China's bullet trains facilitate market integration and mitigate the cost of megacity growth

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Megacity growth in the developing world is fueled by a desire to access their large local labor markets. Growing megacities suffer from high levels of traffic congestion and pollution, which degrade local quality of life. Transportation technology that allows individuals to access the megacity without living within its boundaries offers potentially large social benefits, because individuals can enjoy the benefits of urban agglomeration while not paying megacity real estate rents and suffering from the city's social costs. This paper presents evidence supporting the claim that China's bullet trains are playing this role. The bullet train is regarded as one of the most significant technological breakthroughs in passenger transportation developed in the second half of the 20th century. Starting in 2007, China has introduced several new bullet trains that connect megacities such as Beijing, Shanghai, and Guangzhou with nearby cities. Through facilitating market integration, bullet trains will stimulate the development of second- and third-tier cities. By offering households and firms a larger menu of location alternatives, bullet trains help to protect the quality of life of the growing urban population. We document that this transport innovation is associated with rising real estate prices in the nearby secondary cities.

high-speed rail | urban growth

In 2010, there were 21 cities in the world with populations that exceeded 10 million people (source: United Nations Database; http://esa.un.org/unpd/wup/index.htm). By the year 2025, this count is expected to grow to 29, with 14 of them located in Asia. Such urban growth offers potentially large benefits, because cities provide greater opportunities to trade, learn, and specialize in an occupation (1).

Rapid urbanization, especially in developing nations, imposes large social costs. Megacity quality of life suffers from a fundamental tragedy of the commons problem (2). The urban air, water, and infrastructure, such as roads, are local public goods. An unintended consequence of urban daily activity is to exacerbate pollution and congestion challenges. Such degradation of nonmarket local pubic goods means that the area's standard of living suffers as the megacities grows (3).

Improving transport infrastructure between nearby cities offers one strategy for mitigating the megacity quality of life challenge. This paper argues that China's recent investment in bullet trains allows individuals to move at speeds of roughly 175 mi/h, and this transportation technology innovation increases the menu of locations that have access to megacities. If individuals can swiftly move from nearby cities to megacities, then they can enjoy the benefits of megacity access without suffering the social costs associated with megacity growth.

There are cities such as Tianjin, Nanjing, and Shaoguan that are located between 100 and 750 km from China's megacities of Beijing, Shanghai, and Guangzhou. [According to the World Bank Working Paper *High-Speed Rail: The Fast Track to Economic Development?* (No. 55856), a high-speed rail service has a time advantage over air travel for journeys of up to 3 h or 750 km. For short journeys, up to 100 km, the private vehicle is the bullet train's main competitor (4).] Those secondary cities become closer (measured in travel time) to the megacities, because bullet trains connect them. The train will be a dominant transportation technology for those cities that are too far to reach by car (and vehicle ownership rates remain low in China) but too close to merit flying to the megacity. Workers and firms who require infrequent face to face meetings with firms and government officials in the megacity will enjoy a reduction in rents by relocating away from the megacities. Such individuals will also benefit from the consumption amenities of visiting the megacity while avoiding the daily quality of life insults of living in an enormous city.

Given that China's bullet trains have only recently been operating, it is too early to examine shifts in the spatial distribution of firms and households across cities. Because current real estate prices reflect expectations of future city rent dynamics, we focus on city-specific real estate prices and document that there is greater real estate price appreciation in cities that have enjoyed greater increases in market potential. As we discuss below, market potential is a concept used by economic geographers to measure a specific geographic area's access to markets for inputs and outputs. The introduction of the bullet train increases market potential and thus, market integration, the most for the secondary cities close to the megacities. We document a robust positive correlation between city growth in market potential and city growth in real estate prices.

Economic Geography of China's Bullet Trains

The concept of the bullet train [or high-speed railways (HSRs)] was born in 1964 with the formal opening of Japan's Shinkansen. The bullet train is regarded as one of the most significant technological breakthroughs in passenger transportation developed in the second half of the 20th century.

