchers have examined the effect of these changes on employment (Michaels 2008); on household income (Chandra and Thompson 2000; Burgess et al. 2015; Donaldson and Hornbeck 2016); on trade flows (Bougheas et al. 1999; Baier and Bergstrand 2001; Clark et al. 2004; Hummels and Skiba 2004; Feyrer 2009; Storeygard 2016; Duranton et al. 2014; Donaldson 2018); on regional development (Banerjee et al. 2012; Faber 2014); and on urbanization (Duranton and Turner 2012; Baum-Snow 2007; Garcia-Lopez and Muniz 2013; Baum-Snow and Hartley 2015; Baum-Snow et al. 2017).

However, research studies on how transport affects rural development are still rare. Some studies identify a positive effect of transport infrastructure on the growth of real income in rural regions. Improved roads and other transport infrastructure enhance rural households' access to markets and technology, which improves productivity of both farming and non-farming activities (Binswanger and Khandker 1993; BIDS 2004; Levy 1996; Adamopoulos 2011). It can reduce poverty in the rural region through higher wages, lower input and transportation costs, and higher output prices (Khandker et al. 2009). Better roads can also benefit farmers through adoption of new technologies, such as chemical fertilizer and hybrid seeds (Aggarwal 2018).

In this research, we examine whether highway access can affect schooling decisions of students in the PRC's rural regions. Human capital accumulation is an important determinant of long-term productivity growth, and many public policies in developing economies aim to improve rural education. However, access to roads can alter rural households' opportunity costs of human capital investments. On the one hand, better transport infrastructure may reduce students' travel costs to school (Muralidharan and Prakash 2017), which improves students' school attendance. However, on the other hand, greater transport connectivity can also expose students to more job opportunities in the present, as they now can drop out of school to join the labor market.

Using data from the 2005 mini-census in the PRC, we calculated the school enrollment of primary schools, junior high schools, and senior high schools between 1999 and 2004, in both the PRC's counties and municipal districts, which mainly comprise rural and urban regions respectively. We find that highways have a negative effect on the high school enrollment rate in counties: once a city/prefecture is connected with a highway, the high school enrollment rate in its counties drops by 9% or correspondingly 3.34 percentage points. Given that the PRC's high school enrollment rate in counties is 36% overall, this is not a trivial effect. Yet highway connectivity has no significant effect on the enrollment rate of both junior high and elementary schools in the counties. Because both levels of schooling are required by the PRC's Law of Compulsory Schooling (LoCS) and students at these stages are younger than 16, the PRC's legal minimum working age, it is not surprising that enrollment rates are not responding to the change in opportunity costs of education brought by the highway connectivity.

Our predictions also imply that the effect of highway connectivity on the school enrollment rate in urban regions should be smaller. This is because urban students' benefits of attending high school education could be larger than for rural students, as they are more likely to work in urban cities with well-paying jobs due to their advantage of having urban Hukou.[1] And our empirical results show that highway connectivity has

[1] Hukou is a household registration system, which is connected to all social programs provided by the government, such as education, pension, medical insurance and so on.

no significant effect on the enrollment rate of elementary, junior high, and senior high schools in urban regions.

The rest of the paper is structured as follows. Section 2 presents our empirical model, Section 3 introduces the data and variables, Section 4 reports and discusses the results, and Section 5 concludes.

2. MODEL SPECIFICATION AND IDENTIFICATION STRATEGY

In this study, we are interested in the impact of highway access to investment in human capital, measured by school enrollment, in rural areas. Specifically, we are using the following fixed effect model:

$$log(SE_{it}) = \beta_0 + \beta_1 HW_{it} + X_{it}'\beta_2 + u_t + u_i + \varepsilon_{it} \quad (1)$$

where SE_{it} is the school enrollment rate of region *i*, either a city or a prefecture[2] (hereafter called city generally for simplicity), in year *t*; HW_{it} is a dummy variable indicating whether region *i* has connected to the highway in year *t*, 1 for yes and 0 for no; X_{it}' is a vector of control variables including the log of gross regional product (GRP) per capita, number of high schools per 10,000 persons, teacher–student ratio in secondary education, proportion of industrial and tertiary sectors to the GRP, log of railway passenger volume per capita, and log of passenger volume by other transportation methods; u_t are the year fixed effects such as the nationwide education policy change; u_i are city fixed effects such as their initial economic endowments; and ε_{it} is the idiosyncratic error term, which is uncorrelated to the explanatory variables.

One might question the exogeneity of the variable of highway connection, namely HW_{it}. After all, highways are not randomly routed. Thus one identification issue here is the nonrandom placement of transport infrastructure, i.e., the fact that placement of highway routes can be selective. Whether a region is connected with highways is very likely to be associated with the region's socioeconomic conditions. For example, highways are more likely to be built in regions with greater growth potential. Hence, this could cause an endogeneity problem. On the one hand, highways could affect regions' economic outcomes. On the other hand, regions' socioeconomic conditions can also affect their likelihood of being connected. The city fixed effects in our model setting can partially address this issue as they can capture some of the regions' initial conditions and endowments. In addition, following the previous literature, we will also use instrumental variables to address this endogeneity problem.

