Do China's High-Speed-Rail Projects Promote Local Economy?
---New evidence from a panel data approach

(Preliminary draft)

Xiao KE
Wang Yanan Institute for Studies in Economics
Xiamen University
Email: xiaokeproperty@163.com

Haiqiang CHEN
Wang Yanan Institute for Studies in Economics
Xiamen University
Email: hqchen2009@gmail.com

Yongmiao HONG
Department of Economics
Cornell University
Email: yh20@cornell.edu

Cheng HSIAO
Department of Economics
University of Southern California
Email: chsiao@usc.edu

Abstract: This paper evaluates the effect of High Speed Rail (HSR) projects on the economic growth of targeted city nodes (HSR cities) in China using prefectural-level city data from 1990 to 2013. Employing a panel data program evaluation method devised by Hsiao, Ching and Wan (2012), we construct hypothetical counterfactuals for per capita real GDP of HSR cities in the absence of their respective HSR projects using the outcomes in selected non-HSR cities. We find that HSR projects have raised per capita GDP for most targeted cities we studied, while the ATEs of some HSR cities differ in magnitude or even in sign. Also, we find significant "run up" effects, indicating considerable treatment effects during the HSR construction period. HSR cities with positive ATEs spatially agglomerate on Huning corridor, and along Southeast coast HSR corridor. In general, the gain for local economies is greater for cities that are more industrialized, with more ability of the service sector to absorb enough labor, and with better supporting infrastructure. On the other hand, local protectionism hampers the development of HSR cities. We also show that at different project stages, HSR cities experience different gains.

Keywords: panel data; cross-sectional dependence; counterfactual analysis; transportation infrastructure; High-Speed-Rail; economic growth

JEL classification: C23, C51, C54, O18, R11

1. Introduction

Transportation infrastructure is a key to promote growth and development in a country. Since the birth of the world's first High-Speed Railway (HSR) in 1964, a huge amount of investment has been made mostly in the developed countries, e.g. Japan, Germany, France, Italy, Spain, the U.S, and etc. (International Union of Railways, 2010). In China, HSR has experienced a major growth and the HSR networks have expanded drastically over the past decade. China has constructed the world's longest HSR network with over 16,000 km of tracks in service, connecting 28 of the 33 provinces and regions, which is more than the rest of the world's HSR tracks combined together. In all, the Chinese government has planned to spend $300 billion to build a 25,000 km HSR network by 2020.

Given the increasing prevalence of HSR and the continuing huge amount of investment, a natural question is how effective HSR is in promoting economic growth. Existing studies for developed countries are far from conclusive. For example, Sasaki, Ohashi & Ando (1997) show that denser Shinkansen network do not contribute to regional dispersion of population. In contrast, Ahlfeldt & Feddersen (2010) finds that HSR in Germany sustainably promote economic activity for regions that enjoy an increase in accessibility. For China, a few emerging studies focus on HSRs. Zheng & Kahn (2013) discovers that HSR connection boosts housing prices. And Lin (2014) shows that HSR lead to an increase in urban employment but have no effect on GDP growth. However, Qin (2014) suggests that periphery counties on the upgraded rail lines slightly suffer from reduction in GDP and GDP per capita.

This study interested in answering the question: will the large-scale HSR construction projects benefit local economic growth for targeted city nodes? On one hand, if targeted city nodes along HSR benefit from the transportation project, the economic advantage of the regions with better political and/or economic status will be reinforced due to the HSR project, because these cities are more likely to be chosen as targeted nodes. This exactly runs counter to regional equality. On the other hand, it is possible that some regions gain very limited benefits or even loss in some aspect, due to the exiting of human and physical capitals as a result of lower transportation costs (Chandra & Thompson, 2000; Banerjee, Duflo & Qian, 2012)[1]. For policymakers to consider the trade-offs of investing in HSR and the distributional impact of infrastructure, a rigorous evaluation of the treatment effect of HSR projects on local economic growth is the first step.

This study uses a panel data program evaluation method recently developed by Hsiao, Ching and Wan (2012) to identify the effect of HSR projects on the targeted city nodes in China. The basic idea of Hsiao et al. (2012) is to exploit the cross-sectional dependence among HSR cities and selected non-HSR cities to construct counterfactuals of per capita GDP of HSR cities in the absence of respective HSR projects. Those cross-sectional correlations are attributed to the presence of a few latent common factors, e.g. global financial crisis, export shocks etc. in our empirical context, that explain the bulk of the variance of per capita real GDP[2].

---

1 For theoretical discussion, we refer to agglomeration shadow (Fujita & Krugman, 1995). For empirical evidence, we refer to "leakages effect" e.g. Munnell, 1992; Rephann & Iserman, 1994; Chandra & Thompson (2000), Faber (2014).

2 The rationality is well documented in Sargent and Sams (1997); Giannone Reichlin and Sala (2005); Stock and Watson (2005); Onatski, (2009).

Our main results are as follows. HSR projects have raised per capita GDP for most targeted cities we studied. We evaluate treatment effects city by city and find that 68% of the studied HSR cities have positive average treatment effects (ATEs) over the policy evaluation period. The ATEs differ in magnitude or even in sign. Also, we find significant “run up” effects, indicating considerable treatment effects during the HSR construction period. Third, HSR cities with positive ATEs spatially agglomerate on Huning corridor, and along Southeast coast HSR segments. Further estimates indicate that the gain on the local economy is greater for cities that are more industrialized, with more ability of the service sector to absorb labor, and with better supporting infrastructure. Local protectionism tends to hamper the development of HSR projects.

The rest of the paper is organized as follows: Section 2 describes the background. Section 3 introduces the method and data. Section 4 and 5 present the empirical results and Section 6 concludes.

2. High Speed Rail in China

Rail transport is an important mode of inter-region transportation in China, mainly because China is a very large country with a high population density and widely spaced large cities. Before the six rounds speed upgrading of existing rail lines from 1997 to 2007, the development of rail transportation lagged behind other transportation forms especially roads and aviation[3]. After ten years of preparation, the large-scale construction of HSR was on the agenda in the first decade of the 21st century. In 2008, the country embarked on a HSR construction boom. The State Council, in its revised Mid-to-Long Term Railway Development Plan, set the goal of expanding the railroad length to 120,000 kilometers by the end of 2020. The so called Four Vertical and Four Horizontal HSR framework constitutes the arterial HSR corridors of China and is built with priority. This national HSR network composed of four north-south corridors including: Beijing -Shanghai, Beijing-Guangzhou -Shenzhen-HongKong, Beijing-Harbin, Hangzhou-Fuzhou -Shenzhen, and four east-west corridors including: Xuzhou-Lanzhou, Shanghai-Kunming, Qingdao-Taiyuan and Shanghai-Wuhan- Chengdu HSRs (State Council, 2008). See Fig. 1 for a map of this national HSR grid. Construction of the Four Vertical lines have been completely and opened to public by the end of 2015.

The scheme of this HSR grid, according to the Plan, is to connect provincial capitals and other major cities with fast transportation corridors. Ministry of Railways (MOR) in China stated that, in general, the design of HSR lines and route placement should be based on a comprehensive consideration of economic development, population, resource distribution, national security, environmental concerns as well as social stability of each region.