In the 1990s, the average speed of Chinese conventional trains was below 60 km/h. The speed had been raised several times in the late 1990s and early 2000s, but the highest speed did not exceed 150 km/h. The Ministry of Railway (MOR) announced its ambitious bullet train plan in 2006. [The typical financing arrangement for constructing bullet train lines is that the MOR pays 50–60% of the total cost and the destination cities pay the remainder (http://finance.people.com.cn/GB/1037/8743758.html).] The first set of bullet train lines opened in April of 2007, boosting the speed of some major trains to 200–250 km/h. In August of 2008, to coincide with the 2008 Beijing Olympic Games, new bullet trains opened between Beijing and Tianjin. They reached a higher top speed of about 350 km/h. By the end of 2010, China's bullet train service length reached 8,358 km. By 2020, China's total service HSR length will reach 12,000 km. (The average construction cost is about 100 million Renminbi (RMB) per kilometer for newly constructed bullet train lines, and this cost is

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much lower for upgraded railway lines. The average operating cost is about 0.3 RMB per person per kilometer.)

In Fig. 1, we provide a geographical overview focused on which cities are located close but not very close to the three Chinese megacities of Beijing, Shanghai, and Guangzhou and connected by bullet trains. Throughout this paper, the region in the range of 100–750 km (about 60–470 mi) to the megacities is called bullet train (BT) -impacted area. Tianjin is about 130 km from Beijing, and there is no flight between them. The Beijing–Tianjin BT ships about 400,000 passengers (one way) per week. [The one-way price per ride of the Beijing–Tianjin BT is 55 RMB Yuan (8.9 US dollars), roughly 2.5 times the conventional train fare. The fare price of the Wuhan–Guangzhou BT is roughly 60% of the flight fare. China's middle class can afford BT travel. Poor rural migrants would not choose BTs, but they do not travel much. Most of them only travel one time per year, when they return to their hometowns for the Chinese New Year.] Before the BT was introduced in 2008, the conventional train shipped 150,000 passengers/wk, but this number has declined to about 45,000 passengers/wk; highway traffic has also declined (www.cnbuses.com/news/201105/36656.htm). The number of air flights between Wuhan and Guangzhou dropped from 13 to 9 per day after the opening of the Wuhan–Guangzhou BT, but the total passenger flow has experienced a huge net increase. This evidence suggests that the BT stimulates additional intercity trips.

The MOR's criteria for selecting which cities to connect by BT have not been publicly stated. One possibility is that the MOR sought to build BT lines between megacities and the cities that they knew would boom, because introducing such links would maximize their ridership. The other possibility is that BT lines were built to connect weak cities to help them to grow. In Table 1, we compare several growth indicators between the cities with BT stops and other cities in BT-impacted areas for 2001–2005 (we exclude the three megacities when doing this comparison). We report sample means and conduct *t* tests for statistical differences in means. The *t* tests cannot reject the hypothesis of no statistically significant difference between the means for these two groups with respect to gross domestic product growth, wage growth, and distance to the closest megacity. The cities without BT connection seem to have higher population growth (the *t* statistic is statistically significant at the 10% level).

	One way travel time change in minutes	2006 (Before)	2010 (After)	One way travel time change in minutes	2006 (Before)	2010 (After)	One way travel time change in minutes	2006 (Before)	2010 (After)
With bullet train connection	Beijing-Tianjin	75	30	Shanghai-Suzhou	47	23	Guangzhou-Qingyuan	55	23
	Beijing-Baoding	85	58	Shanghai-Hangzhou	120	45	Guangzhou-Shaoguan	130	46
	Beijing-Shijiazhuang	160	120	Shanghai-Shaoxing	150	105	Guangzhou-Shenzhen	90	66
Without bullet train connection	Beijing-Hengshui	180		Shanghai-Huzhou	-		Guangzhou-Zhuhai	-	
	Beijing-Zhangjiakou	200		Shanghai-Yangzhou	300		Guangzhou-Foshan	25	
	Beijing-Chengde	330		Shanghai-Wuhu	400		Guangzhou-Huizhou	110	

Legend
Mega city
City with bullet train stop
City with conventional train stop
Bullet train line
Conventional train line
Impacted area
Province boundary

Fig. 1. BT lines in the Beijing Area, the Yangtze River Delta, and the Pearl River Delta in 2010 and travel time changes in nearby cities. (Source: Ministry of Railways of China.)