As mentioned in the previous section, highway connection reduces the transportation costs of both goods and people, and thus it may alter the opportunity costs of human capital investments. Although better transport infrastructure may facilitate children's travel to school, it can expose the youth to greater job opportunities. This is because better access to transport infrastructure reduces trade costs, which enhances the gains from local economic trade (Donaldson 2018). Hence it can create more jobs. Furthermore, lower travel cost for passengers can facilitate people's move (Morten and

2 The PRC's local governments consist of a three-tier system: (1) provincial-level division, including provinces, autonomous regions, municipalities directly under the central government, and special administrative regions; (2) city-level divisions, including prefectures, prefectural-level cities, and autonomous prefectures; and (3) county-level divisions, including counties, municipal districts, county-level cities, and autonomous counties. At the third tier, municipal districts comprise mainly urban regions, while the others comprise mainly rural regions.

Oliveira 2016). Youth can have better access to the job market elsewhere. Therefore, the opportunity cost of education for youths increases. We thus expect that the coefficient of connection to the highway is **negative in our model specifications**.

In addition, there are a few more testable implications here. First, the effect of the labor market shock brought by the highway connection will be trivial on the enrollment of students at elementary and junior middle schools. This is because students at these two stages are younger than 16, which is the minimum age required by law for a person to work, and both levels of education are mandated by the PRC's LoCS. Thus, the opportunity costs of schooling are largely unchanged. Second, for urban households that have higher income, they may value education more compared to rural households. Therefore, even though highway access increases the opportunity cost of education, the effect should be much lower on urban residents than on rural residents. The effect on urban residents may even be positive, because access to the highway may increase the return to education, and thus a large proportion of urban households with a higher discount rate may decide to invest more in children's education. In sum, we expect the effect of highway connectivity should have the **largest negative** effect on the enrollment ratios of high schools among rural residents.

3. DATA

3.1 Data and Variables

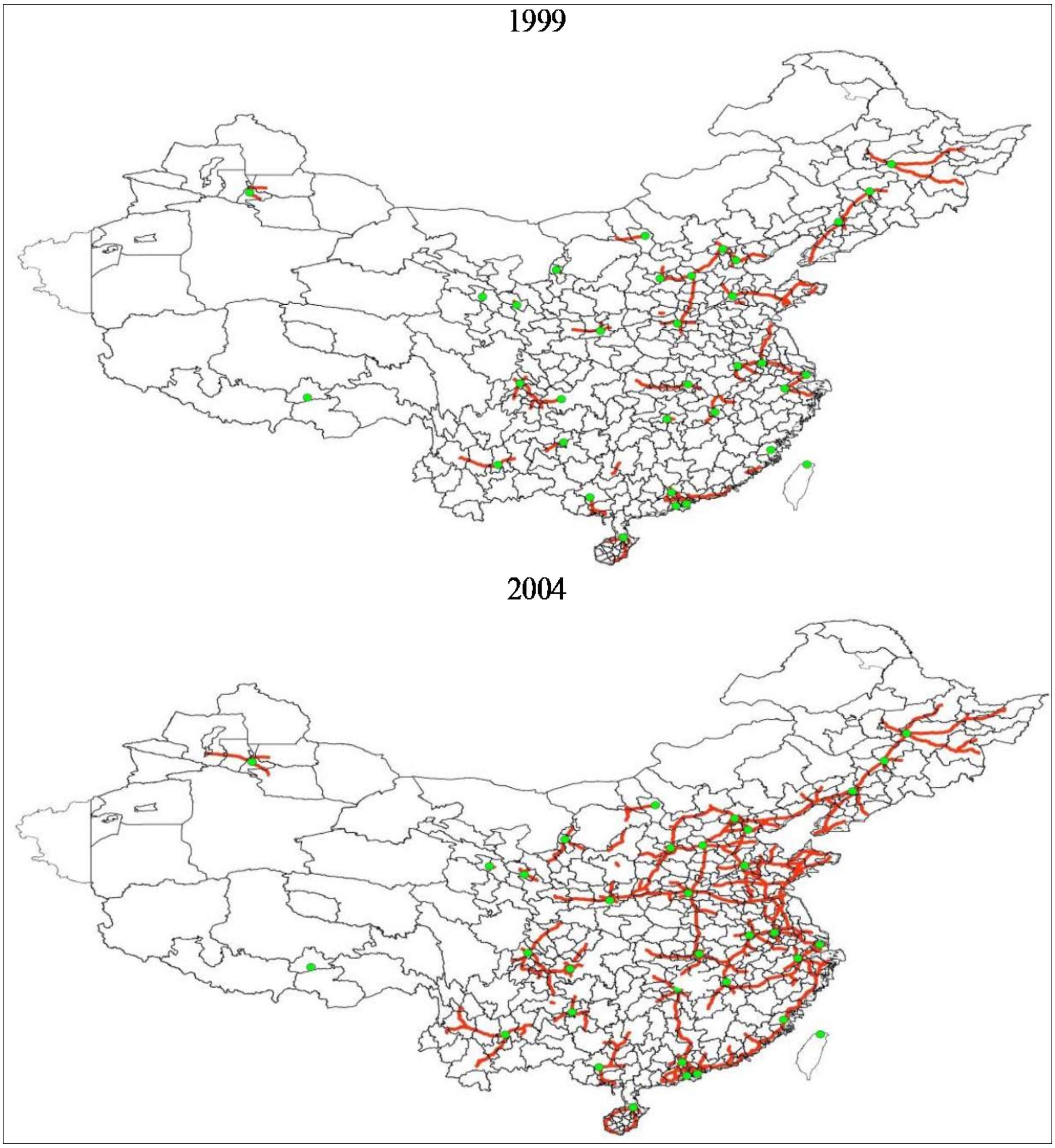
Highway connectivity and school enrollment of each city are the two key variables in this study. Digitalized highway data are based on highway maps published by the China Communications Press, the official publisher of PRC maps. This data contains the specific geographic information for the PRC's highway network on an annual basis. Figure 1 shows the highway network in 1999 and 2004. In 1999 only a few cities were connected to the highway. Only five years later, the PRC's highway system expanded substantially and formed a thick network covering a large territory in eastern PRC.

