"No County Left Behind?" The Distributional Impact of High-Speed Rail Upgrade in China

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Abstract

Infrastructure investment may reshape economic activities. In this paper, I examine the distributional impacts of high-speed rail upgrade in China. By exploiting the quasi-experimental variation in whether counties were affected by this project, my analysis suggests that the affected counties on the upgraded railway lines suffered from reductions in GDP and GDP per capita following the upgrade, which was largely driven by the concurrent drop in fixed asset investment. In addition, such impact is heterogeneous across sectors, and might be explained by the strengthened agglomeration forces in cities connected with high-speed rail.

Keywords: Transportation; High-speed rail; Distributional impact; China

JEL classification: R11; R12; R40; O18; O33; O53

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1 Introduction

Infrastructure investments are regarded as key instruments to promote overall economic growth. However, such investments are not evenly distributed across different regions of a country, possibly due to differences in expected returns, budget constraints, planning concerns, and so on. For example, in the most recent highway construction boom in China, the highway length per capita in the affluent Guangdong Province quadrupled from 2003 to 2010, while it increased by only one fourth in the relatively underdeveloped Guizhou Province during the same period.[1] Therefore, the regions or sectors more "local" to investments (such as Guangdong Province) may benefit more than less-affected regions or sectors (such as Guizhou Province). The distributional consequences will be even more pronounced if investments biased toward one sector or region hurt less-affected sectors or regions.

In this paper, I explore this possibility by investigating the distributional impacts of one such infrastructure investment: high-speed rail upgrade in China. There are several reasons why this is a useful case to study. First, investment in high-speed rail is prevalent in both developed and developing countries. Currently, more than 10 countries in the world have high-speed rail, including Spain, Japan, Germany, France, China, the United States, Belgium, Italy, the Netherlands, the United Kingdom, Korea, Taiwan (China), and Turkey (International Union of Railways (UIC), 2010). As well, a number of other countries, such as India, Russia, Brazil and Canada, plan to upgrade their railway lines into high-speed rail (International Union of Railways (UIC), 2010). China is a very relevant country to study high-speed rail's impact since such investment in the country is very large in scale. Among all the infrastructure investment in China, investment in railroads takes up to 23 percent with a high growth rate in recent years.[2] The annual investment in the railroad sector in year 2010 (around 120 billion US Dollars) was more than ten times that of the investment in 2003 (around 10 billion US Dollars). A large proportion of investment in the railroad sector was for high-speed rail upgrades on existing railway lines and the construction of new high-speed rail. After the high-speed rail upgrade in 2007, the total length of high-speed rail reached 6,000 kilometers in China, top in the world even today.

Second, like all such investments, high-speed rail upgrades in China are known to favor urban areas. High-speed rail, by definition, is a type of passenger rail transport that travels at speeds above 200 kilometers per hour. In order to maintain the high speed, the featured service of high-speed rail, the bullet trains, stop only in populous urban areas, where there are higher demands for time savings, in contrast with small cities and rural areas. Thus,

[1] China Statistical Yearbooks, 2004-2011.
[2] China Statistical Yearbooks, 2004-2011.

counties with upgraded railway lines may find bullet trains bypassing them (Economist, 2011). Indeed, as suggested by Figure 1, around 3,000 out of around 6,100 passenger train stops in China have been abandoned in the past ten years due to the speed acceleration of passenger train services, especially after year 2004, when high-speed rail upgrading began. That is to say, even though the high-speed trains help facilitate economic activities across cities due to significantly less travel time, they may actually hurt the small counties along the accelerated railway lines by passing them by and depriving them of access. In the urban planning literature, this is known as the "tunnel effect," defined as "an improvement in access to major cities but at the expense of breaking up the space between them. The increase in dynamism in large nodes is compensated by a decrease in the activity of areas between the connection points" (Albalate and Bel, 2012). The latest World Bank report on China's high-speed rail development also documents the fact that some conventional train services were removed after the introduction of high-speed rail (Bullock et al., 2012).

Third, whether the non-targeted counties have been affected by the upgrade process has been quasi-random to a large extent, which facilitates credible empirical analysis on the causal impact of high-speed rail upgrade on such affected counties. The two rounds of high-speed rail upgrade, parts of China's railway speed acceleration project since 1997, were implemented in the year 2004 and 2007. There are two reasons why the upgrade has been quasi-random for the affected counties. First, all the upgrades were implemented on existing railway lines, which mitigates the concern of the selection problem on high-speed rail placement. Second, as the selection for high-speed rail upgrade mainly depends on which large cities the existing railways are connected to, the counties in between cities affected by the speed acceleration can be regarded as quasi-random since they were not selected on purpose (Michaels, 2008; Datta, 2012).

I exploit this quasi-experimental variation in whether counties were affected to examine the distributional impacts of the upgrade. Specifically, I examine the impact of high-speed rail upgrade by comparing the economic outcomes of the counties located on the affected railway lines with the counties located on non-affected railway lines, before and after, using county level statistics collected from statistical yearbooks and other published statistical reports. I first apply a difference-in-difference setting in order to compare the high-speed rail affected counties and non-affected counties, before and after. The common trend assumption required by difference-in-difference analysis satisfies since the pre-trends of outcome variables are similar between control and treatment groups. To strengthen my estimation, I conduct several robustness checks. First, I rule out the possibility of regional favortism in program treatment. Second, I instrument the selection of affected counties by whether a county is located on the five main railway lines in China (four lines connecting Beijing to the north:

Haerbin; south: Guangzhou and Hong Kong; east: Shanghai, while one connects Lianyungang in the east to Urumqi in the west). Third, I employ the methodology proposed by Bertrand et al. (2004) to correct for the standard error of difference-in-difference estimation with a relatively large T in panel data.

My analysis conveys several main findings. First, the estimations using OLS and Two-Stage Least Square (2SLS) consistently suggest that being located on the high-speed railway lines decreases a county's total GDP and GDP per capita by 4-6 percent on average, which is around 336-503 million *yuan* (54-81 million US Dollars), given the average county level GDP as 8.39 billion *yuan* (around 1.35 billion US dollars) in 2006 in the affected regions. In addition, the negative impact due to high-speed rail upgrade can explain around 64% of the predicted GDP growth rate differentials right after the upgrade between the affected and non-affected counties. The results still hold if I collapse the panel data from multiple years into two periods, i.e., "pre" and "post," following the suggestion of Bertrand et al. (2004) on correctly estimating the standard errors in difference-in-difference analysis. Such implies that the urban-biased investment of high-speed rail upgrades hurt the economic growth of non-targeted counties located on the upgraded railways.

Second, the reduction of GDP is likely to be investment driven, as evidenced by the 10-11 percent reduction of fixed asset investment in the affected counties. This is not surprising since investment is a driving force of GDP growth in China (Qin et al., 2006; Yu, 1998). Intuitively, when the cities had been more conveniently connected by high-speed trains, investment left the counties and crowded into the cities in pursuit of higher returns due to expected growth. The result still holds for robustness checks.

Third, the impact of the railway upgrade varies in different sectors. Since high-speed rail significantly reduces transportation cost of passengers rather than goods, its negative impact in the affected counties is more pronounced in the service sector than in the manufacturing sector. More precisely, the growth rate of service sector value added is reduced by 3-4 percent after the high-speed rail upgrade, while the growth rate of industrial sector value added is not significantly affected.

Fourth, I discuss the channels that may account for the investment-driven economic slowdown in the affected counties. Specifically, I test two possible channels: 1) increases in trade cost due to reduced train services in the affected counties may lead to decreases in economic activities; 2) increases in agglomeration spillovers with a more tightly connected transportation network between large cities may divert economic activities from counties to populous urban districts. I find that the second channel plays a more important role in explaining the negative impact of high-speed rail upgrade.

The contributions of this paper are threefold. First, to my knowledge, this is the first paper documenting the distributional consequences of high-speed rail projects to the non-targeted rural areas, which complements the rich body of literature examining the causal relationship between access to infrastructure and various aspects of economic development in both developing and developed countries (Ahlfeldt, 2011; Atack et al., 2010; Banerjee et al., 2012; Baum-Snow, 2007; Baum-Snow et al., 2012; Datta, 2012; Ghani et al., 2012; Donaldson, 2013; Duflo and Pande, 2007; Faber, 2014; Jedwab and Moradi, 2014; Zheng and Kahn, 2013). Specifically, this paper provides the first set of results demonstrating an investment-driven GDP reduction in the non-targeted rural areas affected by infrastructure investment. Second, the main findings of this paper provide an empirical test to the core-periphery model (Fujita et al., 2001), especially its recent development by introducing the service sector (Leite et al., 2013). The evidence in this paper suggests that the periphery rural areas may experience a reduction in service sector output when transportation cost (of people) decreases in urban core. This is different than the impact of highway construction, which is more pronounced in the manufacturing sector due to its function of freight transportation(e.g., (Faber, 2014)). Lastly, this paper also provides useful insights in understanding the increasing rural-urban disparity in China in the past few decades, where urban biased infrastructure investment may have played a role (Kanbur and Zhang, 2005; Xu, 2011).

The paper is organized as follows: Section 2 describes the policy background of high-speed rail upgrade in China. Section 3 describes the identification strategy and data sources. Section 4 shows the main findings and robustness checks. Section 5 discusses the heterogeneous impacts of the railway upgrade in different sectors, possible channels the impact may work through and the magnitude of such impact. Finally, Section 6 concludes.

2 Background of China's High-Speed Rail Upgrade

2.1 Railway speed acceleration and high-speed rail upgrade

Mainly in response to the profit loss under the competition of road and air transportation, China's Railways Ministry started several rounds of speed acceleration on existing railway lines spanning from 1997 to 2007. [3] The project had two stages. In the first stage, train speed was increased gradually in the first four waves, namely 1997, 1998, 2000 and 2001. In 1997, the first round of speed acceleration was initiated on three main railway lines connecting from Beijing to Shanghai, Guangzhou, and Haerbin. The average passenger train speed was increased from around 48.1 kilometers per hour to 54.9 kilometers per hour. Subsequently in 1998, 2000 and 2001, another three waves of speed acceleration were implemented on the

[3] Please refer to Appendix A for more background information about railway network in China.

main railway lines, increasing the average train speed nationwide to 61.6 kilometer per hour by the end of 2001.

In the second stage, speed acceleration was targeted towards upgrading the existing railway into high-speed rail, with sustained speed greater than 200 kilometers per hour or higher. In 2004, around 1,960 kilometers of railroad had been upgraded to high-speed rail, with 19 pairs of city-to-city nonstop passenger trains operating on it. In 2007, the upgraded high-speed rail was expanded to around 6,000 kilometers with 257 pairs of China Railway High-speed (CRH) trains operating on a daily basis, which significantly shortened the commuting time between large cities. For example, the travelling time from Beijing to Fuzhou, the provincial capital of Fujian in the south of China, was reduced from around 33 hours to 19.5 hours with the introduction of CRH trains in 2007. The travelling time by train was reduced by more than half from Shanghai to Nanchang and Changsha, which are the two provincial capitals in southeast China. According to the vice Minister of the Chinese Railways Ministry, the travelling time between cities by CRH trains was reduced by an average of 20-30 percent [4].