3. Econometric Method and Data

3.1 Econometric Method

To assess the impact of HSR projects in China, we use the real GDP per capita series of non-HSR-cities[4] to construct the counterfactuals of HSR-cities, that is, the real GDP per capita of HSR-cities had they not been subject to the policy intervention of HSR projects. Similar to the

[3] From 1985 to 1996, railway operation mileages increase 4600 kilometers with an annual growth rate of just 1%, which is far below economic growth and the growth rate of roads.

approach of Hsiao et al. (2012), we exploit the dependence structure of per capita real GDP among different cities. The method attributes the cross-dependence to the presence of unobserved common factors that drive the per capita output level of relevant cities.

Specifically, let (y_{it}^1, y_{it}^0) denote the potential outcomes of city $i's$ per capita real GDP in year t with and without the HSR project intervention respectively. Then the treatment effect due to the HSR project to city i at time t is just

$$\Delta_{it} = y_{it}^1 - y_{it}^0 \tag{1}$$

As discussed above, we do not simultaneously observe y_{it}^0 and y_{it}^1. In other words, there is a missing data problem. The observed data is in the form of (y_{it}, d_{it}),

$$y_{it} = d_{it} y_{it}^1 + (1 - d_{it}) y_{it}^0 \tag{2}$$

where $d_{it} = 1$ if the $i'th$ city receives the HSR treatment and $d_{it} = 0$ otherwise.

Following Hsiao et al. (2012), we assume that there exists a $K \times 1$ vector of unobservable common factors f_t that drives per capita real GDP of all cities to change over time. We consider the case that there is no treatment to y_{it} for all i and for $t = 1,...,T_1$. For $t = T_1 + 1,...,T$ there is one unit, let us suppose the first unit without loss of generality, that receives a treatment, but all other units y_{it}, $j = 2,..., N$, do not receive any treatment.

Suppose y_{it}^0 is generated by a factor model of the form

$$y_{it}^0 = b_i^{'} f_t + \alpha_i + u_{it}, \quad i = i,..., N, t = 1,..., T, \tag{3}$$

where f_t denotes the $K \times 1$ (unobserved) common factors that vary over time, the loading coefficient b_i denotes the $K \times 1$ vector of constants that may vary across i, α_i is the fixed individual-specific effect and u_{it} is the idiosyncratic error with $E(u_{it}) = 0$.

Let $y_t = (y_{1t},..., y_{Nt})^{'}$ be an $N \times 1$ vector of y_{it} in year t. Since there is no policy intervention before T_1, then the observed y_t takes the form

$$y_t = y_t^0 = \alpha + \mathrm{B} f_t + u_t \quad \text{for} \quad t = 1,..., T_1, \tag{4}$$

where $y_t^0 = (y_{1t}^0,..., y_{Nt}^0)^{'}$, $\alpha = (\alpha_1,...,\alpha_N)^{'}$, $\mathrm{B} = (b_1,..., b_N)^{'}$ is the $N \times K$ factor loading matrix and $u_t = (u_1,..., u_N)^{'}$.

Since at time $T_1 + 1$, namely the cut-off point, the HSR project construction took effect for the first city, then from time $T_1 + 1$ on we have

$$y_{1t} = y_{1t}^1 = \alpha_1 + b_1^{'} f_t + \Delta_{1t} + u_{1t} \quad \text{for} \quad t = T_1 + 1,..., T, \tag{5}$$

where Δ_{1t} is the treatment effect capturing the impact of the HSR project on per capita real GDP in city 1 after the implementation of new HSR line construction.

As for non-HSR cities that are not affected by the HSR project, for all time horizons, we have

$$y_{it} = y_{it}^0 = \alpha_i + b_i^{'} f_t + u_{it} \quad \text{for} \quad i = 2,..., N \quad \text{and} \quad t = 1,..., T \tag{6}$$

Since y_{it}^0 is not observable for, $t > T_t$, we need to estimate the counterfactual outcome y_{it}^0, we adopt the procedure by Hsiao et al. (2012) to construct the counterfactuals y_{it}^0 using the information from observed data $(y_{2t},...,y_{Nt})'$ in lieu of f_t for the post-treatment period.

Recall that $y_t=(y_{1t},y_{-t}')'$, where $y_{-t}=(y_{2t},...,y_{Nt})'$. The pre-treatment data is generated by Eq. (4). Let a be a vector in the null space of B, that is $a'\mathrm{B}=0$. We can always normalize the first element of a to be 1 and denote $a=(1,-a_{-1}')'$ where $a_{-1}=(a_2,...,a_N)'$. We pre-multiply Eq. (4) by a', since $a'\mathrm{B}=0$, the common factors are dropped out, re-aggranging terms we obtain

$$y_{1t}^0=\overline{\alpha}+a_{-1}'y_{-t}+u_{1t}-a_{-1}'u_{-1t} \tag{7}$$

where $\overline{\alpha}=a'\alpha$ and $u_{-1t}=(u_{2t},...,u_{Nt})'$.

Because $u_{1t}-a_{-1}u_{-1t}$ depends on all the u_{jt} for $j=1,...,N$, the above error term and y_{-t} are correlated. Thus, we further rewrite

$$y_{1t}^0=\overline{\alpha}+a_{-1}^{*'}y_{-1t}+u_{1t}^* \tag{8}$$

where $a_{-1}^*=a_{-1}'(\mathrm{I}_{N-1}-\mathrm{cov}(u_{-1t},y_{-1t})\,\mathrm{var}(y_{-1t})^{-1})$, and $u_{1t}^*=a'u_t+a_{-1}'\,\mathrm{cov}(u_{-1t},y_{-1t})$ $\mathrm{var}(y_{-1t})^{-1}y_{-1t}$ are uncorrelated with y_{-1t}. Eq. (8) shows the following procedure to construct the counterfactuals:

Step 1: Regress y_{1t}^0 on y_{-1t} to obtain consistent estimates $\hat{\overline{\alpha}}$ and $\hat{a}_{-1}^*$ using data before the construction of the HSR project, that is $t\le T_1$.

Step 2: Construct the counterfactuals $\hat{y}_{1t}^0=\hat{\overline{\alpha}}+\hat{a}_{-1}^*y_{-1t}$ for $t=T_1+1,...,T$.

A prediction for the effect due to construction of the HSR project on the HSR-city at time t will be

$$\hat{\Delta}_{1t}=y_{1t}^1-\hat{y}_{1t}^0,\ \text{for}\ t>T_1 \tag{9}$$

Then the average treatment effect (ATE) can consistently estimated by

$$(T-T_1)^{-1}\sum_{t=T_1+1}^{T}\hat{\Delta}_{1t}\,. \tag{10}$$

The next issue is to choose a best prediction model to construct the counterfactuals. In our case, in sample observations are not more than 20 years. Using all available cities is generally not an optimal choice unless T_1 go to infinity. To solve this problem, we follow Hsiao et al. (2012) using the 2-step procedure:

Step 1: Use R^2 to select a best predictor for y_{1t}^0 using m non-HSR cities out of N_1 non-HSR cities, denoted by $M(m)^*$, for $m=1,...,N_1$. Where N_1 is the number of non-HSR cities in this study.

Step 2: From $M(1)^*,M(2)^*,...,M(N_1)^*$, choose $M(m)^*$ in terms of the corrected Akaike Information Criterion (AICC; Hurvich and Tsai, 1989).

3.2 Data and Criteria

3.2.1 Data

Prefectural-level cities (Dijishi) are our primary unit of study. To apply the model to data, we need a panel of per capita real GDP across prefectural-level cities including HSR cities and their potential control groups. For a prefectural-level city, it is a “city” (Shi) and “prefecture” (Diqu) that have been merged into one unified jurisdiction. Typically, it is an administrative unit comprising a main central urban area (a city in the usual sense) and its much larger surrounding rural area containing smaller cities, towns and villages.