The PRC mainly made its highway investments after 1998. Before 1998, the majority of areas had no access to the highway. In addition, our dependent variable, the rate of school enrollment, was calculated based on data from the 2005 mini-census, while the school starting age and the education system are not exactly the same across the whole country, which leads to a substantial drop in school enrollment in 2005. **Thus, we restricted our sample to the period from 1999 to 2004.**

School enrollment was calculated based on the 1% population survey in 2005 (hereafter the 2005 mini-census). This data has detailed demographic information including individuals' current education level and birth year. We thus calculated the enrollments of the elementary, junior, and senior high schools in each region between 1999 and 2004. Thus, our final sample includes six years' observations, and they correspond to 18 cohorts.

Specifically, taking primary school enrollment in 2000 as an example, we first assumed that all children start schooling at age 6. Then the primary school enrollment rate in 2000 in a particular city was calculated as the ratio of the number of people who were born in 1994 and at least have a primary school education to the whole birth cohort size in that city. In most areas of the PRC, the duration of primary school and junior high school is six years and three years, respectively. Thus, the enrollment rate of junior and senior high schools in 2000 was based on a similar calculation for the 1988 and 1985 birth cohorts, respectively. Note that those who did not complete primary and junior high school education were excluded from the denominator when calculating the enrollment rates of junior and senior high schools. This is because these people had left school earlier and their education decision should not be affected by what happened later, when they should consider entering junior or senior high school.

Figure 1: The Highway Network in 1999 and 2004



The City Statistical Yearbook was our third data source. We extracted from this database the variables of GRP, the proportion of industrial and tertiary sectors to the local GRP, population, passenger volume, teacher–student ratio in secondary education, and number of high schools.

3.2 Summary Statistics

Table 1 presents the summary statistics. As we discussed in the last section, highway access should have heterogeneous effects on the enrollment rates in urban and rural regions. According to the PRC's administrative divisions, counties mainly consist of rural units, such as villages, where most rural households reside. Municipal districts mainly are urban regions.

Table 1: Summary Statistics

Variables	N	Mean	S.D.
Dependent variables			
Enrollment rate of primary school			
Counties	1605	0.99	0.02
Municipal districts	1688	0.99	0.03
Agricultural Hukou	1687	0.99	0.02
Non-agricultural Hukou	1687	0.99	0.02
Enrollment rate of junior high school			
Counties	1603	0.86	0.14
Municipal districts	1689	0.91	0.13
Agricultural Hukou	1685	0.85	0.15
Non-agricultural Hukou	1687	0.96	0.08
Enrollment rate of senior high school			
Counties	1601	0.36	0.17
Municipal districts	1685	0.54	0.22
Agricultural Hukou	1683	0.31	0.16
Non-agricultural Hukou	1675	0.76	0.18
Key explanatory and control variables			
Access to highway	1689	0.60	0.49
Length of highway (km)	1689	67.66	90.47
Gross regional product per capita (yuan)	1611	10,205.45	11,966.99
Proportion of the tertiary sector in the GRP	1611	0.41	0.10
Proportion of the industrial sector in the GRP	1611	0.45	0.11
Road passenger volume per capita	1603	14.10	17.05
Railway passenger volume per capita	1533	0.99	1.26
Teacher–student ratio in high schools	1610	0.06	0.02
Number of high schools per 10,000 persons	1610	0.66	0.16

Note: The gross regional product (GRP) is in the price of 2000.

We further implemented our analysis by exploring another measure of the PRC's urban–rural divide. In addition to the division of areas, the PRC's population is also divided into agricultural and non-agricultural Hukous. The Hukou system is a major barrier hindering labor mobility in the PRC. Most urban residents hold non-agricultural Hukous, while rural residents mainly have agricultural Hukous. Originally, the Hukou system functioned to contain people's free relocation. People's residency and occupation choices are associated with his/her type of Hukou. Households with rural Hukous are designated to work in the agricultural section and prohibited from residing in urban cities. Although nowadays this restriction has been relaxed to a large extent and there are many migrant workers working in cities, it is still a major factor driving the PRC's urban–rural divide. According to Maurer-Fazio et al. (2015), workers with rural

Hukous earn 40% less than urban workers, and only 16% of them receive employment benefits.