The dramatic expansion of high-speed rail in the year 2007 reflects the "Great Leap Forward" strategy proposed by the ex-Minister of the Chinese Railways Ministry, Zhijun Liu, who was removed due to corruption allegations in early 2011. During Liu's tenure, China invested a huge amount of money into railway expansion, upgrades, and construction of high-speed railway lines. As most of the high-speed railway lines were updated from existing railways, some slow train services on the upgraded lines were cancelled in order to accommodate CRH trains. As a consequence, the number of operating slow trains significantly decreased with the increase of high-speed rail mileage. For example, in 2002—before high-speed rail upgrade—352 pairs of daily slow passenger trains operated nationwide. The number dropped to 224 in 2007.[5]

Even though high-speed rail benefits transportation from city to city, it may do harm to the economy of the small counties along the upgraded high-speed railway lines through two possible channels. First, the affected counties lose their geographic advantage in the transportation network, leading to increases of transportation cost. Specifically, counties located on the high-speed railway lines experienced a reduction of slow train services on the upgraded high-speed rail route. Even though the total number of train services might not have decreased if the affected counties utilized other conventional railway lines as well, the number of train services still decreased in relative terms compared to the counterfactual

[4]See http://news.sina.com.cn/c/2007-04-12/151112762996.shtml for more information.

[5]There is no significant difference in terms of capacity between high-speed rail passenger trains and normal passenger trains. A typical passenger train contains 16-20 coaches, with a capacity of 110 passengers in each coach.

without high-speed rail upgrade; i.e., some of the slow train services on the affected railway lines were not cancelled. Therefore, due to increased transportation cost, the affected counties become less integrated, and economic activities decline in response to the increase in trade barriers.

Second, since the high-speed rail connects large cities more tightly, the economic activities in cities may generate more agglomeration externalities. Therefore, some economic activities in small counties may be diverted to large cities in order to enjoy the agglomeration spillovers. Both the above-mentioned channels lead to lower economic returns to railroads in those places, which affects the overall economic performance.

2.2 Program placement

In this paper, I focus on the high-speed rail upgrade in 2004 and 2007.[6] As upgrading existing railway lines for speed acceleration is costly, not all the railway lines were selected for upgrade. In 2004, the three main railway lines connecting Beijing to Haerbin, Shanghai, and Guangzhou were partially upgraded to high-speed rail, with around 20 pairs of nonstop bullet trains operating on them (Figure 2). Later in 2007, the upgrading was completed on the above-mentioned three railway lines and on two additional main lines (Lianyungang to Urumqi and Beijing to Hong Kong,) as well as four other regional lines (Hangzhou to Zhuzhou, Guangzhou to Shenzhen, Wuhan to Jiujiang, and Qingdao to Jinan, Figure 3).

In general, the priority of high-speed rail upgrade was given to the main railway lines first, as they connect big cities, such as Beijing, Shanghai, and Guangzhou, which generate huge demand for railway transportation. Besides the main lines, several regional railway lines were selected for upgrade, as they pass through regions of high economic growth, such as the Pearl River Delta Region (Guangzhou to Shenzhen) and the affluent regions in Zhejiang Province (Hangzhou to Zhuzhou).

[6]As mentioned in 2.1, there were four rounds of speed acceleration in 1997-2001 before the high-speed upgrade. We will not focus on that since the scale of the project is small compared to the 2004 and 2007 high-speed upgrade. None of the railway lines in China had been upgraded to high-speed rail before 2004. An impact evaluation on the speed acceleration in 1997-2001 using difference-in-difference is shown in Appendix Table A1, which suggests little impact of the four rounds of speed-up on economic performance in the affected counties. However, in order to ensure a cleaner identification, I exclude the observations from 1997 to 2001 in the control group when estimating the impact of high-speed rail upgrade in 2004 and 2007.

3 Data and identification

3.1 Identification strategy

The goal of this paper is to reveal the distributional impact of high-speed rail upgrade in China. Specifically, the urban biased high-speed rail upgrade may hurt the economic growth of non-targeted counties/regions when it improves the connection between urban areas. In order to test the above hypothesis, the difference-in-difference strategy is applied to compare the counties located on the affected railway lines to the counties located on other railway lines, before and after each round of high-speed rail upgrade. It is worth emphasizing that all the urban districts in prefecture level cities have been excluded from the sample since they are likely to be selected on purpose in the high-speed rail upgrade projects.

The key assumption in difference-in-difference analysis is common trend. In this case, it would be violated if counties in the control group and treatment group have different growth patterns prior to high-speed rail upgrade. To test the common trend assumption, I use an event study analysis to show that the control group and treatment group have similar pre-trend in terms of GDP, per capita GDP and fixed asset investment before the upgrade process. More details about the event study are discussed in Section 4.3.

In addition to the difference-in-difference strategy, several robustness checks have been implemented in order to make sure that our estimated impact is solely driven by the railway upgrade instead of other unobservables or correlated factors. First, people may worry about the role or regional favoritism in selecting the upgraded railway lines. As Hodler and Raschky (2014) observe from 126 countries, subnational regions have more intense nighttime light when being the birth region of the current political leader, indicating the existence of regional favoritism. Burgess et al. (2013) finds strong evidence of ethnic favoritism in road construction: districts in Kenya that share the ethnicity of the president receive twice as much expenditure on roads and have four times the length of paved roads built. Therefore, if regional favoritism affects the selection of upgraded counties, it may also affect the same group of counties by other means, such as other infrastructure investment, foreign direct investment, and so on. Therefore, our estimated impact of high-speed rail upgrade is likely to be driven by regional favoritism instead of the upgrade itself. However, regional favoritism is likely to have very limited impact in the program selection of high-speed rail upgrade due to the fact that there was only one existing railway line connecting large cities in China in most of the cases. [7] Therefore the government had very limited power exerting regional

[7] For example, *jinghu xian*, *jingha xian*, and *jingguang xian* were the only existing routes directly connecting Beijing to Shanghai, Beijing to Haerbin, and Beijing to Guangzhou during the period of the upgrade.

favoritism in the railway upgrade. We will formally provide more statistics about this issue in Section 4.4.

Second, a problem posed by difference-in-difference analysis is the non-random placement of the treatment group. That is, in our context, the placement of high-speed rail upgrade is not randomly selected. However, the quasi-experimental nature of high-speed rail upgrade at the county level renders the non-random placement problem much less a concern for two reasons. First, all the upgrades were implemented on existing railway lines, which mitigates some of the concerns in the selection problem of high-speed rail placement.[8] Second, as the selection of affected railway lines mainly depends on the cities it connects, rather than the counties it bypasses, it can be treated as a quasi-natural experiment for the counties located on railway lines. This argument is similar to that of Michaels (2008) and Datta (2012), both of whom argue that if a highway is built to connect two cities, it must pass through areas that lie between the two, which affects the outcomes in such areas as a quasi-random shock. However, for regional lines which pass through only a few counties and cities, the decision to select the railway lines for high-speed rail upgrade may also depend on the counties they cross. Such counties may in fact bias my estimation.

Therefore, I employ an instrumental variable to identify the program selection. Specifically, I use whether a county is located on the main railway lines to identify whether it is affected by the speed acceleration or not. As mentioned in Appendix A, there are six main railway lines in China. I exclude the railway line from Beijing to Baotou (*jingbao xian*) in the identification strategy since it mainly serves freight trains instead of passenger trains, which are not relevant for high-speed rail upgrade.[9,10] The five main railway lines are shown in Figure 2 and 3.

The validity of the instrumental variable requires two assumptions: (1) being located on the main railway lines is correlated with being affected by the high-speed rail upgrade and (2) being located on the main railway lines affects economic growth only through its impact on railway acceleration. The first assumption holds, which can be shown from the high-speed rail upgrade map in Figure 2 and 3. All the five main railway lines have been

[8]In addition to high-speed rail upgrade, China also constructed new high-speed rails, such as high-speed rail from Beijing to Shanghai and Wuhan to Guangzhou. In observance to the fact that the earliest new high-speed rails started to operate in December 2009, I exclude the county statistics after year 2009 in the estimation to avoid the possible intertwined impact of new high-speed rails and high-speed rail upgrade due to network effect. In addition, the counties being affected by newly constructed high-speed rails are also excluded from the estimation.

[9]One may doubt the definition of main railway lines in China. However, the definition here follows the published train schedule, where each main railway line is a section of the schedule. Therefore, the definition is objective.

[10]The railway line from Beijing to Baotou mainly serves to transported coal from Shanxi Province, the largest coal-production base in China, to other provinces.

upgraded to high-speed rail since they connect the largest cities in China. In addition to the main railway lines, several regional lines have also been upgraded as shown on the map. The second assumption is somewhat stronger since the main railway lines are often located in relatively developed regions. However, even if counties located along the main railway lines are selected due to their greater economic potential, it will only bias my estimate downward as I expect the counties located on the accelerated railway lines are negatively affected in the later period of the project.

The estimation equation of a standard difference-in-difference can be expressed as:

$$\begin{aligned} Outcome_{i,t} = &\beta_0 + \beta_1 HSR_i * After_t + \gamma Year_t * Province_i \\ &+ \delta County_i + \epsilon_{i,t} \end{aligned} \tag{1}$$

where $Outcome_{i,t}$ is the economic outcome of county i in time t. In this paper, I am most interested in two categories of outcome variables: (a) yearly county level GDP and GDP per capita, which represent the overall performance of a county and (b) a yearly county level investment measure, i.e., fixed asset investment, which is important because investment is a driving force of GDP growth in China (Qin et al., 2006; Yu, 1998).[11] $HSR_i * After_t$ is the difference-in-difference term, where the dummy variable HSR_i denotes whether county i was affected by high-speed rail upgrade (in 2004 and 2007) or not; and $After_t$ denotes whether it is before or after the high-speed rail upgrade for each time t. $Year_t * Province_i$ controls for year by province time trend.[12] $County_i$ controls for county fixed effect. $\epsilon_{i,t}$ is the error term.

The reduced form instrumental variable estimation can be written as:

$$\begin{aligned} Outcome_{i,t} = &\beta_0 + \beta_1 Mainline_i + \sum \alpha_t Mainline_i * Year\_d_t \\ &+ \gamma Year_t * Province_i + \delta County_i + \epsilon_{i,t} \end{aligned} \tag{2}$$

where $Mainline_i$ denotes whether county i is located in any of the five main railway lines or not; $Mainline_i * Year\_d_t$ denotes $Mainline_i$ interacting with a series of year dummies. Other variable definitions are the same as in Equation (1).

Third, as mentioned in Bertrand et al. (2004), the standard error of the "treatment

[11] Fixed asset investment includes the investment in capital construction, investment in renovation and renewals of existing facilities, investment in real estate development, investment in other fixed assets by state-owned units, investment in other fixed assets by collective-owned units, private investment in housing construction as defined by the National Bureau of Statistics of China.