To calculate per capita real GDP, we use the formula of nominal GDP/yearly average population at the end of year, and then convert nominal variables into real terms with appropriate price deflators. The raw data are provided by the National Bureau of Statistics in China (NBSC). The prefectural-level nominal GDP in years of 1990, 1991, and 1994-2013 is from China City Statistical Yearbook. The GDP data in 1992 and 1993 is not reported in China City Statistical Yearbook; we obtain it from Provincial Statistical Year Book for all related provinces in corresponding years.

The prefectural-level population data we use is total population at the end of year between 1989 and 2013, from China City Statistical Yearbook 1990-2014, provided by NBSC. We calculate the mean population by taking simple average of the total population in two consecutive years. To obtain real terms, we choose to adjust by provincial CPI.

The information of the targeted city nodes, the construction and operation time for HSR Segments/Lines is hand collected from official news or documents by the author.

3.2.2 Criteria

Control group

Two criteria are used when selecting cities into the control group. First, a control city must display a strong correlation with an individual treated city in the outcome variable to be estimated the real GDP per capita in our case. Second, a control city should be exogenous to the treatment due to construction of a HSR project. Accordingly, we exclude all HSR cities from the pool of all prefectural-level cities in China within our research period. For the relevance criterion to be satisfied, we experiment with estimations with these 13 cities to find those which generate the best fit for pre-intervention sample period following the 2-step model selection procedure described in Section 4.1.

Treatment group

We choose the Four Vertical HSR lines running north-south. To obtain data for the policy evaluation period of HSR projects as many as possible, we focus on HSR segments/lines that had started construction as early as possible.

The cut-off point T1+1

We set the cut-off point T_1+1 to be one year before the year in which construction started, first because expropriation and demolition have already started before substantive construction. Second, HSR related investment could start sometime before construction started, with the expectation that HSR projects would bring business and investment opportunities. The choice of T_1+1 will ensure that pre-intervention sample observations are not contaminated by HSR. And we will obtain a sufficiently large sample size for the pre-intervention period i.e. 10 years at the minimum.

4. Estimation of treatment effects

4.1 Huning corridor

The construction of Jinghu HSR Line began on April, 2008 and opened to public on June, 2011. The 1,318km Jinghu HSR is the world's longest HSR line ever constructed in a single phase. This project has the largest investment of 2,209 billion RMB, connecting the municipalities of Beijing, Tianjin, Shanghai, and travelling across 4 provinces of Hebei, Shandong, Anhui and Jiangsu.

For Suzhou, Wuxi, Changzhou and Zhenjiang, the four prefectural-level cities on both Huning Intercity HSR and Huning Segment on Jinghu HSR Line, the cut-off point T_1+1 is set to be 2007, one year before construction started. Thus the policy evaluation period is from 2007 to 2013, with the construction period from 2007 to 2011 and the operation period from 2011 to 2013. We set 1990 as t = 1 for all of them based on data availability. The best prediction model is chosen from the control group of 13 non-HSR cities. For the sake of brevity, we only report result for Changzhou as an example among these four cities[5].

Using the procedure described in section 4.1, we first choose a best prediction model for each HSR city by the AICC criterion, then construct $\hat{y}_{1t}^{0}$ the hypothetical real GDP per capita path of each HSR city had there been no implementation of the HSR project. The OLS weights based on Eq.(8) using the 1990-2006 data are reported in Panel A, Table 1. Fig. 2 plots the actual and hypothetical series on real capita GDP in log levels for the full sample period 1990-2013 and the post-treatment period 2007-2013 respectively. The dotted lines denote the 95 percent confidence bands of the predicted counterfactuals.

The upper panel of Fig. 2 shows that the counterfactual path for the period 1990-2006, produced by the control groups, traces closely the actual path of Changzhou in per capita real GDP, before the implementation of Huning Intercity HSR and Huning Segment projects. Panel A in Table 1 also shows significant t-statistics of the coefficients of the control group of cities with R-square above 0.99 and F-statistic equal to 675.87 which indicates the predictive model performs well.

Next, we construct $\hat{y}_{1t}^{0}$ the counterfactual per capita real GDP of Changzhou without the treatment of Huning Intercity HSR from 2007 to 2013. The actual post-treatment data, the predicted values of counterfactuals and the estimated treatment effects are reported in Table 1. The estimated HSR treatment effects are simply the difference of the two series. We calculate the ATE for the policy evaluation period, the construction period and the operation period respectively following Eq. (10).

According to Panel B Table 1, the HSR policy effect in each year is all positive. The impact of Huning Segment on Changzhou's local income has an increasing trend from 12.76% in 2007 to over 40% in 2013. Accordingly, the ATE during the construction period is positive for Changzhou. Specifically, the average actual log per capita real GDP for Changzhou is 10.3734, while the

[5] Results for Suzhou, Wuxi and Zhenjiang are available in an appendix from the authors upon request.

average predicted value without the HSR intervention is 10.0623. The difference of these two gives that the estimated treatment effect is 0.3110, that is, the per capita real GDP of Changzhou is increased by more than 31 percent compared with the value had there been no HSR project. Also, we find a statistically significant large ATE during the construction period with a magnitude of over 27%. For the operation period, ATE is even higher than 38%. The bottom panel of Fig. 2 shows that the treatment effect is significant at the 5% level in all policy evaluation years.

The other three HSR cities Suzhou, Wuxi and Zhenjiang all have positive average treatment effects during the policy evaluation period 2007-2013. In addition, for all the four HSR cities, we find a relatively large magnitude of treatment effect on local income before this HSR segment opened to public.

4.2 Beijing-Nanjing corridor

Treatment cities along Beijing-Nanjing corridor include: Langfang, Cangzhou, Taian, Jining, and Xuzhou, which we estimate the treatment effect city by city. To save space, we report results for two cities: Langfang in Hebei province with negative estimated ATE and Xuzhou in Jiangsu province with positive ATE[6].

Using the same procedure described above, we first choose a best prediction model for Langfang and Xuzhou respectively by the AICC criterion, then construct $\hat{y}_{1t}^0$ the hypothetical real GDP per capita path of the two cities had there been no implementation of Beijing-Nanjing HSR Segment. For Langfang, the selected control group consists of Yancheng and Jinchang. For Xuzhou, we select Hegang and Yancheng. The OLS weights are reported in Panel A of Table 2 for Langfang and Table 3 for Xuzhou. Fig. 3 and Fig. 4 plot the actual, hypothetical and treatment effects series of per capita real GDP in log levels for the two cities respectively. The dotted lines denote the 95% confidence bands of the predicted counterfactuals.

For Langfang, the upper panel of Fig. 3 shows that, the counterfactual path traces closely the actual path of real GDP per capita before the implementation of the Jinghu HSR project. Based on the pre-treatment data, the combination of the two cities per capita real GDP display a strong correlation in Langfang's per capita real GDP series: the R-square equals 0.9921 and F-statistic is 877.17, as shown in Table 2.

According to Table 2, the ATE for Langfang between 2007 and 2013 is -6.96 percent. The average actual log GDP per capita is 9.5144, while the average predicted log GDP per capita without the HSR project is 9.5840, indicating that the estimated ATE is -6.96%. Fig 3 shows that starting from the treatment year 2007, the actual per capita GDP series move above the hypothetical lines, implying a positive treatment effect. We note that the statistically significant positive treatment effect have started to decrease since 2007. Two years after the HSR policy intervention, the actual series move below the counterfactual values, indicating that the treatment effects turn into negative and become statistically significant in 2011 when construction was finished.