Based on these institutional features, we thus separately calculated school enrollment in counties, municipal districts, and agricultural and non-agricultural Hukous. The enrollment rate for primary school has been as high as 99% in all groups, while the enrollment rates for high school vary across groups. The enrollment rate for junior high school is about 5 percentage points different between the counties and municipal districts and 11 percentage points different between agricultural and non-agricultural Hukous. One reason for this is that the PRC's LoCS, enacted in 1986, makes elementary and junior high school education obligatory for households, yet it was not enforced very strictly in some areas until 2005. Regarding the enrollment rate of senior high school, only 36% of junior high school graduates in counties chose to continue senior high school, while this ratio in municipal districts is 54%. And the difference is even bigger between two Hukou groups: 31% of junior high school graduates chose to continue senior high school among those with agricultural Hukous, and this number is 76% among those with non-agricultural Hukous. Because rural residents may switch to non-agricultural Hukous through college admission or through other channels, this enrollment rate gap between Hukou groups may be overstated to some extent, but it is still quite large after taking account of this factor.

On average, 60% of cities are connected to the highway, and the length of highway is about 68 km within each city. The average GRP per capita is above 10,000 yuan, and the proportions of the industrial and tertiary sectors in the GRP are both above 40%. The road and railway passenger volume per capita is about 14 and 1 person-time, respectively. The teacher–student ratio is 0.06, or in other words, about 17 students have one teacher, and on average 15,000 people have one high school.

4. RESULTS

4.1 Main Results

Table 2 shows our main results. We first look into the regression results for our key variable: connection to highway. Columns (1) to (4) report the results for senior high school enrollment rates in municipal districts and counties, and among people with agricultural and non-agricultural Hukous, respectively. Column (1) shows that highway connectivity has a positive effect on the enrollment of senior high school, but it is statistically insignificant. The result for those with non-agricultural Hukous, reported in Column (3), is similar to results in municipal districts: positive and insignificant but with lower magnitude. In contrast, Column (2) shows that highway connectivity can cause the enrollment rate of senior high school in counties to significantly reduce by 9%, which implies a 3.24 percentage point reduction in school enrollment, because the average senior high school enrollment rate is 36%. Just like the similarity between Columns (1) and (3), Column (4) is also quite close to Column (2): for people with agricultural Hukous, highway connectivity reduces the senior high school enrollment rate by 8%, though it is statistically insignificant. Actually, if we narrow our analysis to the agricultural population in counties, which were not presented in the table but available on request, the effect of highway connectivity becomes more statistically significant and a little more negative. Basically, these results suggest that highway access has a negative effect on the senior high school enrollment rate in rural PRC but has no adverse effect or even has some accelerative effect on the enrollment rate for senior high schools in urban PRC.

Table 2: Highway Access and School Enrollment Rates (Log)

	(1)	(2)	(3)	(4)
	Senior High School			
	Municipal Districts	**Counties**	**Non-agri.HK**	**Agri. HK**
Connection to highway	**0.052**	**–0.091****	**0.029**	**–0.080**
	(0.045)	**(0.046)**	**(0.031)**	**(0.051)**
Gross regional product per capita (log)	–0.041	0.247	–0.193**	0.171
	(0.144)	(0.208)	(0.094)	(0.240)
Proportion of tertiary industry to GRP	0.001	–0.003	0.000	–0.005
	(0.004)	(0.005)	(0.002)	(0.005)
Proportion of second industry to GRP	–0.002	–0.009	–0.001	–0.006
	(0.006)	(0.007)	(0.004)	(0.008)
Teacher–student ratio	0.000	–0.000	–0.000	0.000
	(0.000)	(0.000)	(0.000)	(0.000)
Number of high schools per 10,000 people	–0.054	–0.681**	0.020	–0.601**
	(0.186)	(0.294)	(0.123)	(0.294)
Road passenger volume per capita (log)	–0.124**	0.045	–0.056	0.027
	(0.048)	(0.075)	(0.046)	(0.078)
Rail passenger volume per capita (log)	0.062	0.066**	–0.027	0.129***
	(0.038)	(0.032)	(0.023)	(0.047)
Constant	–0.041	–2.648	1.511**	–2.382
	(1.177)	(1.672)	(0.731)	(1.923)
N	1,341	1,278	1,341	1,323
R^2	0.132	0.383	0.165	0.382
	(5)	**(6)**	**(7)**	**(8)**
	Junior High School			
	Municipal Districts	**Counties**	**Non-agri.HK**	**Agri. HK**
Connection to highway	**–0.011**	**–0.014**	**0.006**	**–0.021**
	(0.016)	**(0.015)**	**(0.009)**	**(0.016)**
Gross regional product per capita (log)	0.215***	0.342***	0.063	0.310***
	(0.069)	(0.091)	(0.043)	(0.098)
Proportion of tertiary industry to GRP	–0.001	–0.004***	–0.000	–0.003
	(0.002)	(0.002)	(0.001)	(0.002)
Proportion of second industry to GRP	–0.006**	–0.011***	–0.001	–0.009***
	(0.002)	(0.003)	(0.002)	(0.003)
Teacher–student ratio	–0.000	–0.000	0.000	0.000
	(0.000)	(0.000)	(0.000)	(0.000)
Number of high schools per 10,000 people	–0.106	–0.333***	–0.081*	–0.190*
	(0.069)	(0.085)	(0.042)	(0.101)
Road passenger volume per capita (log)	0.002	0.010	–0.001	–0.009
	(0.025)	(0.014)	(0.010)	(0.017)
Rail passenger volume per capita (log)	–0.007	0.024*	0.009	0.019
	(0.015)	(0.013)	(0.012)	(0.013)
Constant	–1.582***	–2.212***	–0.456	–2.157***
	(0.542)	(0.705)	(0.325)	(0.748)
N	1,357	1,303	1,355	1,354
R^2	0.502	0.673	0.451	0.687