[12] I can also use year fixed effect instead of year by province fixed effect here if the assumption is released so that there is no heterogeneity in terms of growth trend across different provinces. The main findings do not change if year fixed effect is used.

variable" in difference-in-difference analysis may be underestimated due to the serial correlation among the observations of the same object over years. Bertrand et al. (2004) suggest collapsing the data into "pre" and "post" periods to minimize the number of periods for each object, which helps to mitigate the serial correlation problem in difference-in-difference analysis. Following this method, I collapse the data from 2005-2009 into "pre" period (year 2005 and 2006) and "post" period (year 2007, 2008, and 2009). Similarly, I collapse the data from 2002-2009 into three periods: "pre" period I (year 2002 and 2003), "pre" period II (year 2004, 2005, and 2006), and "post" period (year 2007, 2008, and 2009).

It is worth noting that our sample is restricted to counties with a railroad at the beginning of our sampling period (year 1996). As county train stations also vary by size, we further exclude 98 out of 957 counties which own "large train stations" due to their historical importance in the railway system, as they might have also been considered important connections in the high-speed rail route.[13] However, the estimation results change little even if we include the counties with "large train stations."

3.2 Railroad data

In order to estimate the impact of high-speed rail upgrade in year 2004 and 2007 on counties being affected, I compare the economic performance of counties located on the upgraded railway lines to the counties located on conventional railway lines before and after high-speed rail upgrade, from year 2002 to 2009. Therefore, the railway status information of all the counties in China as of year 2008 is collected from the *People's Republic of China Railroad Atlas* published in 2008. A dataset including the list of counties with access to railroad in 2008 is constructed based on the above information, along with the name of the railway line(s) on which each county is located. In addition, I identified the railroads being constructed in each year from 1996 to 2007 along with its bypass counties from the annually published China Railroad Yearbook. I excluded from the sample such counties that did not have railroad access until year 1996, since the positive economic impact of a relatively new railroad may contaminate our estimation of high-speed rail upgrade on existing railway lines.

In addition to county railroad status, the frequency of daily passenger train stops in each county during 1996-2009 is also collected for descriptive purposes. The information is manually compiled from the published passenger train schedules in each year. Each train stop is matched to its county using the *China Train Station Encyclopedia*, published in 2003. The train stops not listed in the book are matched by online resources. It turns out that only

[13] Passenger train stations have been categorized into six levels according to their size and capacity, namely VIP stations and level one to level five stations. We denote "large train stations" as train stations above level three according to the standard in the 1990s.

a very small proportion of train stops (around 100 out of 6,000 stops) cannot be matched to its county, as these counties are very small in size in most cases. Because those small stations are generally serviced by very few trains, this fact little affects my descriptive statistics.

Figure 1 shows the number of operating passenger railway stations from 1996 to 2009. Around 3,000 passenger train stations were closed during the ten years of speed acceleration, especially during the high-speed rail upgrade (starting in 2004). More surprisingly, the number of counties with functioning passenger train stops is also decreasing, even with the expansion of new railway lines, as suggested in Figure 4. Hence the number of counties that have lost train service recently has exceeded the number of counties with new access to railroads. In contrast, the accessibility of railroads in cities has slightly increased.

Figure 5 shows the average daily train stops in each city and county during 1996-2009. It is clear that train service is much more frequent in cities than in counties. The average number of daily train stops is around 70-90 times for cities during 1996-2009, compared to merely 20-30 times for counties. Furthermore, after 2004, the average number of daily train stops indicates a decreasing trend for counties but an increasing trend for cities, in accordance with the fact that the train stations in small counties were skipped after the introduction of high-speed rail.

Figure 6 and 7 provide the distribution of average daily train stops in counties in 1996 and 2007, respectively. Two stylized facts can be revealed from those maps. First, the accessibility to trains is distributed unequally across counties in both years. The county with the least accessibility to railroad had only one daily train stop in 1996, while the county with the most accessibility had 345 daily train stops. However, in 2007, the county with the most accessibility to railroad service had 165 train stops, a 50 percent reduction from 1996. Second, the accessibility to trains decreased during the speed acceleration. The median of daily train services is 18 trains per day in 1996 and 14 trains per day in 2007. The two color-coded maps illustrate the decline in average accessibility to trains that accompanied the speed acceleration that occurred between 1996 and 2007.

3.3 County statistics data

The county statistics dataset is collected from the China Economic and Social Development Statistical Database provided by China National Knowledge Infrastructure (CNKI), which is compiled from all the publicly available statistical yearbooks and other published statistical reports.[14] All the counties and county-level cities in China have been included in the analysis except (1) counties administered by the four municipalities, namely Beijing,

[14]The database is available at http://tongji.cnki.net/kns55/Dig/dig.aspx with institutional access.

Shanghai, Tianjin, and Chongqing, as they are directly governed by the municipalities and are too close to the start of main railway lines, and (2) counties in Tibet, as none of them had access to railroad until 2007, which makes it unnecessary to include them in the sample based on my identification strategy. Therefore, a total of 1,878 counties are included in the sample for descriptive purposes, with information on county GDP, GDP per capita and fixed asset investment. However, only counties with train access before 1996 are included in my estimation as mentioned in Section 3.2. There are 957 counties for estimation purposes. The time span of the county statistics is from 2002 to 2009.

People may have some concerns about the quality of GDP data in China. However, as suggested by Au and Henderson (2006), the GDP and other economic indicators at the local level are indeed of high quality. Since our unit of analysis in this paper is at the county level, there should be little concern that the results are driven by the quality of the data.

4 Findings

4.1 Descriptive statistics

Table 1 shows the descriptive statistics for county level railway status and economic outcome indicators. As mentioned in the previous section, only counties with a railroad before 1996 are included. Thus, a total of 957 counties have been included in the sample, with 171 of them located on five main railway lines and 786 located on other railway lines. On average, in year 2003, around 28 trains stopped in counties located on main railway lines on a daily basis, compared to around 22 trains stopping in counties located on other railway lines. However, in 2007, both numbers dropped, from 28 to 21 and from 22 to 18, respectively. This is evidence that the reduction in train service accessibility is more severe for counties located on main railway lines than for others. In terms of economic outcomes, counties located on main railway lines on average have higher GDP, GDP per capita, and fixed asset investment. The GDP doubled from 2003 to 2007 for both groups of counties. The fixed asset investment almost tripled for both groups.

4.2 Difference-in-difference (OLS) estimation

Table 2 shows the OLS regressions for the impact of high-speed rail upgrade in 2004 and 2007. Estimation results are reported for two sub-samples: 2005-2009 (which is tested for the high-speed rail upgrade in 2007) and 2002-2009 (which is tested for the high-speed rail upgrade in both 2004 and 2007). The OLS estimation using difference-in-difference specification generally suggests that the high-speed rail upgrade, especially in year 2007, hinders economic development in the affected counties. Column 1-4 of Table 2 suggests a significant GDP and GDP per capita reduction after the high-speed rail upgrade in 2007 in the counties located on the affected railway lines, which is around 4-5 percent in magnitude.[15] However, the impact of earlier upgrade in 2004 is not significant with a negative magnitude in Column 2 and 4. The insignificant coefficient can be explained by two facts. First, the mileage of high-speed rail upgrade in 2004 is 1,960 kilometers, which is only one third of the completed upgrade in 2007 (around 6,000 kilometers.) Second, only 19 pairs of nonstop city transit trains were operating on the upgraded lines in 2004, compared to 257 CRH trains operating on the high-speed rails in 2007. Both facts illustrate that the intensity of the upgrade in 2004 is less than that in 2007. The GDP reduction is likely to be driven by a reduction of investment, as suggested in Column 5-6 of Table 2. The decrease of fixed asset investment in the high-speed rail affected counties in 2007 is around 10-11 percent, which is doubled compared to the reduction of GDP.

4.3 Event study

The OLS estimation suggests that the high-speed rail upgrade in 2007 significantly hurts the economic growth in the affected counties. However, a prerequisite for the validity of difference-in-difference design is that the pre-trend of outcome variables between control and treatment groups should be similar. In this subsection, I present event study graphs that plot the effects of high-speed rail upgrade in 2007 on the economic performance of affected counties. These graphs are derived from the following regression model:

$$\begin{aligned} Outcome_{i,t} = &\beta_0 + \sum_{k=-5}^{2} \alpha_k HSR_i * \mathbb{1}\{Yr_t = k\} \\ &+ \gamma Year_t * Province_i + \delta County_i + \epsilon_{i,t} \end{aligned} \tag{3}$$

where $\mathbb{1}\{Yr_t = k\}$ is an event time indicator equal to 1 for each year before and after the high-speed rail upgrade. Year zero is the year that the high-speed rail upgrade was implemented. For example, in year 2007, $Yr_t = 0$; while in year 2006, $Yr_t = -1$. In order to compare the effects of the event over years with the year right before the high-speed rail

[15]The impact of high-speed rail upgrade on GDP per capita may work through its impact on population changes. However, as suggested in Appendix Table A2, population is basically not affected in the treated counties of high-speed rail upgrade. There seems to be a one percent increase in overall population after high-speed rail upgrade in 2007 in one of the two specifications. But none of the other population measures (rural population, total number of households, and total number of rural households) is significantly affected by high-speed rail upgrade.

upgrade, year 2006 is taken as the baseline year. Therefore its coefficient ($k = -1$) is not reported in this event study. It is worth mentioning that counties that were affected by the high-speed rail upgrade in 2004 have been excluded from this analysis since the event study focuses on the upgrade in 2007.

Figure 8 plots the event study coefficients, α_k, and 95% confidence intervals within a seven-year event window. The point estimates represent the time path of outcome variables, i.e., GDP, GDP per capita, and fixed asset investment affected by high-speed rail upgrade relative to non-affected counties conditional on county and province*year fixed effects. All three graphs support the validity of the design since none of the coefficients are significantly different from zero prior to the high-speed rail upgrade in year zero, which indicates little difference in prior growth trend between the treatment and control groups. The graphs also suggest that there seems to be a drop in GDP, GDP per capita, and fixed asset investment right after the high-speed rail upgrade, which is consistent with the previous estimation. Additionally, the negative effect is estimated to be larger as time goes by.

4.4 Regional favoritism

In order to further verify the irrelevance of regional favoritism, we collect the hometown and working experience information for all the state level, vice state level leaders, as well as Minister and Vice Minister of Railways during the period 2002-2009. In total, we have 56 counties which are the hometown of the high rank leaders in the country during 2002-2009, 91 counties which are either the hometown of such leaders or the counties the leaders previously worked in. Table 4 provides the statistics to compare the status of those "politically connected" counties with the "non-connected" counties in terms of railway upgrade and railway accessibility. Interestingly, we actually find that a slightly lower share of "politically connected" counties were selected for railway upgrade compared to the share of "non-connected" counties. Moreover, on average, those "connected" counties also have less railroad access compared to the rest of the counties. Conditional on having railroad access, the share of counties selected into railway upgrade is about the same in both groups. [16] Therefore, it is unlikely that the estimated impact is driven by regional favoritism.