---

[6] Results for the other four cities are available from the authors upon request.

For Xuzhou, Table 3 shows that the pre-intervention in-sample fit performs well too, with R^2 around 0.99, and F-statistic equal 524.35. The best predictors chosen by AICC are Hegang and Yancheng with significant t-statistics for the estimated coefficients. The ATE from 2007 to 2013 is 7.03%. The average actual log GDP per capita is 9.3571, while the average predicted log GDP per capita without the HSR project intervention is 9.2868 using the group of cities selected. Thus, per capita real GDP of Xuzhou is raised by more than 7.03% compared with the value had there been no Jinghu HSR constructed. The treatment effect is positive in most of the years and significant at the 5% level. It keeps a relatively large magnitude around 11-12% during the construction period, while after Jinghu HSR opened to public in 2012, the treatment effect started to decrease. The ATE during the construction period is 10.05%, for the operation period in the short run of 2011 to 2013 it decreases to 3.20%.

4.3 Wuguang corridor

The construction started in September, 2005 and opened to public on December 2009. It is constructed in a single phase. The cut-off point $T_1 +1$ is set to be 2004, thus the policy evaluation period is from 2004 to 2013, with the construction period from 2004 to 2009 and the operation period from 2009 to 2012. We choose 1990 for t = 1. A best prediction model is chosen from the control group of 10 non-HSR cities using the AICC criterion.

Prefectural-level treatment cities on Wuguang Segment include: Xianning, Yueyang, Changsha, Zhuzhou, Hengyang, Chenzhou, Shaoguan, and Qingyuan, going across three provinces Hubei, Hunan and Guangdong. To save space, we report results for Qingyuan in Guangdong province. The OLS weights based on the 1990-2004 data are reported in Panel A of Table 4. Fig. 5 plots the actual and hypothetical series on real capita GDP in log levels for the full sample period 1990-2013 and for the post-treatment period 2004-2013.

Fig. 5 shows that the counterfactual path for 1990-2003, traces closely the actual path of Qingyuan in per capita real GDP, before the implementation of the Wuguang HSR project. Panel A of Table 4 gives significant t-statistics of the coefficients of the group of best predicting cities Wuhai, Jinchang, Karamay and Baotou with R^2 equal 0.99 and F-statistic equal 200.35. Next, we construct the counterfactual per capita real GDP of Qingyuan without the treatment of the Wuguang HSR project for the post-treatment period 2004-2013. The actual, constructed GDP per capita series and estimated treatment effects are reported in Panel B, Table 4. The HSR policy effect is positive for each year. Starting from the treatment year to 2009, the per capita real GDP of Qingyuan is raised from 16.19% till up to 87%, with ATE equal 50.06% during the construction period. After Wuguang HSR started operation, treatment effects keep relatively constant at a high level with ATE equal to 85%. During the whole policy evaluation period, the average actual log per capita real GDP of Qingyuan is 8.8448, while the average predicted value without the HSR intervention is 8.2063, indicating that per capita real GDP of Qingyuan is raised by more than 52% compared with the value had there been no HSR project.

4.4 Ningbo-Taizhou-Wenzhou-Fuzhou-Xiamen corridor

The construction started in 2005 and opened to traffic in September, 2009 for Yongtaiwen and Wenfu Segments, in April 2010 for Fuxia Segment. Prefectural-level treatment cities on the three segments include: Taizhou, Wenzhou, Fuzhou, Ningde, Putian and Quanzhou. T_1+1 is set to be 2004, thus the pre-intervention sample period is from 1990-2003, and the policy evaluation period is from 2004-2013. We choose 1990 for t = 1 for all the six cities.

We show results for Quanzhou in Fujian province. The OLS weights based on the 1990-2003 data are reported in Panel A, Table 5. Fig. 6 plots the actual and hypothetical series on real capita GDP in log levels for the full sample period 1990-2013 and the post-treatment period 2004-2013 respectively. The upper panel of Fig. 6 reveals that before the HSR treatment, predicted series closely tracks the actual series of Quanzhou. R-square reaches 0.99 and F-statistic equals 283.537, implying that per capita real GDP series of our control cities serve as good predictors for Quanzhou. After the treatment in 2004, the hypothetical counterfactuals went below the actual series in most of the years. The positive treatment effect first increased from around 30% in 2005 to 65% in 2007, then gradually deceased to -10.23% in 2013. The ATE equals 37.90%. Put intuitively, the per capita real GDP of Quanzhou is raised by more than 37% compared with the value had there been no HSR project constructed during 2004 to 2013. For the construction period, the estimated ATE is 47.03%, when it opened to public till 2013, the ATE is 23.90%.

Finally, we summarize the performance of in sample fit and ATEs of the 22 HSR cities in Tables 6 and 7. Table 6 shows that not only the above reported cities, all the studied HSR cities along the four HSR lines have good in-sample fit with R-square around 0.99 and F-statistic above 100. Table 7 shows that, first, among the 22 HSR cities, 68% have positive ATEs during the whole policy evaluation period. For construction period, this ratio is even higher of 73%, while for early operation period it is 46%. Second, HSR cities with positive ATEs spatially agglomerate along the coastal regions. Third, for over 70% of the 22 HSR cities, ATEs are larger during the construction period than during the early operation period. This is consistent with the finding for the U.S. interstate highway system that there was a declining effect of transportation infrastructure as the US interstate highway system evolved through different stages (Fernald, 1999; Manuneas & Nadiri, 2006 among others).

5. Factors affecting disparity of HSR impacts

To explore potential explanations for the above empirical findings, we conduct regression analysis focusing on the questions in what aspects do the HSR cities with positive ATEs differ from those with negative ATEs? We use a two-way fixed effects model relating the HSR impacts to a series of city characteristics:

$$\hat{\Delta}_{it} = y_{it} - \hat{y}_{it} = \alpha + X_{it}\beta + u_i + v_t + \varepsilon_{it},$$

where subscripts i and t denote city and year, respectively.

$\hat{\Delta}_{it}$: the treatment effect of real GDP per capita due to construction of HSR projects.

X_{it} : level of industrialization in terms of output and employment size; social and economic conditions i.e. population density, average wage rate, trade openness, and relative employment size of state-owned enterprises (SOEs); supporting infrastructure, road density.

Table 9 shows that industrialization measured in output is positively correlated with treatment effect and highly significant. When controlling for both city and year fixed effects, having a 1% higher proportion of second industry in output is correlated with 1.7% higher increase in HSR treatment effect of per capita GDP (compared with the case if the HSR project had not been undertaken) and the strong positive effect is statistically significant at the 1% level. Similarly, the share of service sector in output is shown to be positively and very significantly correlated with treatment effect due to the HSR project. The above results are very robust after controlling for various controls. Also, we find that road density is positively and significantly correlated with treatment effect. As HSR stations in China are usually designed to be built in suburbs, thus better supporting infrastructure is a necessary condition for HSR to be fully utilized and to facilitate the local development.