continued on next page

Table 2 *continued*

	(9)	(10)	(11)	(12)
	Primary School			
	Districts	Counties	Non-agri.HK	Agri. HK
Connection to highway	**–0.005**	**0.003**	**0.004**	**0.001**
	(0.004)	**(0.002)**	**(0.003)**	**(0.002)**
Gross regional product per capita (log)	–0.019	0.019	0.000	0.001
	(0.016)	(0.016)	(0.010)	(0.013)
Proportion of tertiary industry to GRP	0.000	–0.000**	0.000	–0.000
	(0.000)	(0.000)	(0.000)	(0.000)
Proportion of second industry to GRP	–0.000	–0.001*	–0.000	–0.001
	(0.001)	(0.000)	(0.000)	(0.000)
Teacher–student ratio	0.000	0.000	–0.000	0.000
	(0.000)	(0.000)	(0.000)	(0.000)
Number of high schools per 10,000 people	0.001	–0.002	0.004	0.010
	(0.013)	(0.010)	(0.009)	(0.011)
Road passenger volume per capita (log)	0.009	–0.003	–0.001	0.001
	(0.008)	(0.005)	(0.004)	(0.005)
Rail passenger volume per capita (log)	0.001	–0.001	0.006**	–0.002
	(0.003)	(0.002)	(0.003)	(0.002)
Constant	0.138	–0.116	–0.004	0.012
	(0.127)	(0.129)	(0.079)	(0.101)
N	1,356	1,305	1,356	1,356
R^2	0.090	0.242	0.065	0.268

Note: All regressions control for city fixed effects and year fixed effects. Robust standard errors are clustered at the city level. * p < 0.10, ** p < 0.05, *** p < 0.01. The GRP is in the price of 2000.

The results for junior high school (Columns (5) to (8)) and primary school (Columns (9) to (12)) are very different from those for senior high school: **highway connectivity has no sizable effect on junior high school enrollment or on primary school enrollment in all groups**. These results are not surprising because the change of opportunity cost does not apply to primary and junior high school students, as these levels of education are compulsory by law and the age of students is still below the legal minimum threshold for work, which is 16 in the PRC. These results, together with those for senior high school, are **consistent with our expectation, and shed light on the debate regarding tradeoff and interaction between physical capital and human capital accumulation** (Graca et al. 1995; Turnovsky and Mitra 2013)**.**

The other regression results are also interesting. First, all the variables have no significant or sizable effect on primary school enrollment. Given that the enrollment rate of primary school is nearly 100%, it should have no strong relationship with any factor.

Second, the GRP per capita has a positive effect on junior high school enrollment in all groups. Because junior high school education is part of compulsory schooling in the PRC and students at this stage do not meet the minimum age threshold of working outside, these results suggest that a better regional economy could provide more abundant resources for junior high school education, which makes the attendance rate higher. But for senior high school enrollment, the results are mixed. Because senior high education is not compulsory and students who are older than 16 can work legally, a better regional economy on the one hand might provide more education resources, yet on the other hand it may also expose students to better job opportunities, which induces dropout.

All in all, these results are consistent with our prediction: highway access increases the opportunity cost of education for students who are eligible to work, which induces high school dropout in rural areas. This is because higher opportunity costs in the present can outweigh the long-term benefits of education for poorer families. Our results suggest that transport infrastructure may improve rural households' income in the short run, as suggested by the previous literature, and it could also corrode the accumulation of human capital, an engine for economic growth in the long run.

4.2 Robustness Tests

We conducted robustness checks using different measures of highway connection and estimated model specification with lagged variables of highway connections. Overall, our results are robust to these specifications.

First, to estimate the intensive margin of the highway connection, we measured highway connectivity using the length of highway within the city rather than a dummy variable of connectivity. Because some cities were not connected to the highway during our sample period, we took the logarithm for the length of highway plus one. These results are reported in Panel A of Table 3. The results are similar to those in Table 2 in sizes and signs, but they are statistically insignificant. This implies that it is the extensive margin (i.e., connected with highway or not) instead of the intensive margin that affects the enrollment rate.