4.5 Instrumental variable estimation

In addition to the standard difference-in-difference estimation, I use an instrumental variable estimation strategy to account for the possible non-random placement of high-speed rail

[16] 18.5 percent and 18.1 percent for "connected" and "non-connected" counties in Panel A, respectively; 19.4 percent and 18.1 percent for "connected" and "non-connected" counties in Panel B, respectively.

upgrade. More specifically, I use whether a county is located on the main railway lines to identify whether it is affected by the speed acceleration or not. Table 3 presents the reduced form estimation following Equation (2), by regressing the economic indicators on the "main railway lines" dummy and its interaction with year dummies, controlling for county fixed effect and the growth trend in each province and year. It can be seen from the significance of the coefficients that the instruments, namely being located on the main railway lines over years, are good explanatory variables of GDP and GDP per capita variations at the county level. Moreover, being located on the main railway lines is a greater disadvantage for county economic growth during the high-speed rail upgrade. For example, the coefficients on $Mainline*Year07$ are negative in all of the six regressions in Table 3, with three of them significant at the 0.01 level. The coefficients for $Mainline*Year08$ and $Mainline*Year09$ are all negative and generally larger than the coefficient for $Mainline*Year07$, which describes the trend of increasing discrepancy of GDP growth between counties located on main railway lines and other lines.

Table 5 reports the Two-Stage Least Square (2SLS) estimation for the impact of high-speed rail on the three outcome variables. The First stage F statistic is 12.16 for the endogenous variable "$HSR07*After$" and 71.91 for "$HSR04*After$," which shows the strong correlation between instruments and endogenous program placement. The magnitude and significance for the 2SLS estimation is similar to the OLS estimation, except for the coefficient of "$HSR04*After$" on the impact of GDP growth (Column 2, Row 1 of Table 5). The same coefficient is negative without significance in the OLS regression in Table 2. However, the coefficient is negative and significant at the 0.05 level in the 2SLS estimation, which is consistent with the significant negative coefficient on $Mainline*Year04$ in the reduced form estimation (Column 2, Row 3 of Table 3.) In addition, the predicted average GDP growth rate for the non-affected counties and affected counties are 24.6% and 18.5% from year 2006 to 2007 according to the 2SLS estimation.[17] Therefore, the estimated impact of high-speed rail upgrade on GDP growth, which is 3.9% after translating the coefficient on log GDP into growth rate, explains around 64% of the GDP growth rate differences between the two groups.

To summarize, the findings in Table 2 and Table 5 suggest that high-speed rail upgrade negatively impacts the economic growth of the counties located on the affected railway lines. More specifically, the GDP and GDP per capita of such counties decrease by 4-6 percent, which is around 336-503 million *yuan* annually, given the average county level GDP as 8.39

[17]Specifically, the average predicted values of log GDP for non-affected counties are 3.65 and 3.87 in 2006 and 2007, so the growth rate is $e^{0.22}-1$ which equals to 24.6%. Similarly, the average predicted log GDP for affected counties in these two years is 4.11 and 4.28, so the growth rate is $e^{0.17}-1$ which equals to 18.5%. The predicted values are derived from the 2SLS estimation.

billion *yuan* in 2006 in the affected regions. Such negative impact explains around 64% of the GDP growth differentials between the affected and non-affected counties in the year of the high-speed rail upgrade. Furthermore, the reduction of fixed asset investment is doubled in terms of GDP reduction, which is around 10-11 percent in terms of magnitude. This can be translated as a reduction of 365-402 million *yuan* annually, given the average county-level fixed asset investment as 3.65 billion *yuan* in 2006 in the affected regions. Therefore, it can be concluded that the GDP reduction is mainly investment driven and can be explained by the drop in fixed asset investment to a large extent.

4.6 Robustness check using collapsed data

The OLS estimation for the collapsed data is reported in Table 6. The results for OLS regressions are consistent with the estimation using disaggregated data, which further verifies the robustness of the difference-in-difference specification.

5 Discussion

5.1 Heterogeneous impacts in different sectors

The main findings discussed in the above section suggest that the counties located in the high-speed rail upgrade railway lines have suffered from economic slowdown in terms of GDP, GDP per capita, and fixed asset investment compared to counties located on the non-affected railway lines. In addition, such negative impact is especially strong for the high-speed rail upgrade in 2007 compared to the early round of upgrade in 2004 due to its wider coverage with higher-lifted speed.

Since high-speed rail upgrade only affects the passenger rail services, while leaving the freight services almost unchanged, it may generate a larger negative impact on service industries (more sensitive to transportation cost of passengers) than on manufacturing industries (more sensitive to transportation cost of goods). To test this hypothesis, I estimate the impacts of high-speed rail upgrade on industrial and service sector value added in log forms following the same specifications as shown in Table 2 and 5.

Table 7 reports the heterogeneous impacts of the railway upgrade on industrial sector and service sector using both OLS and IV estimation. It is suggested that the growth rate of service sector value added was reduced by 3-4 percent after the upgrade in 2007 in the affected counties. However, it seems that high-speed rail upgrade does not significantly affect the growth rate of industrial sector value added. These estimation results validate the hypothesis that the upgrade on passenger rail services affects service industries more than manufacturing industries.[18]

5.2 Impacts by distance to the nearest high-speed train station

Counties are not equally distant to high-speed train stations in the urban areas. Some are close to the urban districts, while others are a few hundred kilometers away. It is thus interesting to examine whether the negative impact of high-speed rail upgrade varies by the geographical proximity to high-speed train stations. On the one hand, it is possible that the counties close to the urban core were negatively affected the most since more investment was diverted from such counties to the well-connected urban areas due to proximity. On the other hand, it is also be possible that the counties distant from the urban areas were hurt the most since positive agglomeration spillovers from the cities to the nearby counties may offset some of the negative impact in these counties close to high-speed train stations.

In order to test the possible heterogeneous impacts by distance to high-speed train stations, I compute the distance (unit:100 km) from the centroid of each county to the centroid of its nearest city with high-speed train stations, and interact the distance and squared distance with the difference-in-difference coefficient to estimate the possible heterogeneous impacts. Table 8 shows the results. "$HSR07 * After * Distance$" and "$HSR07 * After * DistanceSquared$" are the two triple difference terms. In addition to these terms, I also control for each pairwise interaction and the main effects. The results suggest that the impact of high-speed rail upgrade does not vary by the proximity to high-speed train stations in the urban areas. None of the triple difference terms are significant at the 0.1 level. The coefficient on "$HSR07*After*Distance$" is marginally negatively significant for fixed asset investment, indicating some weak evidence that the negative impact of high-speed rail on investment increased by distance.

5.3 Channels

There are two possible channels which may lead to economic slowdown in the high-speed rail affected counties. First, since high-speed trains squeeze out some of the conventional train services in the affected counties, the train accessibility decreases in those counties, which

[18] It will be more interesting to further investigate the impacts of high-speed rail upgrade on different industries within the service sector. However, industry level GDP is not available in the statistical yearbooks. I then use the total employment in different industries in each county reported in the 2000 and 2010 China Population Census to test the impact of high-speed rail upgrade on employment changes in four industries within the service sector: hotel and restaurant; financial services; real estate and rental services. I do not find significant negative impacts of high-speed rail on employment changes in these four industries from year 2000 to 2010.

implies a transportation cost (or trade cost) increase in such places. As a consequence, the affected counties will become less integrated and economic activities will decline in response to the increase in trade barriers. Second, high-speed rail upgrade connects large cities more tightly by reduced commuting time, which intensifies the agglomeration forces between large cities. In that case, it is likely that the economic activities will divert from small counties to large cities in order to enjoy the agglomeration spillovers generated from a more tightly connected transportation network. This possible channel resonates with the findings in Faber (2014) that the national trunk highway system in China leads to reduced industrial output in connected counties, given no reduction in transportation cost in those counties.

As mentioned in Section 2.1, a county being "affected" by high-speed rail, i.e., located on the high-speed rail upgrade lines, does not necessarily have a train service reduction after the rail upgrade since a county's overall train services are also determined by the services provided by other railway lines that pass through the county. Therefore, in order to test the validity of the first channel, I further examine the heterogeneous impact of high-speed rail upgrade in the affected counties that suffered from train service reduction in the year 2007 (group A) and the other affected counties that did not experience train service reduction during the same period (group B). If the increased trade cost due to train service reduction is a channel for the reduced economic activities in the affected counties, the impact of high-speed rail in group A should be more negative than that in group B since group A suffered from a larger increase in trade cost.

Table 9 presents the comparison of high-speed rail's impact between the above-mentioned two groups. The variable "*train service not reduced*" equals to one if the observations belong to group B, otherwise zero. While the interaction term between the double difference coefficient ($HSR * After$) and the trade cost dummy variable (*train service not reduced*) indicates the difference of high-speed rail's impact between the two groups. It is shown that two out of the three interaction terms are positive, which works in favor of our hypothesis that the impact of high-speed rail upgrade on group B is less negative than that on group A. However, the difference in terms of impact is not statistically significant which provides weak support to the first channel.

In order to test the second channel, i.e., whether the improved agglomeration benefits between large cities after high-speed rail upgrade diverted economic activities from small counties to large cities, I collected the highway status of all the counties in the sample before and after the high-speed rail upgrade in 2007. The story is that, if a county has already been connected to the highway network prior to high-speed rail upgrade in 2007, some of its economic activities have already been diverted to the large cities on the highway network (Faber, 2014). Therefore, if the second channel works, the high-speed rail upgrade's negative impact on diverting economic activities away should be smaller comparing to its impact in counties that had no highway network prior to high-speed rail upgrade.

Table 10 displays the comparison of high-speed rail's impact between counties with and without highway access prior to high-speed rail upgrade in 2007. The dummy variable "$connected\ to\ highway\ before$ 2007" equals to one if the county was connected to the highway network before year 2007, zero otherwise. Similar to the test of the first channel, an interaction term between double difference coefficient and highway status ($HSR07 * After * Connected\ to\ Highway\ before$ 2007) is included in the regression to test the differential impact in counties with different highway access. It is shown in Table 10 that all the three interaction terms have a positive coefficient, indicating that counties with highway access prior to 2007 suffered less from high-speed rail upgrade than counties without highway access. Especially, the differential impact between the two groups is most significant for GDP in terms of both magnitude and significance. High-speed rail upgrade reduced GDP by only 3 percent in counties with highway access, while the impact in counties without highway access was three times larger (9 percent). Therefore, the second channel is likely to play a role in explaining counties' reduced economic activities due to high-speed rail upgrade.