BTs Facilitate Cross-City Economic Integration

The BT improves market access, expands labor markets, and enhances spatial agglomeration. As documented in Fig. 1, this new transportation technology allows firms and workers in cities such as Tianjin to access megacities such as Beijing. High home prices and relatively low quality of life in the megacity will also nudge some households and firms to locate in those secondary cities. Because of the BT, these decentralizing households can easily travel to the major cities that offer unique shopping and restaurant opportunities because of the variety of products that can be supplied in such cities (5). Therefore, the BT simultaneously alleviates some of the congestion costs associated with urban growth in the megacities and triggers the growth of the nearby second- and third-tier cities. In this sense, the BT creates the possibility that the nearby second- and third-tier cities become a safety valve for the megacity, which alleviates concern about such cities growing too big. [Au and Henderson (6) find that a large number of Chinese cities are undersized because of the labor migration hukou restriction, but they also find that a few highly favored Chinese cities are significantly oversized.]

Economic geography research posits that information technology allows firms to keep their dealmakers downtown while sending their back office workers to remote areas featuring cheaper land (7). BTs play a similar role, because they encourage firm fragmentation and firm sorting depending on their idiosyncratic demand for megacity access. The introduction of the BT provides firms with the option to locate their headquarters in the major cities and send other activities to nearby cheaper cities. [Media stories report that, after the opening of Beijing–Tianjin BT, some large companies sent their manufacturing sections to Tianjin while their headquarters remained in Beijing. Some Information Technology engineers bought their homes in Tianjin with cheaper housing prices. They work at home and commute by BT one time per week to have meetings at their company's Beijing headquarters (http://news.xinhuanet.com/focus/2009-04/23/content_11221789.htm; www.chinadaily.com.cn/hqpl/zggc/2012-02-19/content_5194378.html).] Firms that need infrequent access to the major city's dealmakers and government officials can decentralize and locate in the BT-accessible second- and third-tier cities. Given that the restriction of China's hukou system on labor mobility has been largely relaxed, if the introduction of the BTs leads to megacities retaining their superstar workers and losing their back office workers to the second-tier cities, then it is possible that the average human capital of residents in both sets of cities will rise. (The hukou system, put in place in the 1950s, was to register people by their hometown origin and urban vs. rural status for the purpose of regulating migration. This hukou restriction was relaxed, and population mobility, especially rural to urban migration, substantially increased in the 1990s when urban housing markets and labor markets were liberalized.) US empirical literature has documented the positive association between average levels of human capital and higher wages and subsequent economic growth (8–11).

Results

Given the short history of Chinese BTs, it is too early in the process to study how this new transportation mode has affected the spatial distribution of population and employment. However, the efficient markets theory of asset pricing posits that real estate prices reflect the expected present discounted value of future rents. This theory suggests that changes in city real estate price dynamics should reflect the expected impact of major infrastructure investments.

We present empirical work investigating the effect of BTs on city real estate price dynamics. We construct a market potential variable (*MP*) to measure a city's access (measured in travel time) to the markets for goods, services, and labor (details in

Table 1. Urban growth trends in connected cities and nonconnected cities between 2001 and 2005 in BT-impacted areas

City group	Urban population growth	Gross domestic product growth	Wage growth	Distance to the closest megacity
Cities with BT stops (μ_1)	23.0%	98.2%	70.0%	377.0 km
Other cities (μ_2)	41.2%	113.5%	75.4%	391.3 km
t test (H_0: $\mu_1 - \mu_2 = 0$)	−1.760*	−1.359	−1.117	−0.612

Data source: National Bureau of Statistics of China.
*$P < 0.10$.

Materials and Methods). The economic geography model of *MP* posits that those geographic areas with greater access to markets will be richer (12–14). The introduction of the BT shifts the spatial distribution of this *MP* measure as cities such as Tianjin enjoy a large increase in their *MP*. We measure the BT's impact through the correlation between real estate price changes and the *MP* changes attributable to BTs. We hypothesize that locations that enjoy this increase in *MP* will experience rising real estate prices.

We recognize that the MOR is unlikely to randomly choose which cities will be connected by BTs to the megacities. To address this concern, we implement an instrumental variables (IVs) regression approach (details in *Materials and Methods*) and compare these results with the results based on ordinary least squares regressions. We seek city-level IVs that are correlated with the likelihood that a city is connected by BTs but unlikely to be correlated with the unobserved determinants of a city's real estate price growth. Using information in the transportation economics literature, we use the nation's historical railway network as one set of IVs (15, 16). In addition, one purpose for China's central government to build the BT network is to ship troops in case of emergency (17). We use information on the spatial distribution of major military troop deployments in 2005 to construct a second IV.