Table 3: Robustness Tests

	(1)	(2)	(3)	(4)
	Senior High School			
	Municipal Districts	Counties	Non-agri.HK	Agri. HK
Panel A: Robustness test 1				
Length of highway (log)	0.007	–0.011	0.003	–0.007
	(0.011)	(0.011)	(0.008)	(0.012)
Panel B: Robustness test 2				
Connection to highway	0.028	–0.100**	0.002	–0.061
	(0.050)	(0.044)	(0.030)	(0.048)
L1. Connection to highway	0.022	–0.063	–0.003	–0.039
	(0.047)	(0.049)	(0.030)	(0.051)
Panel C: Robustness test 3				
Connection to highway	–0.039	–0.086*	–0.021	–0.072
	(0.057)	(0.052)	(0.032)	(0.054)
L1. Connection to highway	–0.004	–0.050	0.005	–0.039
	(0.045)	(0.047)	(0.029)	(0.048)
L2. Connection to highway	0.027	–0.022	0.019	–0.014
	(0.057)	(0.051)	(0.038)	(0.058)

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Table 3 *continued*

	(5)	(6)	(7)	(8)
	Junior High School			
	Municipal Districts	Counties	Non-agri.HK	Agri. HK
Panel A: Robustness test 1				
Length of highway (log)	–0.003	–0.002	0.002	–0.004
	(0.004)	(0.003)	(0.002)	(0.004)
Panel B: Robustness test 2				
Connection to highway	–0.005	–0.007	0.007	–0.012
	(0.016)	(0.016)	(0.009)	(0.016)
L1. Connection to highway	–0.014	–0.016	0.001	–0.021
	(0.021)	(0.019)	(0.011)	(0.020)
Panel C: Robustness test 3				
Connection to highway	0.002	–0.011	0.007	–0.010
	(0.021)	(0.021)	(0.012)	(0.020)
L1. Connection to highway	–0.008	–0.011	–0.002	–0.009
	(0.016)	(0.016)	(0.011)	(0.016)
L2. Connection to highway	–0.019	–0.034	0.011	–0.048**
	(0.030)	(0.022)	(0.017)	(0.025)
	(9)	**(10)**	**(11)**	**(12)**
	Primary School			
	Districts	**Counties**	**Non-agri.HK**	**Agri. HK**
Panel A: Robustness test 1				
Length of highway (log)	–0.001	0.001	0.001	0.000
	(0.001)	(0.000)	(0.001)	(0.000)
Panel B: Robustness test 2				
Connection to highway	–0.005	0.002	0.001	0.001
	(0.004)	(0.002)	(0.003)	(0.002)
L1. Connection to highway	–0.004	0.001	0.004	–0.002
	(0.005)	(0.003)	(0.004)	(0.003)
Panel C: Robustness test 3				
Connection to highway	–0.005	0.002	–0.000	0.001
	(0.005)	(0.003)	(0.004)	(0.003)
L1. Connection to highway	–0.005	–0.000	0.001	–0.002
	(0.007)	(0.003)	(0.004)	(0.003)
L2. Connection to highway	0.003	0.002	0.008	–0.001
	(0.008)	(0.003)	(0.005)	(0.004)

Note: All regressions control for log of GRP per capita, fractions of industrial and tertiary sector in GRP, teacher–student ratio, number of high schools per 10,000 people, log of road passenger volume per capita, log of railway passenger volume per capita, city fixed effects, and year fixed effects. Robust standard errors are clustered at the city level. * p < 0.10, ** p < 0.05, *** p < 0.01. The GRP is in the price of 2000.

Second, we added a lagged variable of highway connection to the model to investigate the cumulative effect. Panels B and C of Table 3 contain one-year and two-year lagged variables for highway connectivity. First, adding lagged variables reduces the magnitude as well as the significance level of the estimates. This is because the lagged variable is usually highly correlated to the concurrent ones. However, there is hardly any change when only adding the first lag of highway connection in the model compared to our main results reported in Table 2, and when the first two lags are controlled for, the main change is that the significance level decreases a little bit to 10% for the senior high school sample.

4.3 Identification Tests

To this end, we have shown that highway access leads to a lower senior high school enrollment in the PRC's rural regions. However, as we discussed above, the nonrandom placement of highways can still cause an endogeneity problem. For example, there could be some unobserved factors affecting both the highway routes and student enrollment simultaneously. To address this issue, we further implemented a placebo test and used instrumental variables for identification.

We first calculated the student enrollment ratios of regions from 1995 to 1998. If the drop in student enrollment is caused by some factors other than highway connection, these factors can also affect the student enrollment ratio between 1995 and 1998. So we implemented a placebo test and estimated our main equation using data in this period by assuming highways were constructed during that time. Panel A of Table 4 reports the results, and no coefficient is significantly different from zero. This means that it is the highway connection itself, rather than some omitted factors determining highway connection, that causes the decrease of high school enrollment.