We replicate such regression for construction period and operation period respectively. Table 10 shows that the significantly positive correlation between GDP ratio of the manufacturing and service industries and local gain due to HSR projects only work for construction period. While the employment share of both industries become positive correlated with TEs with even larger impact during operation period and very significant. One notable result is that, during the operation period, the local protectionism measured by the employment ratio of SOE is negative correlated with TEs and very significant. It suggests that when the HSR projects opens to public, local residents could lose the benefit of local protection. Finally, the positive relationship between supporting infrastructure and TEs are rather robust in both periods. These findings are consistent with recent European evidence that the impact of HSR on regional economic activity is not unambiguous. It depends on the specific situation of the region initial levels of accessibility, the change in them and the existence of other policy measures which may accompany the transport improvement.

6. Conclusions

This paper aims to make two primary contributions. First, we are the first to use a recently developed panel data program evaluation approach by Hsiao et al. (2012) to explore the impact of High Speed Rail projects on the economic growth of targeted city nodes in China. We consistently estimates treatment effect by exploiting the correlations across cross-sectional units to construct counterfactuals, without specifying any structural regression model originated from economic theory.

Second, this study documents new evidence on how large-scale transportation infrastructure affects local economies, with a focus on the recently constructed HSR in China. We find that HSR projects have raised local real GDP per capita among most of the studied HSR cities. The treatment effect of receiving a new HSR project occurs even before the project actually opens. The local gains are highly different among targeted city nodes and the spatial distribution pattern differs by HSR segments/lines. Additional empirical evidence suggests that the treatment effect from HSR projects is greater for cities that are more industrialized, and those with high capacity of service sector to absorb enough labor. Besides, local protectionism could significantly hamper the development of HSR projects.

References

Aschauer, D.A. (1989). Is public expenditure productive? *Journal of Monetary Economics*, 23(2), 177-200.

Atack, J.F.B., Haines, M., & Margo, R.A. (2010). Did railroads induce or follow economic growth? Urbanization and population growth in the American Midwest, 1850-1860. *Social Science History*, 34(2), 171-197.

Bai, J., & Ng, S. (2002). Determining the number of factors in approximate factor models. *Econometrica*, 70(1), 191-221.

Banerjee, A., Duflo. E., & Qian, N. (2012). On the road: Access to transportation infrastructure and economic growth in China. *Working paper*. National Bureau of Economic Research.

Baum-Snow, N. (2007). Did highways cause suburbanization? *The Quarterly Journal of Economics*, 122(2), 775-805.

Burgess, R., & Donaldson. D. (2010). Can openness mitigate the effects of weather fluctuations? Evidence from India's famine era. *American Economic Review: Papers & Proceedings*, 100(2), 449-453.

Ching, H.S., Hsiao, C., & Wan, S.K., (2012). Impact of CEPA on the labor market of Hong Kong. *China Economic Review*, 23(4), 976-981.

De Rus, G. (2012). The economic effects of high speed rail investment. *Working paper*. OECD Joint Transportation Research Center.

Demurger, S. (2001). Infrastructure development and economic growth: An explanation for regional disparities in China? *Journal of Comparative Economics*, 29(1), 95-117.

Duranton, G., & Turner, M.A. (2012). Urban growth and transportation. *Review of Economic Studies*, 79(4), 1407-1440.

Faber, B. (2014). Trade integration, market Size and industrialization: Evidence from China's national trunk highway system. *Review of Economic Studies*, 81(3), 1046-1070.

Fogel R. (1964). *Railroads and American economic growth: essays in Econometric History.* Baltimore, MD: Johns Hopkins Press.

Giannone, D., Reichlin L., & Sala, L. (2005). Monetary policy in real time, In Mark Gertler and Kenneth Rogoff, editors, *NBER Macroeconomics Annual* 2004, MIT Press, 161-200.

Heckman, J.J. (1979). Sample selection bias as a specification error. *Econometrica*, 47(1), 153-161.

Hsiao, C., Ching, H.S., & Wan, S.K. (2012). A panel data approach for program evaluation—Measuring the benefits of political and economic integration of Hong Kong with mainland China. *Journal of Applied Econometrics*, 27(5), 705-740.

Hurvich, C.M., & Tsai, C.L. (1989). Regression and time series model selection in small samples. *Biometrika*, 76(2), 297-307.

Marti-Hennenberg,J. (2000). Un balance del tren de alta velocidad en Francia. Enseaszas para el caso Espaol. *Eria*, 52, 131-143.

Onatski, A. (2009). Testing hypotheses about the number of factors in large factor models, *Econometrica*, 77(5), 1447-1479.

Rosenbaum, P., & Rubin, D.B., (1983). The central role of propensity score in observational studies for causal effects. *Biometrica*, 70 (1), 41-55.

Sargent,T.J., & Sims, C.A. (1977). Business cycle modeling without pretending to have too much a-priori economic theory. In C. Sims et.al. eds., *New Methods in Business Cycle Research*, Minneapolis: Federal Reserve Bank of Minneapolis.

Sasaki, K., Ohashi, T., & Ando, A. (1997). High-speed rail transit impact on regional systems: Does the Shinkansen contribute to dispersion? *The Annals of Regional Science*, 31(1), 77-98.

Stock, J.H., & Watson, M.W. (2005). Implications of dynamic factor models for VAR analysis. *Working paper*. National Bureau of Economic Research.

Zheng, S.Q., & Kahn, M.E. (2013). China's bullet trains facilitate market integration and mitigate the cost of megacity growth. *Proceedings of the National Academy of Sciences*, 110(14), E1248-E1253.

Fig. 1. A general view of China's 4+4 national HSR framework. In this map, the bold lines represent for the Four vertical HSR lines and the fine lines represents for the Four horizontal HSR lines.

Table 1: Changzhou in Jiangsu province

Panel A: Weights of control groups, 1990-2006			
	b	se	t
Yancheng	0.0432	0.01	4.32
Karamay	0.5198	0.0762	6.82
Liupanshui	0.2665	0.054	4.93
Constant	0.931	0.4611	2.02
R^2	0.9936		
F	675.87		
Panel B: Treatment effects, 2007-2013			
	Actual	Predicted	Treatment
2007	10.0408	9.9132	0.1276
2008	10.1522	9.9996	0.1525
2009	10.2592	9.8455	0.4137
2010	10.4081	10.0783	0.3298
2011	10.5141	10.1643	0.3498
2012	10.5863	10.1933	0.3931
2013	10.6529	10.2422	0.4107
Mean	10.3734	10.0623	0.3110
2007-2011			
Mean	10.2749	10.0002	0.2747
2011-2013			
Mean	10.5844	10.1999	0.3845