Using city-level data, our key dependent variable is the log change between 2006 and 2010 of a city's average housing price [Δlog(*HP*)] (5, 18). [We do not have reliable official wage data for all 262 cities. Cross-city *HP* dynamics provide useful information about the productivity and consumption amenity effects associated with the introduction of the BT (5, 18).] As reported in Table 2, we explain cross-city variation in this variable as a function of the 2006–2010 log change of a city's own population [Δlog(*POP*)], the log change of its *MP* [Δlog(*MP*)], and a number of key quality of life indicators. Our data sample includes 262 cities.

Table 2 reports the regression results. Table 2, column a presents the ordinary least squares (OLS) estimation result for all cities. The coefficient of Δlog(*MP*) is positive and statistically significant at the 1% level. In Table 2, column b, we use the IV regression technique. The coefficient of Δlog(*MP*) shrinks from 0.567 to 0.450. This coefficient is statistically significant at the 1% level. Given that the IV coefficient estimate is smaller than the OLS estimate, this result suggests that China's central government located BTs in booming cities. This elasticity estimate implies that a 10% increase in a city's *MP* is associated with a 4.5% increase in its average *HP*. (Our calculations suggest that the introduction of the BTs is responsible for 59% of the *MP* increase on average for the cities connected by BTs during our study period.)

In estimating Eq. **2**, a potential concern is that we may overestimate the role of BTs, because we assume no increased connectivity between cities because of improvements in highways or air travel (details in *Materials and Methods*). Several facts suggest that this concern may not be serious during our study period from 2006 to 2010. First, the domestic airline's speed and coverage network for our sample of cities have not changed much in our study period. (There were a few new airports being built during 2006 and 2010, such that the share of cities with new airports increased by 6 percentage points. The number of newly opened air routes is also small.) Second, roughly 70% of the cities in our sample had been connected by highways in our base year (year 2006), and highway construction activity significantly

Table 2. Cross-city home price difference regressions from 2006 to 2010

	Full sample			Subsample	
Variables	OLS (a)	IV (b)	IV (c)	IV: cities within BT-impacted areas (d)	IV: other cities (e)
Dependent variable: Δlog(*HP*)					
Δlog(*POP*)	0.255	0.548*	0.522*	0.585*	0.666*
	(1.60)	(1.84)	(1.72)	(1.67)	(1.74)
Δlog(*MP*)	0.567‡	0.450‡	0.428‡	0.410‡	0.348†
	(17.00)	(7.50)	(6.49)	(5.88)	(2.28)
HIGHWAY			0.233	0.793‡	0.0401
			(1.33)	(2.74)	(0.18)
Control variables	Δlog(*GREEN*), Δlog(*HEALTHCARE*), Δ*EDUCATION*				
Observations	262	262	262	145	117
R^2	0.802	0.599	0.619	0.675	0.620

The first-stage regression results:
Δlog(*MP*) = 1.330*Δlog(*POP*) + 0.470*RAIL1961* + 0.226*MILITARY2005* + 0.798*HIGHWAY* + *controls*
(6.05‡) (7.23‡) (3.31‡) (4.54‡) Obs. = 262, R^2 = 0.731

t statistics are in parentheses.
*$P < 0.10$.
†$P < 0.05$.
‡$P < 0.01$.