Table 4: Placebo Test and Instrument Variables Estimation

	(1)	(2)	(3)	(4)	(5)
	Senior High School				
	Districts	Counties	Non-agri.HK	Agri. HK	Counties* Agri.HK
Panel A: Placebo test (1995–1998)					
Connection to highway	0.031	0.082	–0.051	0.170	0.077
	(0.064)	(0.069)	(0.044)	(0.177)	(0.117)
Panel B: First stage					
Ming road	0.382***	0.397***	0.398***	0.397***	0.390***
	(0.082)	(0.082)	(0.083)	(0.082)	(0.083)
Yuan road	0.655***	0.635***	0.642***	0.644***	0.642***
	(0.066)	(0.067)	(0.068)	(0.067)	(0.068)
F-stat	427.49	391.37	409.51	401.62	404.45
Panel C: IV(Historical road)					
Length of highway (log)	0.040	–0.120**	0.067*	–0.095	–0.155**
	(0.054)	(0.059)	(0.037)	(0.064)	(0.067)

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Table 4 *continued*

	(6)	(7)	(8)	(9)	(10)
			Junior High School		
	Districts	Counties	Non-agri.HK	Agri. HK	Counties* Agri.HK
Panel A: Placebo test (1995–1998)					
Connection to highway	0.016	–0.004	–0.003	0.005	–0.012
	(0.010)	(0.012)	(0.004)	(0.012)	(0.022)
Panel B: First stage					
Ming road	0.395***	0.394***	0.396***	0.395***	0.395***
	(0.082)	(0.082)	(0.082)	(0.082)	(0.082)
Yuan road	0.641***	0.638***	0.641***	0.641***	0.638***
	(0.067)	(0.067)	(0.067)	(0.067)	(0.067)
F-stat	405.09	393.46	405.68	404.97	394.58
Panel C: IV(Historical road)					
Length of highway (log)	–0.032	–0.007	0.007	–0.022	–0.003
	(0.021)	(0.016)	(0.010)	(0.020)	(0.019)
	(11)	**(12)**	**(13)**	**(14)**	**(15)**
			Primary School		
	Districts	Counties	Non-agri.HK	Agri. HK	Counties* Agri.HK
Panel A: Placebo test (1995–1998)					
Connection to highway	0.004	–0.000	0.002	0.001	0.001
	(0.003)	(0.002)	(0.002)	(0.002)	(0.003)
Panel B: First stage					
Ming road	0.395***	0.394***	0.395***	0.395***	0.395***
	(0.082)	(0.082)	(0.082)	(0.082)	(0.082)
Yuan road	0.641***	0.638***	0.641***	0.641***	0.639***
	(0.067)	(0.067)	(0.067)	(0.067)	(0.067)
F-stat	405.39	394.10	404.80	404.63	394.47
Panel C: IV(Historical road)					
Length of highway (log)	–0.006	0.007	0.000	0.003	0.007
	(0.006)	(0.006)	(0.003)	(0.003)	(0.008)

Note: All regressions control for log of GRP per capita, fractions of industrial and tertiary sector in GRP, teacher–student ratio, number of high schools per 10,000 people, log of road passenger volume per capita, log of railway passenger volume per capita, city fixed effects, and year fixed effects. Robust standard errors are clustered at the city level. * p < 0.10. ** p < 0.05. *** p < 0.01. The GRP is in the price of 2000.

Furthermore, we also adopted instrumental variables to address the endogeneity problem. One type of frequently used instrumental variable in the literature is historical roads. This is because the plan of historical roads is unlikely to be associated with today's socioeconomic conditions. For example, both Duranton and Turner (2012) and Michaels (2008) used the railroad built decades ago as the instrumental variable of current highway routes in the US; Garcia-Lopez (2012) used ancient Roman Empire roads as the instrumental variable of current highways in Spain. In this study, we used postal roads in the Yuan (1271–1368 AD) and Ming (1368–1644 AD) dynasties as instrumental variables for the PRC's modern highways.