5.4 Magnitude of the impact

The main results suggest that high-speed rail upgrade negatively impacts the GDP growth rate of the counties located on the affected railway lines by 4-5 percent. Answers to the following two questions may help us better understand the magnitude of such impact. How large is the impact compared to the average economic growth rate in those areas? The annual GDP grew from 4.38 billion *yuan* in 2002 to 13.65 billion *yuan* in 2009 in the affected counties, with an overall growth rate of 311.6%, translating into an annual growth rate of 17.6%. This implies that the magnitude of 4-5 percent GDP reduction is economic significant for the economic growth of the counties affected by the upgrade. [19]

[19]Given that high-speed rail upgrade leads to significant economic slowdown in the affected counties, the next question to ask is whether the GDP reduction in counties outweighs the economic gains in cities, which makes high-speed rail upgrade an unattractive investment in terms of its economic returns. Given that the average GDP for the 183 affected counties is 8.39 billion *yuan* in 2006, the total loss of GDP in the 183 counties is 76.77 billion *yuan* in 2007.[20] During our sample period, a total of 80 cities have been connected with high-speed rail in 2007, thus the net economic return of the investment in its first year would be positive as long as the average economic benefit in cities exceeds 76.77/80 = 0.96 billion *yuan*. In Appendix B, I briefly discuss about the issues on estimating high-speed rail's impact on cities being better connected. Since there is no credible estimate on the causal impact of high-speed rail upgrade on GDP growth in cities, I use Panel B of Table A3 as a possible benchmark, where the estimated benefit of the upgrade is 16.76-21.67 billion *yuan* of GDP increase in the affected cities. Based on that, the benefit that high-speed rail upgrade brought to cities seems to be more than enough to compensate for the losses in counties.

6 Conclusion

Infrastructure is supposed to promote economic growth. However, infrastructure investment with a preference in the urban sector may generate negative externalities to the less developed rural sector in developing countries. The quasi-experiment of high-speed rail upgrade in China in the year 2004 and 2007 provides an ideal case to study the distributional consequences of infrastructure investment.

Applying difference-in-difference strategy, I come out with the following main conclusions. First, by comparing GDP and GDP per capita of counties located on the affected railway lines to counties located on other railway lines, evidence suggests that there is a 4-6 percent significant reduction in GDP and GDP per capita after the 2007 high-speed rail upgrade in the counties located on the affected railway lines. Such impact could explain around 64% of the predicted GDP growth differentials between the affected and non-affected counties right after high-speed rail upgrade. Second, the GDP reduction in the high-speed rail bypassed counties, which is around 336-503 million *yuan*, given the average county level GDP as 8.39 billion *yuan* in 2006, can be largely explained by the concurrent drop in fixed asset investment. Third, since high-speed rail upgrade affects the transportation of passengers and not transportation of goods, its negative impact is more pronounced in the service sector than in the manufacturing sector. Lastly, the diverted economic activities from small counties to large cities due to increased agglomeration forces is likely to be a channel accounting for the negative impact of high-speed rail. Together, these results imply that the distributional implications of these types of investments can be dramatic.

One caveat of the paper is that we ignore the "general equilibrium" effect of high-speed rail upgrade in the overall transportation network. For example, the counties not selected for high-speed rail upgrade, or even without railway accessibility, could still be impacted indirectly by the project since they were connected with the affected counties by railroad, highway, road, and other modes of transportation. Similarly, these counties were also connected with the cities upgraded into high-speed rail in some ways. Therefore, the "control counties" actually could experience both negative spillovers from the counties left behind, as well as positive spillovers from the cities being better connected after the railway upgrade. However, in our analysis, we assume that these counties not on the upgraded railway lines were not affected by the project, which might not be true. Even though we have tried our best to mitigate the concern about this issue, for example, by providing the event study, we await for future research to understand more about the "general equilibrium" effect in infrastructure investment.

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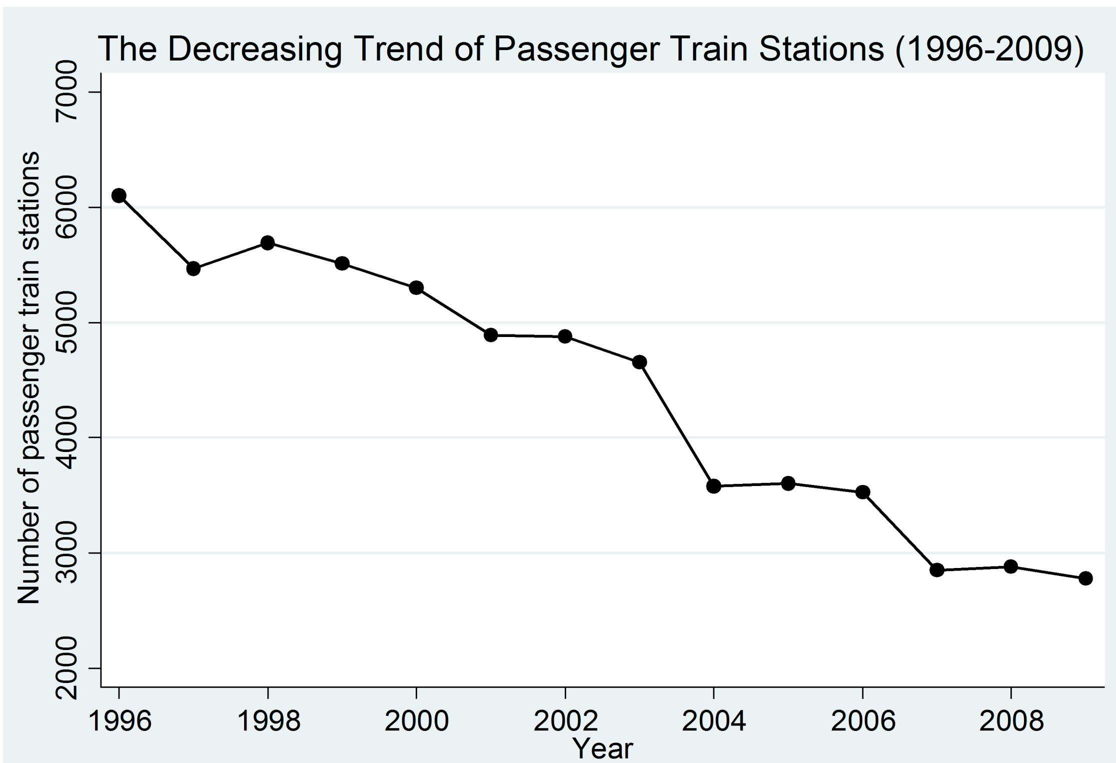
Figure 1: The Decreasing Trend of Passenger Train Stations (1996-2009)



Source: Author's calculation based on passenger train schedule, 1996-2009.

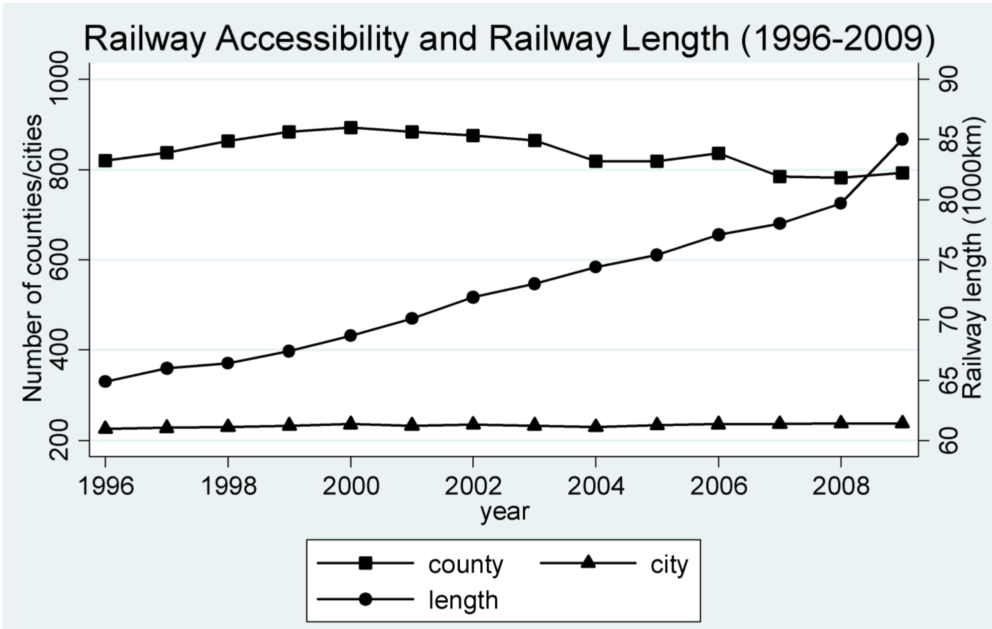
Figure 2: High-Speed Rail Upgrade in 2004

GIS source: China Data Center (University of Michigan).

Figure 3: High-Speed Rail Upgrade in 2007

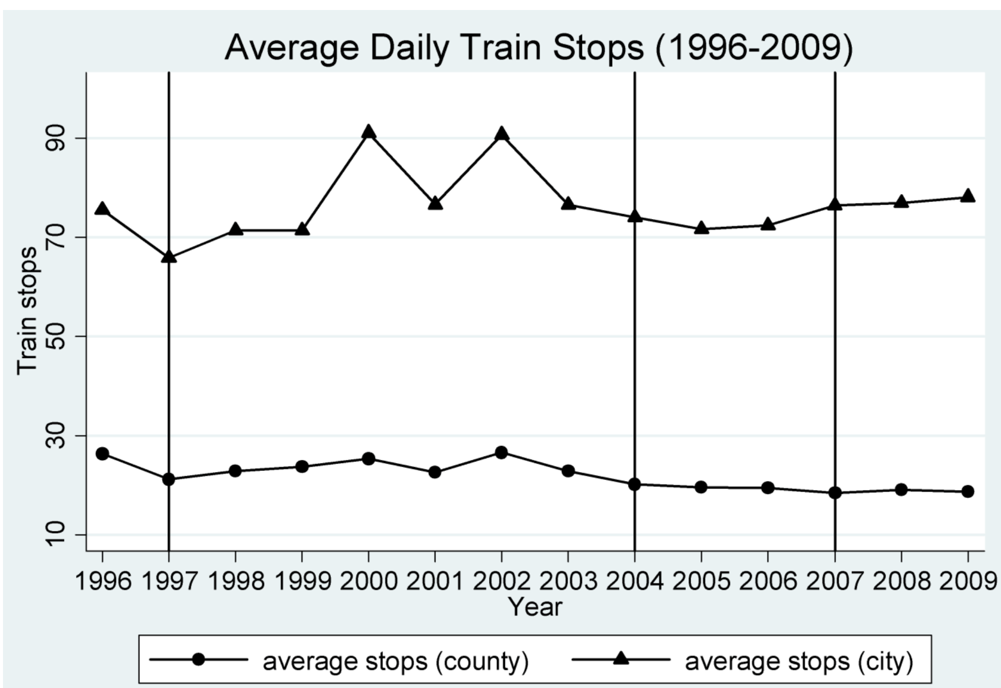
GIS source: China Data Center (University of Michigan).