slowed down between 2006 and 2010. (The average annual growth rate of highway length was 52.6% in 1995–1999, 20.4% in 2000–2004, and 12.2% in 2005–2009. A published report *The National Highway Network Planning* by the Ministry of Transportation in 2004 states: "We already finished highway construction connecting cities with population larger than 0.5 million, and 60 percent of the cities with population larger than 0.2 million are connected by highways.") To address this issue more formally, we create a variable *HIGHWAY* to measure the highway improvement around a city during 2006–2010 [this variable measures the share of nearby cities (within the 100-mi circle) that enjoyed new highway connection during 2006–2010)] and include it as a control variable in Eq. **2** (19). (In ref. 19, the authors exploit plausibly exogenous determinants of highway construction during the time periods 1990–2000 and 2000–2010 to study how within-city improvements in transportation affect the within-city distribution of population and employment. They document that highway construction is associated with population decentralization (19). In contrast, we focus on cross-city real estate price dynamics associated with the recent introduction of the BT during the 2006–2010 period.) The IV regression in column c in Table 2 shows (the first-stage regression is shown in the legend to Table 2) that this control variable is statistically insignificant in the full sample regression. Including this highway control slightly decreases the coefficient of Δlog (*MP*) by 4.9%. This coefficient is roughly 150% of the size reported in US and European studies on *MP* in which the dependent variable is a function of the wage (13, 20, 21). Based on the ridership data for two major BT lines, we calculate that the average *HP* growth per billion passenger-kilometers is 4.2%. [China's MOR has not formally released the annual BT ridership data by city. We obtained data on the annual passenger-kilometers (PKMs) of two important BT lines—Wu-Guang Line (connecting Wuhan and Guangzhou) and Hu-Ning Line (connecting Shanghai and Ningbo)—in the year 2009 from the Ministry of the Environment's Economic and Planning Research Institute. For these four cities, we calculate the increase in *MP* per billion PKMs and the induced growth of *HP* per billion PKMs because of travel distance decreases induced by BTs, holding other factors (city population, per capita income, and highway network) constant at their base year (2006) level. We estimate that there is a 4.3% average increase in *HP* per billion PKMs. This estimate is based on the four cities and does not represent the nationwide average effect.] There are at least two possible explanations for our large coefficient estimate of Δlog(*MP*). First, China's MOR anticipates that the BT ridership will double in the next 10–15 y, equivalent to a roughly annual growth rate of 4.7–7.2%. By standard asset pricing theory, this expected growth will be capitalized in *HP*. Second, given China's amazingly strong economic growth and booming (somewhat overheated) real estate market, it is possible that investors are overreacting to the optimistic expectation of the benefits that BTs will bring, and this results in a higher *HP* growth rate. We acknowledge that we are unable to test this conjecture. Future research should examine this possibility.

In columns c and d in Table 2, we contrast our regression estimates between cities located in the BT-impacted area (column c) and all other cities (column d). The coefficient of Δlog (*MP*) in column c is larger (and also has a much larger *t*-statistic value) than the coefficient of Δlog(*MP*) in column d. This finding provides additional support for the hypothesis that the BT is contributing to cross-city market integration in China.

Discussion and Conclusion

Macroeconomists view urbanization to be a necessary condition for long-run economic growth, but when such growth is centered in megacities, significant threats to local quality of life arise. If quality of life is declining in growing cities in less developed countries (LDC), then gross national product (GNP) growth overstates improvements in the standard of living (22, 23). In nations with many cities, households can vote with their feet and migrate to another city if a specific megacity's quality of life or local labor market opportunities declines.

The introduction of the BT facilitates this migration by expanding the menu of options of Chinese urbanites and boosting second- and third-tier cities in the BT-impacted area. The *HP* appreciation evidence that we present in this paper supports the claim that the BTs are playing an important role in integrating China's cities into a system of open cities. If this integration leads to less suburban growth in the megacities, then it will encourage a more sustainable urban development.

Our findings offer some insights for other countries planning to build BTs. First, high population density, a sufficient number of secondary cities in reasonable proximity to one another along railway corridors, and already congested traffic on competing travel modes are key factors that determine the cost-effectiveness of BTs (4, 21). These factors are all key determinants of a city's gain in *MP* attributable to the BT. These conditions may hold in some European countries but are less likely to hold in a decentralized state such as California. Second, China's unique political structure is likely to allow it to implement megaprojects efficiently. Chinese governments have strong power in supplying state-owned land, spending public money, and ignoring the possibly negative effects (such as noise) of HSRs on nearby residents. Such projects would face more "Not In My Back Yard" (NIMBY) opposition in the United States (4).

Materials and Methods

Sample and Data. At the end of 2011, there were 15 major newly constructed BT lines and about 3,000 km of upgraded railway lines in operation with speed of or above 200 km/h in China (Qin-Shen, He-Ning, Jiao-Ji, Shi-Tai, He-Wu, Da-Cheng, Wen-Fu, Yong-Tai-Wen, Wu-Guang, Zheng-Xi, Fu-Xia, Hu-Hang, and Jing-Hu lines). By the European Commission's definition, they are both HSRs. (The European Council Directive 96/48 specifically establishes that high-speed infrastructure comprises three different types of line: first, newly built high-speed lines equipped for speeds of or above 250 km/h; second, upgraded conventional lines equipped for speeds of or above 200 km/h; and third, other upgraded conventional lines, which have special features as a result of topographical or land-planning constraints, on which the speed must be adapted to each case.) One-quarter of Chinese prefecture-level and above cities have been connected by BT lines.