Figure 2: Historical Roads of the Yuan and Ming Dynasties

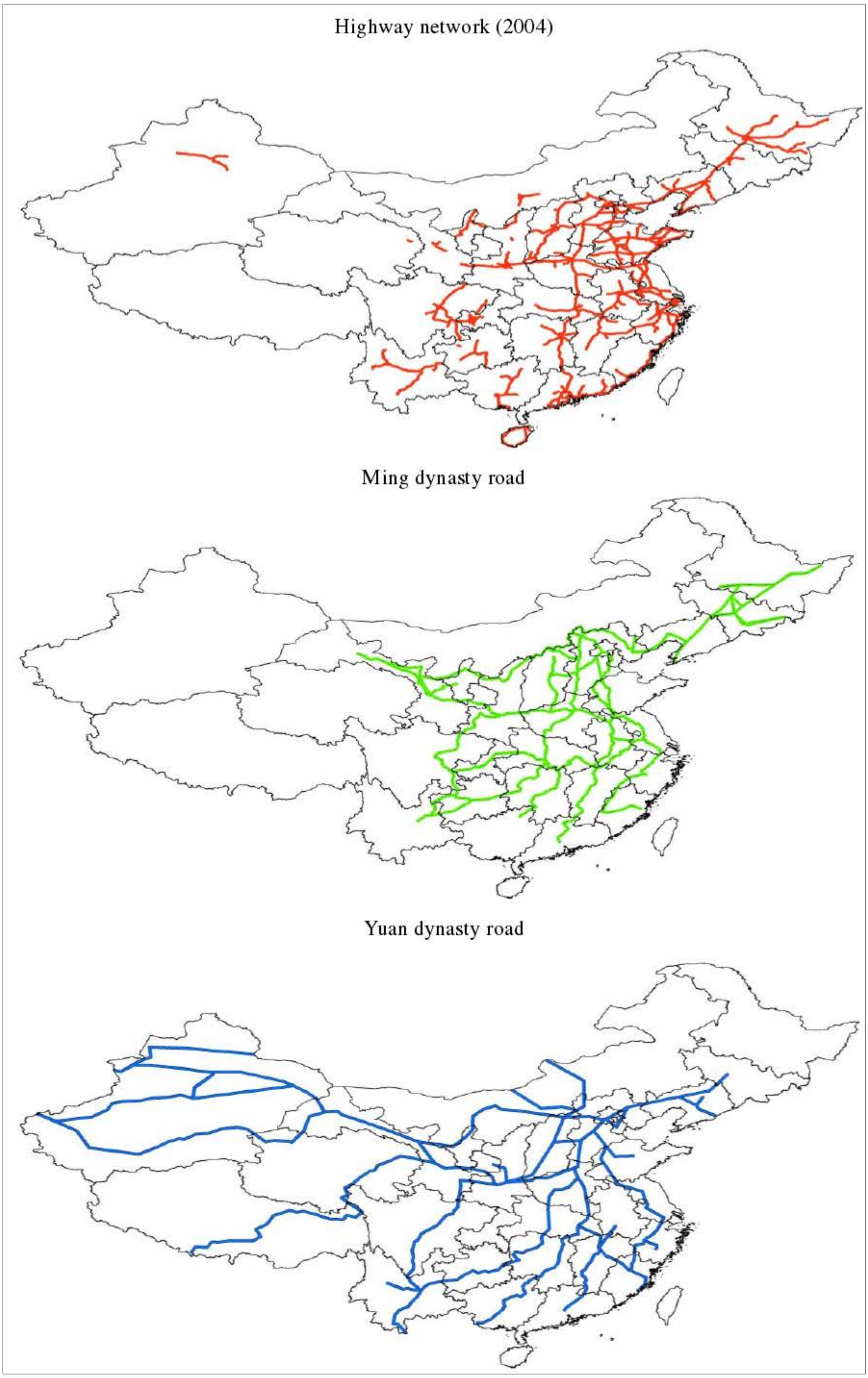

Figure 2 shows the historical roads of the Yuan and Ming dynasties in the PRC. As we can tell, these historical roads and current highway routes are closely associated. Panel B of Table 4 shows the first-stage regression results of the 2SLS estimation. The coefficients are positive. This means that regions connected by ancient roads are more likely to be linked with current highways. And Panel C of Table 4 is the result of the second-stage estimation of our 2SLS specification. Our estimation shows that highways significantly reduce the enrollment ratio of high school students by 12%, which is consistent with our prediction. This result also indicates that without considering the selection issue of highway routes, one may underestimate the effect of highway access to school enrollment.

5. CONCLUSION

In this paper, we studied the effect of highway infrastructure investments on households' educational decisions in the PRC's rural regions. Highway access reduces travel costs of people. Thus, it can expose households to more job opportunities as they gain access to a larger labor market. As a result, it may alter the opportunity costs of education. The poor can forfeit future return to education for working at the present. Given the PRC's institutional features, this implies that highway access may reduce the enrollment rate of senior high schools in rural regions, as the youth now are more likely to get a job and drop out of school. However, it may not affect the enrollment rate of schools at earlier stages. This is because both junior high and elementary schools are subject to the PRC's Law of Compulsory Schooling, and their students are under age 16, the PRC's legal minimum working age. Thus, their decisions are less likely to be affected by highway connectivity.

We tested these hypotheses using the PRC's mini-census of 2005. We find that highway connections to the PRC counties have a negative effect on the student enrollment of senior high schools. Once a city/prefecture is connected with a highway, its high school enrollment rate drops by 12% or correspondingly 4.45 percentage points. On the other hand, highway access has no significant effect on the enrollment rates of junior high and elementary schools. Further robustness tests show that highway connections don't significantly affect the enrollment rates of elementary and high schools in urban regions. This finding is also consistent with our prediction, as urban students' potential benefit from education could be higher than that of students in rural regions.

These results have strong policy implications. Although transport infrastructure investments can facilitate rural development by enhancing agricultural productivity and regional integration, as suggested by the previous literature, they may also induce higher dropout rates for poor students who are eligible for work and lead to lower human capital accumulation for rural households. Better transport connectivity may improve rural households' income in the short run but may have negative effect for regional growth in the long run. Developing economies should take this negative externality into consideration when making rural development policies.

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