Figure 4: Railway Accessibility and Railway Length (1996-2009)



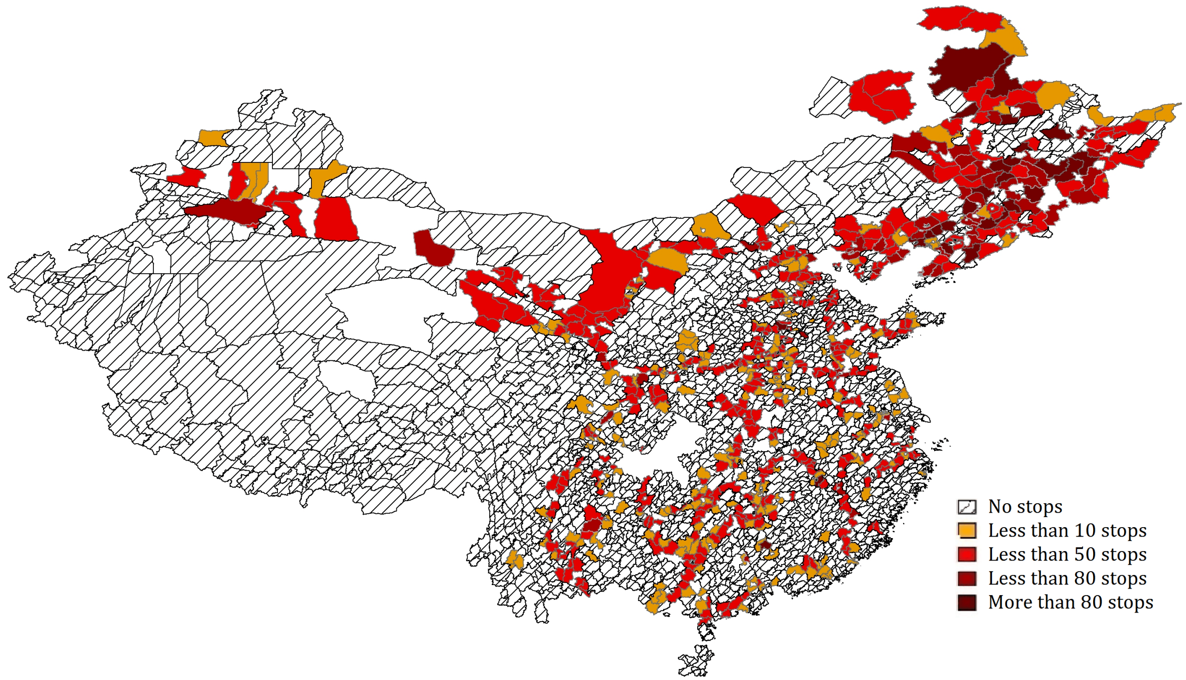
Sources: 1. Data on railway length is from National Statistical Yearbook; 2. Data on railway accessibility is by author's calculation based on passenger train schedule, 1996-2009.

Figure 5: Average Daily Train Stops by City and County (1996-2009)



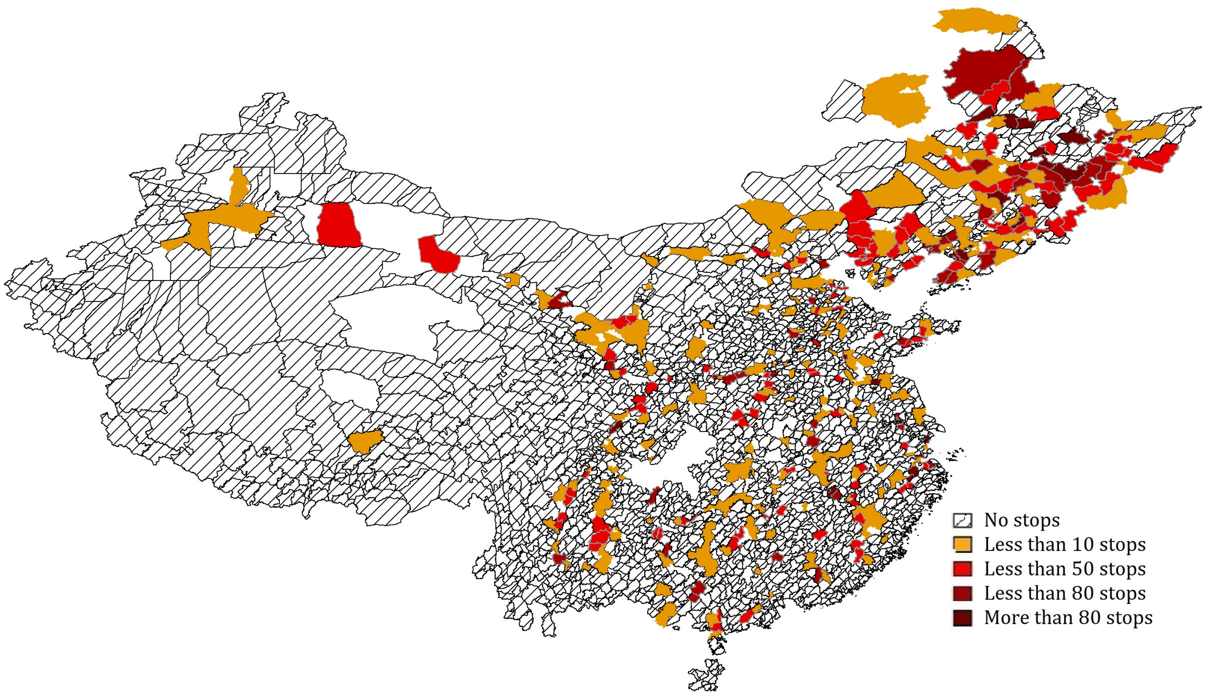
Source: Author's calculation based on passenger train schedule, 1996-2009.

Figure 6: Daily Average Train Stops in the Counties, 1996



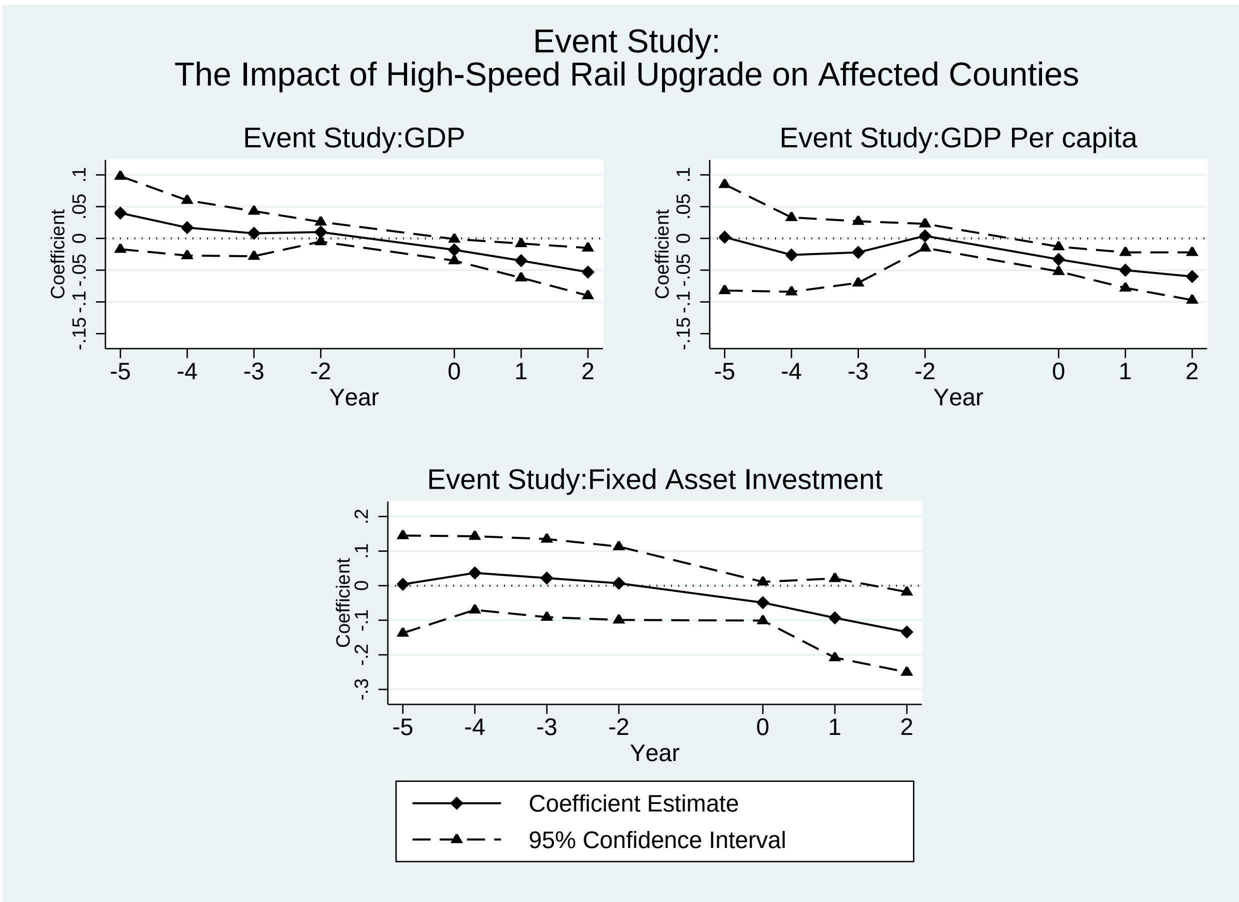
GIS source: China Data Center (University of Michigan). Blank areas are urban districts of prefecture-level cities, which are not included in our analysis.

Figure 7: Daily Average Train Stops in the Counties, 2007



GIS source: China Data Center (University of Michigan). Blank areas are urban districts of prefecture-level cities, which are not included in our analysis.

Figure 8: Event Study: The Impact of High-Speed Rail Upgrade on Affected Counties



Notes: 1. Year 0 indicates year 2007, when the second round of high-speed rail upgrade was implemented. Year -1 (year 2006) is the baseline year for comparison. 2. For each coefficient, the 95% Confidence Interval is reported.

Table 1: Descriptive Statistics

	2003		2007		Source
A. Railway Status	Main RL	Other RL	Main RL	Other RL	
Number of Counties	171	786	171	786	*Peoples Republic of China Railroad Atlas*
Average Daily Train Services (with Stops)	27.67	21.74	20.79	17.62	*China Passenger Train Schedule (annually)*
	(26.22)	(22.91)	(20.04)	(17.87)	
B. Economic Outcomes					
GDP (100 million yuan)	47.19	36.72	94.77	73.61	*China Economic and Social Development Statistical Database*
	(44.29)	(37.59)	(107.65)	(74.94)	
GDP Per Capita (1000 yuan)	9.58	7.24	16.06	15.01	*China Economic and Social Development Statistical Database*
	(14.87)	(4.96)	(15.42)	(12.19)	
Fixed Asset Investment (100 million yuan)	15.03	12.56	41.87	36.87	*China Economic and Social Development Statistical Database*
	(17.16)	(15.82)	(40.59)	(37.30)	

Notes:1. Main RL stands for"Main Railway Lines"; Other RL stands for "Other Railway Lines." 2. Mean and standard deviation (in parentheses) is reported for each of the variables.