Our sample includes 262 prefecture-level and above cities, and the study period is 2006–2010. We set the base year to be 2006, because the formal news of BT introduction was announced in November of 2006 by MOR; also, the first group of BT lines was opened in April of 2007. (If real estate investors anticipated before 2006 that the BT would significantly benefit specific cities, then they would invest early in real estate. If this arbitrage activity raised local real estate prices, then it is possible that we would observe no change in real estate prices in certain cities, because the new news of the opening of the BT was already capitalized into real estate prices before our study period begins.) Based on the definition of BT-impacted area in *Economic Geography of China's Bullet Trains*, there are 145 such cities within BT-impacted areas.

Construction of *MP* Variable. The introduction of BTs reduces the cross-city passenger travel time and thus, enlarges the opportunities in trading, labor market, and knowledge spillover between cities that are physically close but not very close to each other. Because the demand for goods and services in a city is the sum of purchasing power in other cities and closer cities have larger effects, we define *MP* as the distance weighted purchasing power of neighboring cities. Using the information in refs. 12 and 13, we construct the *MP* for city *i* in year *t*:

$$MP_{i,t} = \sum_j INCOME_{j,t} \cdot e^{-\alpha \cdot T_{ij,t}} = \sum_j POP_{j,t} \cdot INCOME\_PC_{j,t} \cdot e^{-\alpha \cdot T_{ij,t}} \quad (i \neq j), \qquad [1]$$

where $POP_{j,t}$ is the nonagricultural population of city *j* in year *t*; $INCOME\_PC_{j,t}$ is the average income per capita of city *j* in year *t*; $INCOME_{j,t}$ is total income of city *j* in year *t*; and $T_{ij,t}$ is the distance between city *i* and *j* in year *t* measured in travel time (in minutes; we will explain how we calculate it below). The spatial decay parameter, α, is expected to be positive, and it

Table 3. Variable definitions and summary statistics

Variable	Definition	Year	Observations	Mean	SD
HP	Average sale price of newly built homes (Yuan/m^2; source: China Statistical Yearbook for Regional Economy)	2006	262	1,998.2	1,298.9
		2010	262	3,723.9	2,738.4
INCOME_PC	Average annual personal income (Yuan; source: China Statistical Yearbook for Regional Economy)	2006	262	10,724	3,152.6
		2010	262	17,870	4,417.6
POP	Urban population (million; source: China City Statistical Yearbook)	2006	262	86.322	124.57
		2010	262	95.566	143.29
GREEN	Public green area per capita (m^2; source: China City Statistical Yearbook)	2006	262	30.86	41.57
		2010	262	41.79	55.22
HEALTHCARE	Number of beds in hospitals per 10,000 persons (source: China City Statistical Yearbook)	2006	262	85.86	32.54
		2010	262	101.75	47.05
EDUCATION	Teacher-to-pupil ratio in middle schools (source: China City Statistical Yearbook)	2006	262	0.065	0.034
		2010	262	0.071	0.035
HIGHWAY	Highway improvement in neighbor cities during 2006–2010 (%; source: Sinomaps Press)	2010	262	0.098	0.156
RAIL1961	Dummy variable: 1 = the city was connected to railway network in 1961, 0 = others (source: China Railway Press)	1961	262	0.363	0.482
MILITARY2005	Dummy variable: 1 = major troops were deployed in the city in 2005, 0 = others (source: Chinese military enthusiast's website; https://www.tiexue.net)	2005	262	0.309	0.463

measures the decay rate of a neighbor city *j*'s influence on city *i* as city *j* moves farther away from city *i*. We set this decay parameter to be 0.02, which is in the middle of the range of estimates derived from the Harris type *MP* equations reported in the literature (13, 20, 21, 24). [We have experimented with other values of this decay rate in the range (0.01–0.05) suggested in the literature. The estimation of β_2 in Eq. **2**, which is our main interest, is quite robust to the choice of this parameter's value in this range.]