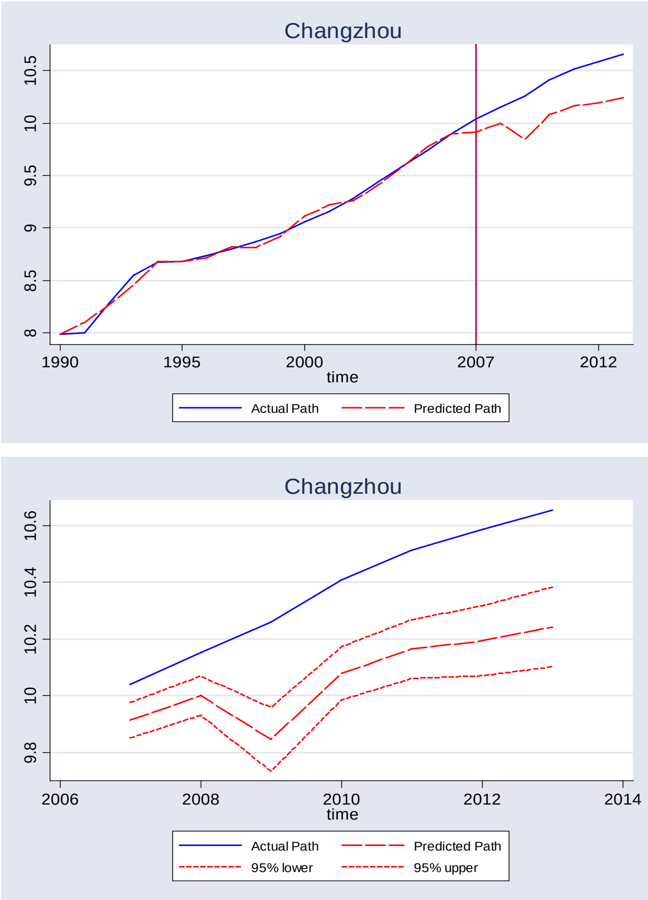

Fig. 2. Actual and hypothetical series on per capita real GDP (in log levels) for the whole sample period and the post-treatment period, for Changzhou on Huning corridor. The bottom panel signifies the treatment effects.

Table 2: Langfang in Hebei province

Panel A: Weights of control groups, 1990-2006			
	b	se	t
Yancheng	1.0769	0.0333	32.31
Jinchang	-0.1685	0.0391	-4.30
Constant	1.1634	0.2348	4.95
R^2	0.9921		
F	877.1718		
Panel B: Treatment effects, 2007-2013			
	Actual	Predicted	Treatment
2007	9.2353	9.1337	0.1016
2008	9.3426	9.2730	0.0696
2009	9.4132	9.4150	-0.0018
2010	9.5334	9.5754	-0.0421
2011	9.6403	9.7562	-0.1159
2012	9.7055	9.9221	-0.2166
2013	9.7307	10.0127	-0.2820
Mean	9.5144	9.5840	-0.0696
2007-2011			
Mean	9.4330	9.4307	0.0023
2011-2013			
Mean	9.6922	9.8970	-0.2048

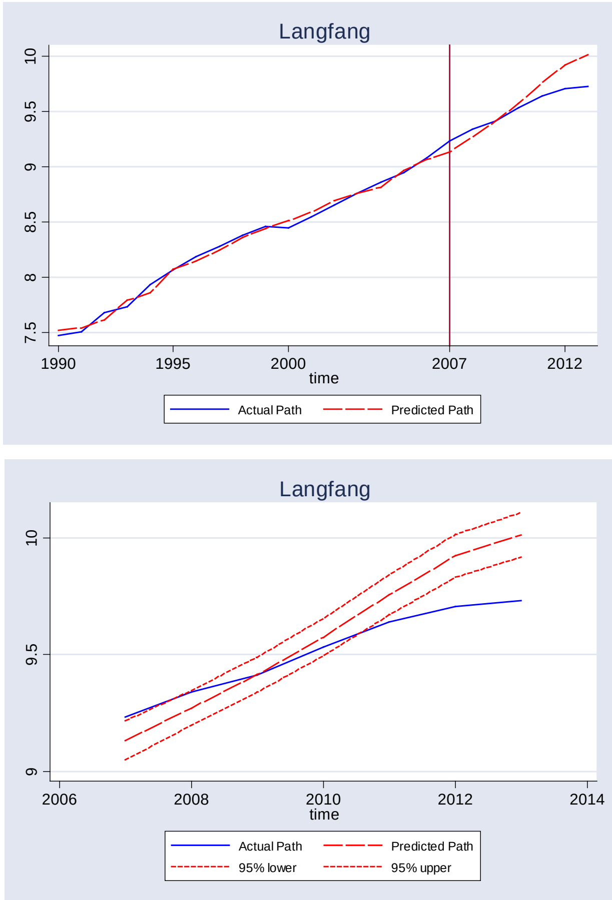

Fig. 3. Actual and hypothetical series on per capita real GDP (in log levels) for the whole sample period and the post-treatment period, for Langfang in Hebei province. The bottom panel signifies the treatment effects.

Table 3: Xuzhou in Jiangsu province

Panel A: Weights of control groups, 1990-2006			
	b	se	t
Hegang	-0.4468	0.1117	-4
Yancheng	1.2836	0.0864	14.85
Constant	1.349	0.3069	4.4
R^2	0.9897		
F	670.5029		
Panel B: Treatment effects, 2007-2012			
	Actual	Predicted	Treatment
2007	8.9817	8.9322	0.0496
2008	9.1155	9.0047	0.1108
2009	9.2316	9.1316	0.1000
2010	9.3884	9.2522	0.1361
2011	9.5149	9.4039	0.1110
2012	9.6035	9.5572	0.0463
2013	9.6644	9.7258	-0.0614
Mean 2007-2011	9.3571	9.2868	0.0703
Mean 2011-2013	9.2464	9.1449	0.1015
Mean	9.5943	9.5623	0.0320

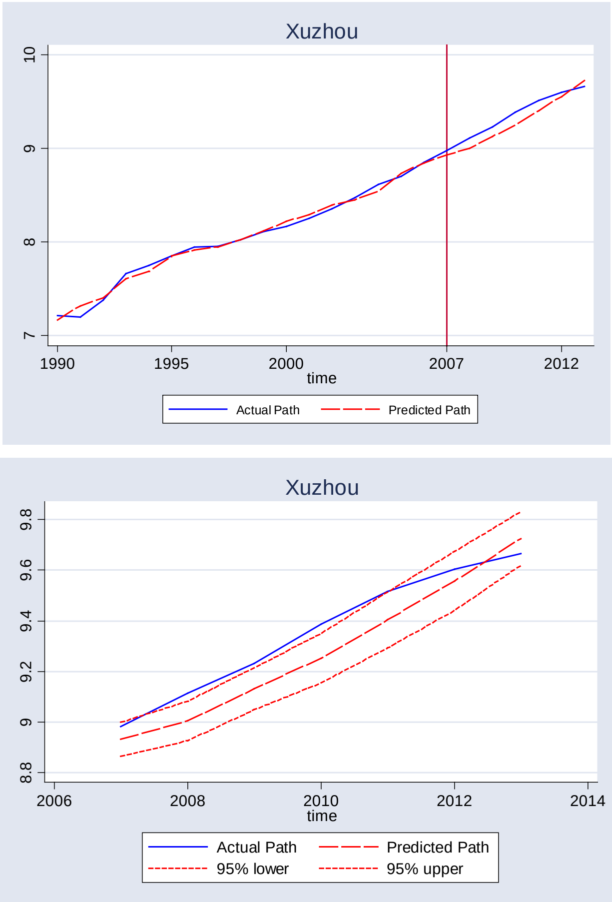

Fig. 4. Actual and hypothetical series on per capita real GDP (in log levels) for the whole sample period and the post-treatment period, for Xuzhou in Jiangsu province. The bottom panel signifies the treatment effects.