Table 2: The Impact of High-Speed Rail on County Economic Outcomes (OLS)

	Dependent Variables					
	Ln GDP		Ln GDP Per Capita		Ln Fixed Asset Investment	
	2005-2009	2002-2009	2005-2009	2002-2009	2005-2009	2002-2009
HSR04*After		-0.04		-0.08		-0.07
		(0.03)		-0.07		(0.05)
HSR07*After	-0.04***	-0.05***	-0.05***	-0.05***	-0.10**	-0.11***
	(0.01)	-0.02	(0.01)	-0.01	(0.04)	(0.04)
County Fixed Effect	Yes	Yes	Yes	Yes	Yes	Yes
Province*Year Fixed Effect	Yes	Yes	Yes	Yes	Yes	Yes
R-Squared	0.99	0.98	0.92	0.91	0.89	0.90
Observations	4,689	7,498	4,614	6,431	3,953	6,327

Notes:1. Robust standard errors clustered at county level are reported in parentheses. 2. * significant at the 0.1 level; ** significant at the 0.05 level; *** significant at the 0.01 level.

Table 3: The Impact of High-Speed Rail on County Economic Outcomes (Reduced Form)

	Dependent Variables					
	Ln GDP		Ln GDP Per Capita		Ln Fixed Asset Investment	
	2005-2009	2002-2009	2005-2009	2002-2009	2005-2009	2002-2009
Mainline	-0.47***	-0.15***	0.15***	0.61***	-0.36***	-0.36***
	(0.02)	(0.04)	(0.02)	(0.04)	(0.07)	(0.06)
Mainline*Year03		-0.01		0.04		0.05
		(0.01)		(0.06)		(0.04)
Mainline*Year04		-0.04**		0.00		0.00
		(0.02)		(0.03)		(0.05)
Mainline*Year05		-0.03		0.01		-0.01
		(0.02)		(0.04)		(0.06)
Mainline*Year06	-0.02**	-0.06**	-0.01	0.00	-0.05	-0.06
	(0.01)	(0.03)	(0.01)	(0.04)	(0.05)	(0.05)
Mainline*Year07	-0.04***	-0.07***	-0.04***	-0.03	-0.08	-0.09
	(0.01)	(0.03)	(0.01)	(0.04)	(0.05)	(0.06)
Mainline*Year08	-0.05***	-0.08***	-0.07***	-0.06	-0.13**	-0.14**
	(0.02)	(0.03)	(0.02)	(0.04)	(0.06)	(0.07)
Mainline*Year09	-0.07***	-0.10***	-0.08***	-0.07	-0.16**	-0.17***
	(0.02)	(0.03)	(0.02)	(0.04)	(0.07)	(0.06)
County Fixed Effect	Yes	Yes	Yes	Yes	Yes	Yes
Province*Year Fixed Effect	Yes	Yes	Yes	Yes	Yes	Yes
R-Squared	0.99	0.98	0.92	0.91	0.89	0.90
Observations	4,689	7,498	4,614	6,431	3,953	6,327

Notes:1. Robust standard errors clustered at county level are reported in parentheses. 2. * significant at the 0.1 level; ** significant at the 0.05 level; *** significant at the 0.01 level.

Table 4: Test of Regional Favoritism

	Panel A: Hometown Connection			
	Connected		Not Connected	
	Number	Share	Number	Share
Upgraded	5	8.9%	177	9.7%
Not Upgraded	22	39.2%	800	43.9%
No Rail	29	51.8%	845	46.4%
Total	56	100%	1822	100%
	Panel B: Hometown and Career Connection			
	Connected		Not Connected	
	Number	Share	Number	Share
Upgraded	7	7.7%	175	9.8%
Not Upgraded	29	31.9%	793	44.4%
No Rail	55	60.4%	819	45.8%
Total	91	100%	1787	100%

Notes: 1. Panel A only considers hometown connection, while Panel B considers both hometown and career connections. 2. Data is hand collected from online resumes of political leaders by the author.

Table 5: The Impact of High-Speed Rail on County Economic Outcomes (2SLS)

	Dependent Variables					
	Ln GDP		Ln GDP Per Capita		Ln Fixed Asset Investment	
	2005-2009	2002-2009	2005-2009	2002-2009	2005-2009	2002-2009
HSR04*After		-0.08**		-0.06		-0.10
		(0.03)		(0.09)		(0.07)
HSR07*After	-0.04***	-0.04***	-0.06***	-0.05***	-0.10***	-0.11***
	(0.01)	(0.01)	(0.01)	(0.01)	(0.04)	(0.04)
County Fixed Effect	Yes	Yes	Yes	Yes	Yes	Yes
Province*Year Fixed Effect	Yes	Yes	Yes	Yes	Yes	Yes
R-Squared	0.99	0.98	0.92	0.91	0.89	0.90
Observations	4,689	7,498	4,614	6,431	3,953	6,327

Notes:1. Robust standard errors clustered at county level are reported in parentheses. 2. * significant at the 0.1 level; ** significant at the 0.05 level; *** significant at the 0.01 level. 3. The first stage F statistic is 12.16 for column 1, 3, 5; 71.91 and 12.16 for the two endogenous policy variables in column 2, 4, 6.

Table 6: The Impact of High-Speed Rail on County Economic Outcomes (OLS, Collapsed Data)

	Dependent Variables					
	Ln GDP		Ln GDP Per Capita		Ln Fixed Asset Investment	
	2005-2009	2002-2009	2005-2009	2002-2009	2005-2009	2002-2009
HSR04*After		-0.04		-0.09		-0.09*
		(0.03)		(0.09)		(0.05)
HSR07*After	-0.04**	-0.05**	-0.05***	-0.05***	-0.11**	-0.12**
	(0.02)	(0.02)	(0.02)	(0.02)	(0.05)	(0.05)
County Fixed Effect	Yes	Yes	Yes	Yes	Yes	Yes
Year Fixed Effect	Yes	Yes	Yes	Yes	Yes	Yes
R-Squared	0.99	0.98	0.95	0.92	0.89	0.92
Observations	1,880	2,819	1,880	2,528	1,616	2,458

Notes:1. Robust standard errors clustered at county level are reported in parentheses. 2. Year fixed effect instead of year*province fixed effect is used in the regressions since the estimation of year by province trend requires a panel data of more than two periods. 3. * significant at the 0.1 level; ** significant at the 0.05 level; *** significant at the 0.01 level.

Table 7: Heterogeneous Impacts of High-Speed Rail Upgrade in Different Sectors

	Panel A: OLS Estimation			
	Ln (Industrial Sector Value Added)		Ln (Service Sector Value Added)	
	2005-2009	2002-2009	2005-2009	2002-2009
HSR04*After		-0.05		-0.05
		(0.05)		(0.03)
HSR07*After	-0.03	-0.04	-0.03*	-0.03
	(0.02)	(0.03)	(0.02)	(0.02)
County Fixed Effect	Yes	Yes	Yes	Yes
Province*Year Fixed Effect	Yes	Yes	Yes	Yes
R-Squared	0.99	0.96	0.98	0.96
Observations	4,705	7,528	3,564	5,819
	Panel B: IV Estimation			
	Ln (Industrial Sector Value Added)		Ln (Service Sector Value Added)	
	2005-2009	2002-2009	2005-2009	2002-2009
HSR04*After		-0.09		-0.02
		(0.05)		(0.04)
HSR07*After	-0.03	-0.03	-0.03**	-0.04*
	(0.02)	(0.02)	(0.02)	(0.02)
County Fixed Effect	Yes	Yes	Yes	Yes
Province*Year Fixed Effect	Yes	Yes	Yes	Yes
R-Squared	0.98	0.96	0.98	0.96
Observations	4,705	7,528	3,564	5,819

Notes:1. Robust standard errors clustered at county level are reported in parentheses. 2. * significant at the 0.1 level; ** significant at the 0.05 level; *** significant at the 0.01 level. 3. LIML instead of 2SLS estimator is used in Column 4 of Panel B due to asymmetric and singular variance matrix problem.

Table 8: The Impact of High-Speed Rail Upgrade Interacted with Distance to High-Speed Train Station

	Dependent Variables		
	Ln GDP	Ln GDP Per Capita	Ln Fixed Asset Investment
HSR07*After*Distance	0.00	0.00	-0.07
	(0.01)	(0.01)	(0.05)
HSR07*After*Distance Squared	0.00	0.00	0.00
	(0.00)	(0.00)	(0.00)
HSR07*After	-0.04**	-0.05**	-0.06
	(0.02)	(0.02)	(0.06)
Distance	-0.42***	-0.04***	-0.32***
	(0.00)	(0.00)	(0.04)
Distance Squared	0.02***	0.00***	0.01***
	(0.00)	(0.00)	(0.00)
Distance*After	-0.01	0.00	0.01
	(0.01)	(0.01)	(0.02)
Distance Squared*After	0.00	0.00	0.00
	(0.00)	(0.00)	(0.00)
Distance*HSR07	0.50***	0.08***	0.08*
	(0.01)	(0.01)	(0.05)
Dsitance Squared*HSR07	-0.02***	-0.00***	0.00
	(0.00)	(0.00)	(0.00)
County Fixed Effect	Yes	Yes	Yes
Province*Year Fixed Effect	Yes	Yes	Yes
R-Squared	0.99	0.91	0.88
Observations	4,054	3,979	3,374

Notes:1. Robust standard errors clustered at county level are reported in parentheses. 2. * significant at the 0.1 level; ** significant at the 0.05 level; *** significant at the 0.01 level. 3. The unit of distance is 100 kilometers.

Table 9: Channels: Increased Trade Cost in Affected Counties (2005-2009)

	Dependent variables		
	Ln GDP	Ln GDP Per Capita	Ln Fixed Asset Investment
HSR07*After	-0.05***	-0.05***	-0.12***
	(0.02)	(0.02)	(0.04)
Train service not reduced	0.09***	0.63***	-1.29***
	(0.02)	(0.02)	(0.06)
HSR07*After*Train service not reduced	0.02	0.00	0.04
	(0.02)	(0.02)	(0.05)
County Fixed Effect	Yes	Yes	Yes
Province*Year Fixed Effect	Yes	Yes	Yes
R-Squared	0.99	0.92	0.89
Observations	4,689	4,614	3,953

Notes:1. Robust standard errors clustered at county level are reported in parentheses. 2. * significant at the 0.1 level; ** significant at the 0.05 level; *** significant at the 0.01 level.

Table 10: Channels: Diverted Economic Activities to Large Cities (2005-2009)

	Dependent variables		
	Ln GDP	Ln GDP Per Capita	Ln Fixed Asset Investment
HSR07*After	-0.09***	-0.08***	-0.12**
	(0.03)	(0.03)	(0.05)
Connected to Highway before 07'	0.84***	0.81***	-0.43***
	(0.01)	(0.00)	(0.05)
HSR07*After*Connected to Highway before 07'	0.06*	0.03	0.01
	(0.03)	(0.03)	(0.06)
County Fixed Effect	Yes	Yes	Yes
Province*Year Fixed Effect	Yes	Yes	Yes
R-Squared	0.99	0.92	0.89
Observations	4,689	4,614	3,953

Notes:1. Robust standard errors clustered at county level are reported in parentheses. 2. * significant at the 0.1 level; ** significant at the 0.05 level; *** significant at the 0.01 level.