In Eq. **1**, the key term $T_{ij,t}$ is taken from a dynamic travel time matrix for each year and city pair. Each element of this matrix, cell (*i*, *j*), measures the travel time by train ($T_{ij,t}$; in minutes) between city *i* and city *j* in year *t*. In the base year (2006), we assume that all cities are connected by conventional trains or highways, and the travel times in this matrix are travel distances between cities divided by the average speed of the conventional train (120 km/h; this speed can also be regarded as the maximum highway car speed). [We compared the straight-line distance with the actual railroad distance between cities along the major railroad. We find that the latter is about 1.2 times the former (Beijing–Tianjin: 1.10; Beijing–Shanghai: 1.26; Wuhan–Guangzhou: 1.22). We use this ratio to convert the straight-line distance to railroad distance.] When a new BT line is opened or a conventional line is upgraded, the travel times in related cells shrink. [There are three train types: conventional train, lower-speed BT, and higher-speed BT. For the sake of simplicity, we use the railroad distances between cities to calculate travel times by train and set the running speeds of conventional train, lower-speed BT, and higher-speed BT to be 120, 225, and 275 km/h, respectively. We use our BT database to calculate the travel time matrices for all years. For example, the travel distance between Beijing and Tianjin is 131.8 km (straight-line distance is 109.8 km), and therefore, the corresponding cell in the travel time matrix in base year has the value of 131.8/120 = 65.9 min. After the opening of the lower-speed BT between these two cities in 2007, this value drops to 131.8/225 = 35.1 min. After the opening of the higher-speed BT between these two cities in 2008, this value further drops to 131.8/275 = 28.8 min. Our regression results are robust to using other possible speed specifications.] A city connected by BT lines will enjoy a MP increase.

***HP* Regression Model.** Cities that combine a favorable location in terms of large *MP* with a variety of urban amenities seem to be the most attractive locations for people to live, and thus, they have higher real estate prices (25). The *HP* appreciation regression equation is presented in Eq. **2**:

$$\Delta_{2006-2010}\log(HP_i) = \beta_1\cdot\Delta_{2006-2010}\log(POP_i) + \beta_2\cdot\Delta_{2006-2010}\log(MP_i) + \beta_3\cdot HIGHWAY_i + controls + \varepsilon_i. \quad [2]$$

The dependent variable is a city's log change in *HP*s between 2006 and 2010. It is the average sales price of newly built commodity housing units. Commodity housing sales account for the majority of the housing transactions (more than 70%) in Chinese cities. [These average *HP* statistics in the Yearbook are sometimes criticized for their inaccuracy because of poor structure quality controls. There is no reliable quality-controlled *HP* index for a large number of cities in China. To test the reliability of this price measure, we calculate the correlation of this price measure with the quality-controlled hedonic price index compiled by the Institute of Real Estate Studies at Tsinghua University (ref. 26 has details of the compiling methodology). The correlation coefficient for these 35 cities for which both price sequences can be calculated is very high (0.90). This high correlation raises our confidence that our *HP* measure effectively captures price variation across cities and over time. It is also relevant to note that the *HP* appreciation is our dependent variable, and therefore, measurement error will not bias our results.] The dependent variable is regressed on the percent change between 2006 and 2010 in the city's *MP* variable (Eq. **1**), its own population, the highway improvement in its surrounding area [this variable measures the share of nearby cities (within the 100-mi circle) that enjoyed new highway connection during 2006–2010], and a series of quality of life variables. The quality of life indicators include public green space per capita (*GREEN*), the number of hospital beds per 10,000 persons (*HEALTHCARE*), and teacher-to-pupil ratio in middle schools (*EDUCATION*). Time-invariant city attributes are dropped out in this long-difference regression.

In implementing our IVs regression, we first estimate a first-stage regression as shown below:

$$\Delta_{2006-2010}\log(MP_i) = \gamma_1\cdot RAIL1961_i + \gamma_2\cdot MILITARY2005_i + controls + \nu_i. \quad [3]$$

The dummy *RAIL1961* measures whether the city was connected to railway network in 1961. The dummy *MILITARY2005* measures whether major troops were deployed in the city in 2005. These two variables together can explain 53% of the variation in the first-stage regression. These regression results are reported in the legend to Table 2. In the second-stage regression, we regress the log change in housing price on the log changes of a city's own population, its *MP*, and a series of quality of life variables (Eq. **2**).

Table 3 presents the variable definitions and summary statistics.

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