Table 4: Qingyuan in Guangdong province

Panel A: Weights of control groups, 1990-2003			
	b	se	t
Wuhai	-0.3445	0.1231	-2.8
Jinchang	-0.1754	0.0611	-2.87
Karamay	0.4153	0.0836	4.97
Baotou	0.5104	0.0722	7.07
Constant	3.4611	0.4355	7.95
R^2	0.9889		
F	200.3502		
Panel B: Treatment effects, 2004-2013			
	Actual	Predicted	Treatment
2004	8.0733	7.9114	0.1619
2005	8.3106	8.083	0.2276
2006	8.5747	8.1269	0.4478
2007	8.7814	8.1038	0.6775
2008	8.8737	8.2548	0.6188
2009	8.9826	8.1126	0.87
2010	9.1382	8.2506	0.8876
2011	9.2196	8.3693	0.8503
2012	9.223	8.4247	0.7983
2013	9.271	8.4262	0.8448
Mean 2004-2009	8.8448	8.2063	0.6385
Mean 2009-2013	8.5994	8.0988	0.5006
Mean	9.1669	8.3167	0.8502

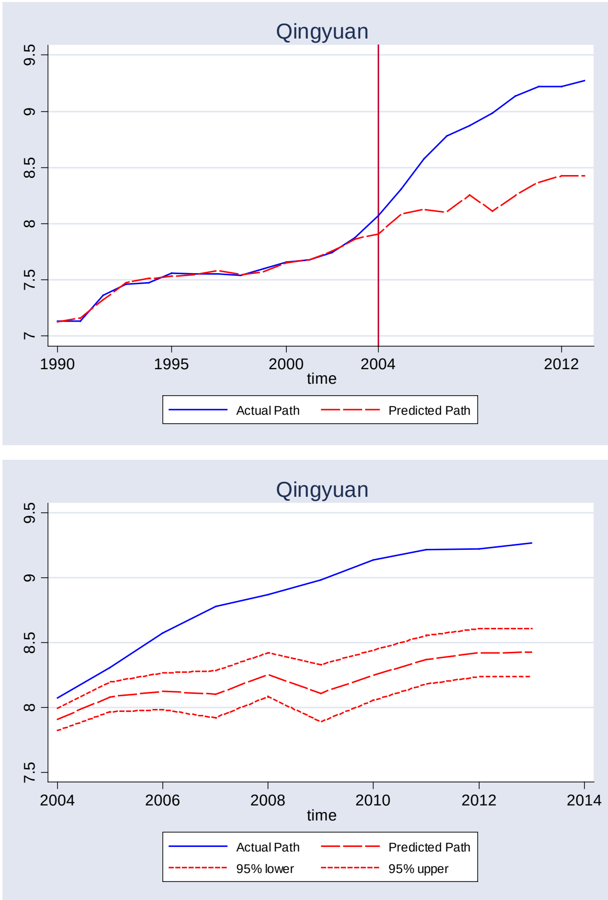

Fig. 5. Actual and hypothetical series on real capita real GDP (in log levels) for the whole sample period and the post-treatment period, for Qingyuan in Guangdong province. The bottom panel signifies the treatment effects.

Table 5: Quanzhou in Fujian province

Panel A: Weights of control groups, 1990-2003			
	b	se	t
Jinchang	-0.6928	0.1566	-4.42
Yancheng	2.5326	0.1429	17.72
Hegang	-1.2958	0.2058	-6.3
Constant	4.439	1.2131	3.66
R^2	0.9884		
F	283.537		

Panel B: Treatment effects, 2004-2013			
	Actual	Predicted	Treatment
2004	9.246	8.8543	0.3917
2005	9.3664	9.0677	0.2988
2006	9.5093	9.0558	0.4535
2007	9.6382	8.9858	0.6524
2008	9.7577	9.1971	0.5605
2009	9.8974	9.42	0.4775
2010	10.0098	9.552	0.4578
2011	10.1329	9.7447	0.3882
2012	10.2045	9.9923	0.2122
2013	10.269	10.3713	-0.1023
Mean	9.8031	9.4241	0.379
2004-2010			
Mean	9.6321	9.1618	0.4703
2010-2013			
Mean	10.1541	9.9151	0.239

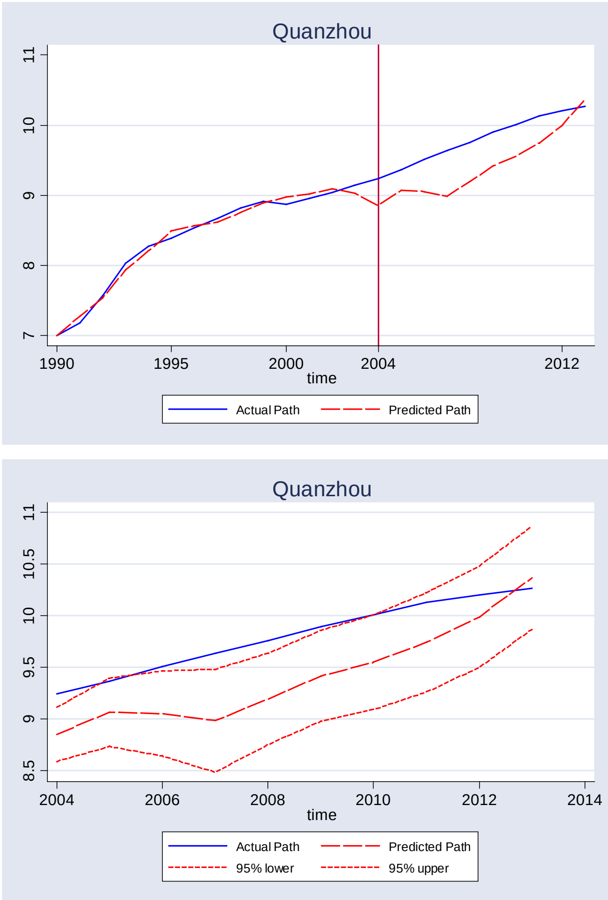

Fig. 6. Actual and hypothetical series on per capita real GDP (in log levels) for the whole sample period and the post-treatment period, for city Quanzhou in Fujian province. The bottom panel signifies the treatment effects.

Table 6: Summary for in-sample fit

Pre-intervention regression			
HSR corridor	Prefectural-level city	In sample fit	
		R-square	F-statistic
Huning corridor	Changzhou	0.9936	675.8655
	Suzhou	0.9979	1042.5284
	Wuxi	0.9976	689.6152
	Zhenjiang	0.9913	495.3097
Beijing-Nanjing corridor	Langfang	0.9921	877.1718
	Cangzhou	0.9852	333.2652
	Taian	0.9940	829.7864
	Jining	0.9961	328.7713
	Bengbu	0.9636	114.5616
	Xuzhou	0.9897	670.5029
Wuguang HSR	Yueyang	0.9937	868.4627
	Changsha	0.9974	865.6484
	Zhuzhou	0.9932	798.1432
	Hengyang	0.9993	2408.8929
	Shaoguan	0.9900	546.1196
	Qingyuan	0.9889	200.3502
Yongtaiwenfuxia corridor	Taizhou	0.9989	1057.2489
	Wenzhou	0.9957	768.6247
	Fuzhou	0.9947	627.4898
	Ningde	0.9983	1288.8516
	Putian	0.9971	767.2936
	Quanzhou	0.9884	283.5370