For Online Publication

A Railway network in China

China is the third Asian country to adopt a railroad system, after Japan and India. The first railroad in China, constructed in the year 1876 by the British, was a local railway near Shanghai. During the 73 years after the first railroad in China and before the founding of the People's Republic of China, around 23,000 kilometers of railroad were constructed in China. However, half of them were destroyed during World War II.

In 1949, railroad construction resumed and has been emphasized in almost all of China's "Five-Year Plans." By the late 1990s, the operating railroad length had been increased to around 66,000 kilometers, with six main railway lines connecting several largest cities in different parts of the country: 1) Beijing-Shanghai (*jinghu xian*); 2) Beijing-Haerbin (*jingha xian*); 3) Beijing-Guangzhou (*jingguang xian*); 4) Beijing-Hong Kong (*jingjiu xian*); 5) Lianyunguang-Urumqi (*longhai-lanxin xian*); 6) Beijing-Baotou (*jingbao xian*).

In late 2002, the new Minister of Railways, Zhijun Liu, proposed his "Great Leap Forward" strategy, which encouraged further expansion of the railroad network and many technology upgrades, including high-speed rail upgrades and construction [21]. The *Mid-long Term Railway Network Plan* enacted by the State Council in 2005 set the goal of expanding railroad length to 100,000 kilometers by the end of 2020, which was further revised to 120,000 kilometers in the year of 2008, with a budget of around 4,000 billion *yuan* (State Council, 2004, 2008). By the end of 2007, all the provinces in China had been connected with railroad networks, as suggested in Figure A1. However, it is clearly shown that the railroad coverage in the west, the relatively poor area, is significantly lower than in the east.

B The impact of high-speed rail placement on cities at the prefecture level

It is shown in the previous section that less connectivity to the outside due to high-speed rail upgrade is detrimental to the small counties located on the affected railway lines. Another relevant question to ask is: have large cities benefited from better connectivity due to high-speed rail placement? It is hard to identify clearly the impact of high-speed rail on cities since they are connected to the high-speed rail "on purpose" instead of "quasi-randomly" assigned. Therefore, the identification strategy used for counties cannot be applied to the

[21] See http://www.curb.com.cn/pageshow.asp?id_forum=000106 for more information.

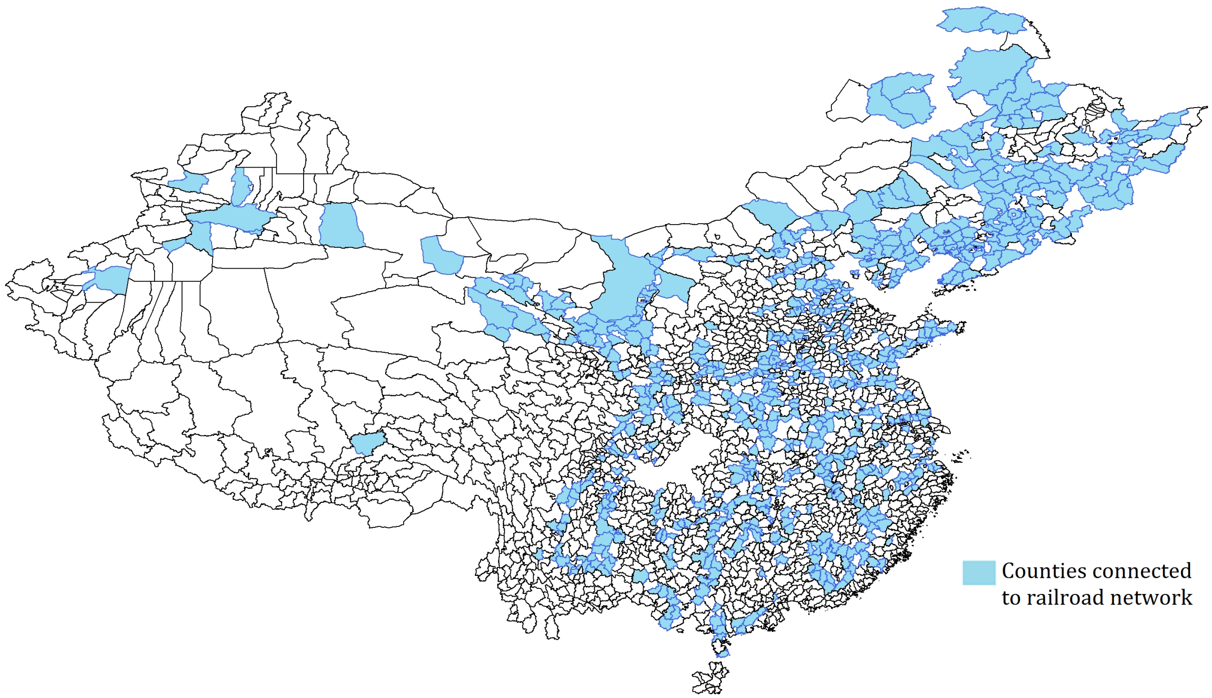
analysis of prefecture-level cities. However, in order to provide some suggestive evidence, an OLS analysis with exactly the same setting as Equation (1) has been conducted using all the prefecture-level cities with railroad access no later than 1996.[22]

Table A3 (Panel A and B) shows the "correlation" of high-speed rail upgrade on prefecture-level cities in terms of both level and growth. Interestingly, high-speed rail placement does not correlate with high economic growth in the affected cities, as none of the coefficients on the double difference term are significant, though 7 out of 9 coefficients have positive signs. However, the level regressions show that GDP and fixed asset investment levels significantly increase in cities with high-speed rail upgrade, while the level change of GDP per capita does not seem to correlate with high-speed rail.

In general, the correlation analysis in cities provides some suggestive evidence that high-speed rail upgrade has only a mild impact on economic growth in the prefecture-level cities. The result, though interesting, is not very surprising for two main reasons. First, a city economy has a much larger base than a county economy. Therefore, a positive shock in transportation technology may have only a trivial impact on economic growth rate, though its impact on economic levels may not be trivial. Second, cities generally have multiple, well-developed modes of transportation networks, including not only railroad, but also highway, air, and, in the coastal areas, water. Thus, the marginal productivity increase from a technological improvement of the railway system may not play an important role. However, the marginal productivity decrease due to lost connectivity to railroad transportation is likely to be more detrimental in counties as they generally have a less developed transportation network.

[22] All of the GDP, GDP per capita, and fixed asset investment measures include only urban areas (districts) affiliated with the prefecture level city.

Figure A1: Counties Connected to Railroad Network by Year 2007



GIS source: China Data Center (University of Michigan) and *People's Republic of China Railroad Atlas*. Blank areas are urban districts of prefecture-level cities, which are not included in our analysis.

Table A1: The Impact of Speed Acceleration on County Economic Development, 1996-2003

	Dependent Variables					
	Ln GDP		Ln GDP Per Capita		Ln Fixed Asset Investment	
	OLS	2SLS	OLS	2SLS	OLS	2SLS
Speed97	0.02	-0.06	0.09	0.20*	0.21	0.10
	(0.03)	(0.06)	(0.06)	(0.11)	(0.15)	(0.22)
Speed98	0.09*	0.07	0.18*	0.19*	-0.31*	-0.33
	(0.05)	(0.08)	(0.10)	(0.10)	(0.18)	(0.26)
Speed00	-0.02	0.02	-0.07	-0.08	0.04	-0.02
	(0.03)	(0.04)	(0.05)	(0.06)	(0.11)	(0.24)
Speed01	-0.01	0.01	-0.06	-0.06	-0.07	-0.08
	(0.02)	(0.01)	(0.07)	(0.06)	(0.09)	(0.07)
County Fixed Effect	Yes	Yes	Yes	Yes	Yes	Yes
Province*Year Fixed Effect	Yes	Yes	Yes	Yes	Yes	Yes
R-Squared	0.99	0.99	0.94	0.94	0.83	0.83
Observations	4,079	4,079	3,008	3,008	3,070	3,070

Notes:1. Robust standard errors clustered at county level are reported in parentheses. 2. * significant at the 0.1 level; ** significant at the 0.05 level; *** significant at the 0.01 level. 3. First stage F statistics are 29.5, 48.71, 108.86 and 8775.15 for the four endogenous variables, respectively.

Table A2: The Impact of High-Speed Rail on Demographics (OLS)

	Dependent Variables							
	Ln Total Population		Ln Rural Population		Ln Total Households		Ln Rural Households	
	2005-2009	2002-2009	2005-2009	2002-2009	2005-2009	2002-2009	2005-2009	2002-2009
HSR04*After		-0.01		-0.01		-0.01		-0.02
		(0.00)		(0.03)		(0.01)		(0.03)
HSR07*After	0.00	0.01**	0.01	0.01	0.00	0.00	0.00	0.01
	(0.00)	(0.00)	(0.03)	(0.02)	(0.00)	(0.01)	(0.04)	(0.02)
County Fixed Effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Province*Year Fixed Effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
R-Squared	0.99	0.99	0.95	0.96	0.99	0.99	0.94	0.96
Observations	4,792	7,696	4,672	7,559	4,791	7,695	4,678	7,573

Notes:1. Robust standard errors clustered at county level are reported in parentheses. 2. * significant at the 0.1 level; ** significant at the 0.05 level; *** significant at the 0.01 level.

Table A3: The Impact of High-Speed Rail on Prefecture Level City Economic Outcomes (OLS)

Panel A: Log Regressions						
	Ln GDP		Ln GDP Per Capita		Ln Fixed Asset Investment	
	2005-2009	2002-2009	2005-2009	2002-2009	2005-2009	2002-2009
HSR04*After		0.01		0.03		0.02
		(0.03)		(0.02)		(0.06)
HSR07*After	-0.01	0.01	-0.01	0.02	0.04	0.01
	(0.02)	(0.03)	(0.02)	(0.02)	(0.04)	(0.05)
City Fixed Effect	Yes	Yes	Yes	Yes		Yes
Province*Year Fixed Effect	Yes	Yes	Yes	Yes		Yes
R-Squared	0.99	0.99	0.98	0.98	0.97	0.96
Observations	1,176	1,884	1,185	1,896	1,177	1,883
Panel B: Level Regressions						
	GDP (100 million)		GDP Per Capita (yuan)		Fixed Asset Investment (100 million)	
	2005-2009	2002-2009	2005-2009	2002-2009	2005-2009	2002-2009
HSR04*After		122.82		1141.43		87.23**
		(100.77)		(1153.80)		(43.24)
HSR07*After	167.61**	216.69**	445.97	461.56	100.83**	109.12**
	(75.81)	(106.42)	(954.34)	(1211.27)	(41.41)	(47.20)
City Fixed Effect	Yes	Yes	Yes	Yes		Yes
Province*Year Fixed Effect	Yes	Yes	Yes	Yes		Yes
R-Squared	0.95	0.99	0.95	0.91	0.90	0.80
Observations	1,176	1,884	1,185	1,896	1,177	1,883

Notes:1. Robust standard errors clustered at city level are reported in parentheses. 2. * significant at the 0.1 level; ** significant at the 0.05 level; *** significant at the 0.01 level.