Table 7: Summary for average treatment effect

NO.	City	Whole evaluation period			Construction period			Operation period		
		Actual	Predicted	ATE	Actual	Predicted	ATE	Actual	Predicted	ATE
1	Changzhou	10.3734	10.0623	0.3110	10.2749	10.0002	0.2747	10.5844	10.1999	0.3845
	Suzhou	10.9187	10.8312	0.0875	10.7752	10.6592	0.1160	11.1100	11.0605	0.0495
	Wuxi	10.7780	10.7241	0.0539	10.6909	10.6158	0.0751	10.9677	10.9570	0.0108
	Zhenjiang	10.2446	10.2258	0.0188	10.1389	10.0715	0.0673	10.4608	10.5200	-0.0592
2	Langfang	9.5144	9.5840	-0.0696	9.4330	9.4307	0.0023	9.6922	9.8970	-0.2048
	Cangzhou	9.4184	9.4149	0.0035	9.3363	9.2659	0.0703	9.6028	9.7124	-0.1096
	Taian	9.5345	9.5531	-0.0186	9.4402	9.4489	-0.0087	9.7327	9.7932	-0.0606
	Jining	9.3885	9.3422	0.0464	9.3118	9.1966	0.1152	9.5442	9.6369	-0.0927
	Bengbu	8.8169	8.9341	-0.1172	8.6987	8.8527	-0.1541	9.0621	9.1328	-0.0708
	Xuzhou	9.3571	9.2868	0.0703	9.2464	9.1449	0.1015	9.5943	9.5623	0.0320
3	Yueyang	8.9670	9.1531	-0.1861	8.6982	8.8712	-0.1731	9.2986	9.5066	-0.2081
	Changsha	9.7575	9.7112	0.0463	9.4412	9.3483	0.0929	10.1729	10.1759	-0.0030
	Zhuzhou	9.1161	9.0104	0.1057	8.8470	8.7864	0.0605	9.4492	9.2831	0.1662
	Hengyang	8.5804	8.7234	-0.1430	8.3117	8.4026	-0.0909	8.9158	9.1437	-0.2279
	Shaoguan	8.9695	9.0589	-0.0893	8.7641	8.8203	-0.0562	9.2219	9.3639	-0.1421
	Qingyuan	8.8448	8.2063	0.6385	8.5994	8.0988	0.5006	9.1669	8.3167	0.8502
4	Taizhou	9.5241	9.4900	0.0341	9.3575	9.1095	0.2480	9.7331	9.9604	-0.2273
	Wenzhou	9.4510	9.7074	-0.2564	9.2923	9.3512	-0.0589	9.6485	10.1391	-0.4906
	Fuzhou	9.6636	9.5276	0.1360	9.4439	9.2362	0.2078	9.9393	9.8788	0.0605
	Ningde	9.0750	8.9550	0.1200	8.7703	8.6831	0.0872	9.4439	9.2866	0.1572
	Putian	9.1120	8.4206	0.6914	8.9147	8.2897	0.6250	9.5118	8.6432	0.8687
	Quanzhou	9.8031	9.4241	0.3790	9.6321	9.1618	0.4703	10.1541	9.9151	0.2390

Note: Number 1-4 in the first column represents for Huning corridor,Beijing-Nanjing corridor, Wuguang corridor, Yongtaiwenfuxia corridor respectively.

Table 9: Effect of city characteristics on estimated treatment effect

Dependent variable: treatment effect in per capita GDP in log levels due to the HSR project					
	(1)	(2)	(3)	(4)	(5)
Share of 2^{nd} industry in GDP	1.752***	1.795***	1.699***	2.132***	1.764***
	(0.404)	(0.399)	(0.304)	(0.443)	(0.532)
Share of 3^{rd} industry in GDP	1.425***	1.416***	1.881***	1.942***	1.932**
	(0.425)	(0.474)	(0.466)	(0.675)	(0.827)
Share of 2^{nd} industry in employment		0.00618	0.0273	0.0172	-0.0689
		(1.148)	(1.035)	(1.032)	(1.031)
Share of 3^{rd} industry in employment		0.467	0.147	0.186	0.0145
		(0.839)	(0.760)	(0.811)	(0.845)
Ln(average wage)			0.778	0.824	0.882*
			(0.344)	(0.354)	(0.400)
Population density			-0.0570	-0.0535	-0.0550
			(0.0441)	(0.0439)	(0.0453)
Size of SOE employment				-0.125	0.0581
				(0.464)	(0.441)
Trade dependence				-0.185	-0.198
				(0.166)	(0.174)
Fixed asset investment ratio				-0.249	-0.187
				(0.321)	(0.326)
Road density					0.322**
					(0.122)
Constant	45.47*	36.42	226.3**	235.8**	285.0**
	(22.64)	(31.52)	(84.71)	(95.56)	(113.1)
City fixed effect	YES	YES	YES	YES	YES
Year fixed effect	YES	YES	YES	YES	YES
Number of observations	190	190	190	190	190
Number of cities	22	22	22	22	22
R^2 (within)	0.176	0.187	0.272	0.297	0.368

Notes:
1. Data sources: All variables are obtained from the China City Statistical Yearbook for 2005-2013, except for the number of SOE employee and total number of employee, which are from the China Statistical Yearbook for the same years.
2. All specifications report cluster-robust standard errors in parentheses, clustered at the city level.
3. * p<0.10, ** p<0.05, *** p<0.01

Table 10: Effect of city characteristics on estimated treatment effect, subsample

	Construction period					Operation period				
	(1)	(2)	(3)	(4)	(5)	(1)	(2)	(3)	(4)	(5)
Share of 2nd ind. in GDP	1.475***	1.602***	1.597***	1.436***	1.299***	-0.251	-0.371	-0.310	-0.334	-0.345
	(0.255)	(0.212)	(0.206)	(0.254)	(0.261)	(0.259)	(0.224)	(0.223)	(0.458)	(0.364)
Share of 3rd ind. in GDP	1.143*	1.295*	1.239*	0.975	1.005	-1.549	-1.630	-1.225	-2.517*	-2.670**
	(0.631)	(0.661)	(0.640)	(0.857)	(0.694)	(1.230)	(1.332)	(1.154)	(1.343)	(1.259)
Share of 2nd ind. in employ		0.125	0.234	0.124	0.194		3.455***	3.249**	3.371**	3.312**
		(2.118)	(2.097)	(2.296)	(1.596)		(1.066)	(1.200)	(1.312)	(1.273)
Share of 3rd ind. in employ		0.883	1.001	0.518	0.475		3.232***	2.985***	3.497***	3.553***
		(2.115)	(2.128)	(2.555)	(1.811)		(0.868)	(0.927)	(1.099)	(1.062)
Ln(average wage)			-0.106	-0.111	-0.0557			0.212	0.271	0.257
			(0.300)	(0.302)	(0.337)			(0.533)	(0.447)	(0.432)
Population density			-0.011	-0.008	-0.010			-0.003	-0.009	-0.006
			(0.030)	(0.031)	(0.032)			(0.027)	(0.029)	(0.028)
Size of SOE employ				0.592	1.181				-1.274***	-1.103**
				(0.726)	(0.755)				(0.435)	(0.399)
Trade dependence				-0.035	-0.046				0.0246	-0.082
				(0.096)	(0.104)				(0.369)	(0.368)
Fixed asset invest ratio				0.092	0.201				-0.020	-0.004
				(0.175)	(0.177)				(0.163)	(0.110)
Road density					0.260**					0.324***
					(0.100)					(0.103)
Constant	-12.47	-23.60	-49.57	-64.77	-12.08	121.1***	140.4***	190.1	274.0**	268.4**
	(29.99)	(31.70)	(70.21)	(86.34)	(96.19)	(33.53)	(39.96)	(131.5)	(119.7)	(117.3)
City fixed effect	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
Year fixed effect	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
Number of observations	108	108	108	108	108	82	82	82	82	82
R^2(within)	0.237	0.258	0.264	0.274	0.355	0.430	0.471	0.473	0.588	0.618